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DECLARATION

I, SK. Shahadot Hossain, declare that this thesis is the result of my own work and it has not been submitted or accepted for any degree to others university or institution.

Signature

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Approval

This is to certify, SK. Shahadot Hossain, Student ID: 140518, Session 2013-2014, has prepared this thesis entitled "**Deer Habitat Suitability Indexing and Relation to Tiger conservation in Chadpai, Sharankhola Khulna Range of Sundarbans"** under my direct supervision and guidance. I do here by approve the style and content of the thesis. This thesis has been prepared in partial fulfillment of the requirements for the 4 years professional B.Sc. (Hon's) degree in Forestry from Forestry and Wood Technology Discipline.

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DEDICATED TO MY RESPECTABLE

PARENTS

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First, I want to admire to the Almighty ALLAH, the supreme creator and ruler of the universe from the deepest corner of my heart for His blessings that keeps me alive and enable me to accomplish this project work successfully. I want to express my sincere gratitude to my beloved parents who brought me to this earth and helped me in every step of my life.

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ABSTRACT

The integrated habitat suitability index approach includes the evaluation of target areas based on habitat factors, and combining various suitability indices. The aim of this study is to develop a method that will provide possibility to produce geo-referenced ecological information about the habitat requirements of spotted deer and Bengal tiger species. Geographic Information System (GIS) was used to analyze the present result. Furthermore, linear regression methods provide the significance level and connecting (standardizing, weighting, and combining) the habitat needs of different species. Deer are a unique group of mammals recognized for their grace and beauty. Deer comprise a distinctive order of mammals. The general structure of deer is in conformity with the structure of Bovine ruminants. Deer are for the most part inhabitants of forest and grassland.. The main advantages of the method were connected to the possibilities for considering the habitat factors on different scales, to combine habitat suitability evaluations for deer and tiger species, to assess the tiger and its prey habitat, and to weight different species in different ways.

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CHAPTER ONE
INTRODUCTION

1.1 Background of the study

The Sundarbans is the biggest single tract mangrove forest in the world. This forest is situated in the South West part of Bangladesh, in the district of Khulna, Bagerhat and Satkhira. In an overpopulated country like Bangladesh where there is an acute shortage of land even for human settlements and agriculture. It is noteworthy for it to have a single stretch of more than 6,000 (sq. km.) (Shahadat, 2001). The Bangladesh part of the Sundarbans is devoid of any human habitations or permanent settlements (Ekwal Imam et al, 2009). The Bangladesh part sundarban is blessed with rich biodiversity. This beautiful forest is the home of *Panthera tigris tigris*, Axis axis, *Crocodilus porosus* and many more wildlife with wide variety of bird species. Have Bangladesh Forest Department has already declared seven areas covering 1632.03 sq. km. of the Sundarbans as wildlife sanctuaries. Ramsar Site additionally sundarban is also because of this reason.

In context of Bangladesh the Sundarbans is possibly the last hope for the survival of any unique and great population of wildlife in the wild because other forests areas such as the Shal in the central and northern parts, and mixed or semi-evergreen forests in the hill region have virtually become barren or devoid of wildlife (Shariful, 2011). The reasons for such depletion are excessive deforestation or forested lands being brought under monoculture of indigenous and exotic plants or plantation forests comprising commercially viable species and shifting cultivations followed by land grabbing which has changed the composition of local vegetation which in turn has a great impact on major forest-dwelling wildlife species from the country (Razzaque, 2017). Considering the declining and disappearing status of most wildlife in the country it warrents serious initiative to manage and conserve the vast wildlife wealth that we still have in the Sundarbans Mangrove.

Deer are a unique group of mammals recognized for their grace and beauty. The general structure of deer is in conformity with the structure of Bovine ruminants. Deer are the most part inhabitants of forest and grassland. With the development of firearms, deer everywhere become more vulnerable. Medicines, Magical or Other-wise could be made of certain parts. Deer provide numerous readily utilizable products (meat. hides and antlers) and their population has suffered comic durable reduction from over-exploitation. Conversion of

lowland forest areas into the agricultural field is a major threat for deer conservation (Dey, 2004). There are 17 existing genera under family Cervidae. Asia has 9 (2 extending in Europe) including both primitive and derived forms (Grubb and Gardner 1999). Asia is quite rich with Cervus deer. There are 31 species and 97 subspecies of Cervus deer under of genus *Cervus, Allies, Axis, Capreolus, Elaphodus, Elaphurus, Hydropotes, Mazama, Megamuntiacus, Muntiacus and Rangifer* in Asia. Most of them are native to China, Indonesia, Philippines, Cambodia, Japan and Taiwan. In South Asia, there are 7 species and 13 subspecies of Cervus deer.(Islam, 2011)

The tiger is the pride of the fauna of the Sundarbans. Since the tiger is at the top of the ecological pyramid of the mangrove ecosystem, it is also considered as the flagship or umbrella species to conserve the unique biodiversity of the Sundarbans. Tigers have also become ingrained in our culture and drawing public support for conserving an entire ecosystem. Tiger is a symbol of wilderness and wellbeing of the ecosystem. The tiger is the largest of the cats (WWF 2001, Sunquist and Sunquist 2002) and is one of the world's most magnificent animals. Of eight sub-species of the tiger [Bengal tiger (*Panthera tigris tigris*), Caspian tiger (*P. t. virgata*), Amur tiger (*P. t. altaica*), Javan tiger (*P. t. sondaica*), South China tiger (*P. t. amoyensis*), Bali tiger (*P. t. balica*), Sumatran tiger (*P. t. sumatrae*), and Indo-Chinese tiger (*P. t. corbetti*)], the Bengal tiger mainly occurs in India, Bangladesh, Nepal and Bhutan. The Bengal tiger is the most common subspecies of tiger, constituting approximately 80% of the entire tiger population, and is found in Bangladesh, Bhutan, Myanmar, Nepal, and India and has been hunted in those countries for centuries. Bengal tiger (*Panthera tigris tigris*) belongs to Felidae family and is one of the five subspecies. Tigers occupy a great range of habitats and may settle where ever they get enough prey species, adequate cover and access to water. The prey of the tiger in the Sundarbans mainly comprises of deer and boars, and includes monkeys, monitor lizards, birds, crabs and fish (De 1990). In wild condition, tiger can potentially hunt prey varying from the small mammals, medium-sized ungulates to the large bovids, the preferred prey weighing between 60 and 250 kg. They are territorial and wide-ranging, and the effective size of their territory is a function of the density and biomass of prey species in its habitat. Therefore, studies undertaken to address these issues on a tiger are important because it can provide a better insight of tiger ecology and behavior. Radio telemetry provides data on carnivore home range size and social organization, which can be used to derive, estimates of densities and survival rates (Aniruddha et. al 2012).As they are found in dry deciduous, moist deciduous, semi-

evergreen, wet evergreen, swamp and mangrove showing remarkable tolerance to variations in altitude, temperature, and rainfall regime.

1.2Problem Statement:

The shooting and killing of deer continued until the end of 1972, even though they have been declared as threatened and endangered animals by the IUCN. The Bangladesh Wildlife Preservation Ordinance was promulgated in 1973 and amended in 1974 to become the Bangladesh Wildlife (Preservation) (Amended) Act 1974 (Gani 2002). But, there are hundreds of the forest cases regarding- illegal hunting, poaching, and shooting of the spotted deer and barking Deer throughout the country. The problem on the protected and preservation of the deer resources in the SRF is execrated by several factors that include rampant poaching, uncontrolled gathering of forest products and fishing, and natural disaster like cyclones which destroy wildlife habitat and kill a considerable number of wildlife including deer (Khan, 2004) This problem is very serious in the SRF and coastal areas. Habitat suitability indexing depends on the other factors such as inundation height, salinity, water body and disturbance.

Despite human pressures, poaching and illegal hunting of the Spotted Deer population in the SRF, the status of the species still not threatened (Khan, 2004). The past offense records showed that illegal hunter and poachers are mixed with the fisherman and they used drop net for hunting. The present study will be the benchmark for future conservation aspects and scientific study the tiger is among the most endangered members of the cat family. They are in danger of extinction and kept in the category of critically endangered species by the international union for the conservation of nature and natural resources (IUCN). Wild tiger habitats continue to shrink and fragment globally under ever-increasing anthropogenic pressures. Presently, tigers are confined in only a small fraction of their potential habitat.

After World War II, deforestation for various commercial purposes accelerated the depletion and fragmentation of forests and grasslands. Because of the excessive exploitation of forest resources, the tiger population is now confined mainly in small and isolated forests designated as Wildlife Sanctuaries, National Parks, Tiger Reserves and other protected areas. That results in a decrease in the number of predators as the food resource becomes smaller which in turn decreases the rate of predation, allowing the prey species population to flourish again (predator-prey relationship, Heather Brennan).

1.3 The objective of the Study

The tiger is among the most endangered members of the cat family. Only fewer than 4000 individual tigers are left in the world, the tiger faces severe threats throughout its habitat. The latest tiger count estimate only 106 tigers, presence in the Bangladeshi Subdarban. It is believed that the tiger population in the Sundarbans is at risk of extension. The survival of the species depends on the habitat and its prey base existence. The main prey of sundarban tiger is the spotted deer. The main objective of this study is to build a location specification information to create a habitat suitability index for the deer population (pray base) and subsequently tiger (the predator) in SRF.

1.3.1 The specific objective

The main objective of this study to assess the deer habitat suitability related to tiger conservation in the Chandpai, Sharankhola and Khulna ranges of the Sundarbans.

CHAPTER TWO
LITERATURE REVIEW

2.1 History

One of the earliest portrayals of the tiger in India is found in the Harappa seals from the Indus valley culture, dating back to 2500 BC, and depicting an intricate association between people and tigers. The rock paintings of Warli tribe, which date back to around 3000 BC, also feature the tiger. It is believed that tigers evolved in Northern China and Far East Asia approximately two million years ago. Then, they migrated through woodlands and along river systems into Southwest Asia. In the south and southeast directions, tigers moved through continental Southeast Asia, crossing into the Indonesian islands before they separated from the mainland, and finally reached India (Agrawala, 2003)

2.2 Sundarbans Reserved Forest

The Sundarbans Reserved Forest (SRF) in Bangladesh is the single largest mangrove forest in the world. The SRF is a unique bio-climatic zone in a typical geographically situation in the coastal region of the Bay of Bengal.(Thapa, 2014) It is a landmark of the ancient heritage of mythological and historical events and bestowed with the magnificent scenic beauty of natural resources, which is internationally recognized for its wide biodiversity of mangrove flora and fauna both on land and water. The SRF the immune tidal mangrove forests of Bangladesh is, in reality, a mosaic of islands of different shapes and sizes, perennially washed by brackish water shrilling in and around the endless and mind-boggling labyrinths of turisting water channels (Thapa, 2014)

2.2.1 Location

The SRI is situated in the extreme southwest of Bangladesh between the river Baleswarin the East and the Harinbanga in the West adjoining to the Bay of Bengal. The forest is lying between latitude 21°27'10" and 22°30'00" North and longitude 89°02'00" and 90°00'00" East at the southern part of Khulna, Bagerhat and Satkhira civil districts (Rahman, 2009)

2.2.2 Area

The forest has an area of around 6017 sq. km (7620 sq. km including the marine zone) determined from the visual interpretation of multispectral SPOT satellite data.

Land area including exposed sandbars occupies 4,14,259 ha (70%), water bodies 1,87,413 ha (30%).

Table 2.1: Major physiographic areas of the SRF

Description	Area (km^2)
Land area (including sandbars)	4142.6
Marine zone	1603.2
River, channels, streams and canals	1874.1
Total area including marine zone	7620.0
Total area excluding marine zone	6016.7

2.2.3 Geology

The upper SRF grows on geologically recent soil formations. The substratum consists entirely of Quaternary Era sediments, sand, and silt intercalated with marine salt deposits and clay. Several geo-morphological and resultant hydrological chances have contributed to the present location and condition of the Sundarbans. The rising of the western part of the delta caused separation of ancient branches of the Ganges from the area, which today comprises the Indian Sundarbans. This resulted in the accretion at the river mouth and increase in salinity water intending in the western part of the delta (Chowdhury and Ahmed 1994).

2.2.4 Soil Characteristics

The SRF soil is finely textured and the subsoil is stratified and at greater depth is compacted (Chowdhury 1968), Hassan and Mazumder (1990) mentioned that soils were slightly calcareous, uncured or partly cured clayey deposits which were homogenous both: critically and horizontally. Organic carbon and nitrogen in the topsoil (15 cm depth) were 0.62% ended 0.05% respectively on a dry weight basis. In the eastern part of the forest, the rivers supply fresh silt every year, the top layer is soft and fertile. In the western Sundarbans where there is little fresh supply of silt, then the surface soil has settled down to a hard mass, and the ground is much less suitable for fast tree growth (Chowdhury, 1968)

2.2.5 Tides and hydrology

Tides in the SRF are semi-diurnal with a small diurnal irregularity. In the eastern Sundarbans, the irregularity is minor but much more pronounced in the west (Seidensticker and Hai 1985).

Mean spring range in the mouth of the Passur River (east delta) is 2.4 m. Based on the frequency of tidal inundation, especially during the May—October period, the Sundarbans can be divided into four hydrological zones –(Pulliam, 2015)

- ✓ Areas inundated by all tides
- ✓ An area inundated by normal high tides
- ✓ Areas inundated only by spring high tides
- ✓ Areas inundated by the monsoon high tides

2.2.6 River system

A complex network of streams and rivers varying considerably in width and depth intersects the entire area. Some of the big rivers are several kilometers in width. The Sundarbans receives large volumes of fresh water from inland rivers flowing from the north and of saline water from the tidal incursions from the sea. The fresh water is charged with alluvium containing plant nutrients. This together with the salinity of the tidal water is the major factor determining the productivity of the forest ecosystem (Jakir hossain, 2009)

At a comparatively recent period, all the rivers were connected with the Ganges like Bhairab. Madhumati, Gorai. Now, only die Baleswar has a direct connection and responsible for fresh water supply to the eastern span of the Sundarbans. A number of rivers namely, the Passur, the Sipsa, the Arpangasia, the Malancha and to a slight extent the Jamuna and Raimangal have indirect connections and receive the overflow of the Ganges dating the rainy season. They also received aconsiderable amount of local drainage throughout their long and meandering courses during the monsoon (Pulliam, 2000)

2.2.7 Soil and Water Salinity

The salinity increases from East to West and North to South. Soil salinity in April May remains between 2 and 4.5 don't in most parts of the Sundarbans. The range is at low salinity level. However, salinity has considerably increased in recent years due to the diversion of Ganges water upstream at Farakka in the Indian Territory (Shall 1982). Soil salinity data were collected regularly from four representative areas of the Sundarbans since 1976. Peak salinity level occurs in April l6 and drops gradually in the soil and abruptly in water after lune. Soil salinity shows erratic venations. Based on the degree of soil salinity, the Bangladesh Sundarbans has been divided into three salinity zones, less saline (salinity 42 dS

m-1), moderately saline (salinity 114 dS m-1) and strongly saline (salinity 104 dS m-n). Water salinity along the northern part of the Sundarbans ranging from 1 to 9 ppt in the late monsoon (September). This range in water salinity during the dry season (May) varies from 4 to 28 ppt (Siddiqi 2001).

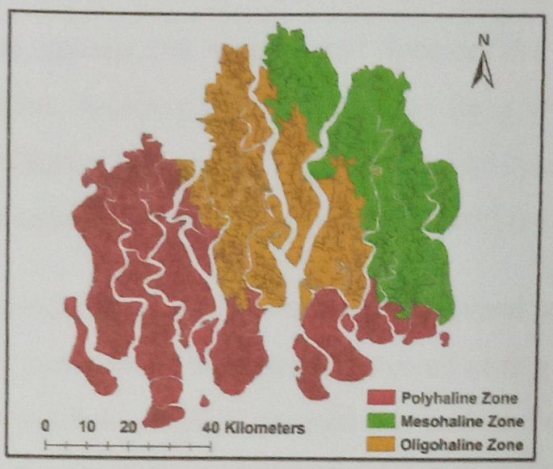


Fig 2.1: Salinity zones in Bangladesh Sundarbans (Mahmood, 2018)

Salinity classification

- ✓ **Oligohaline zone** (NaCl content less than 5 ppt.) that occurs in a small area of the northeastern part of the forest.
- ✓ **Mesohaline zone** (NaCl content 5-10 ppt.) that covers the north central to south-eastern part of the forest.
- ✓ **Polyhaline zone** (NaCl content greater than 10 ppt.) that covers the western part.

2.2.8 Climatic Condition

The climate of the SRF is humid. Temperature is equable due to the proximity of the sea. Highest temperatures occur in April and May and lowest in December and January. Mean annual maximum and minimum temperatures vary between 30° and 21°C, mean annual relative humidity varies from 70% to 80%. Humidity is highest in June-October and lowest in the month of February. Annual rainfall in the Sundarbans is in the range of 1640-2000 mm as apparent from the data recorded in the four stations adjacent to the forests. July, August, and September are the wettest months and December, January and February the driest. On average, 80% of the total annual rain is received from June to September. Following the monsoon from November to February the cool season new in Rom February or March

temperatures begin to rise and in April and May, there are usually violent storms. Further storms may also occur in the monsoon and tidal waves can result in widespread inundation.

2.2.9 Faunal Composition

The SRF is rich in terrestrial, aquatic and avian faunal Species. The forest and waterways provide dealing places, habitats, breeding areas, and refuge for a wide variety of species including & species of amphibian, 42 species of reptiles, 161 bird species and 40 species of mammals many of which are endangered in other parts of the world (Hirzel et al, 2003)

The SRF fauna is rich and varied. However, in recent decades several important animals have disappeared from the area for good. Many more are endangered or in a vulnerable condition. A detailed survey on the population status of animals has seldom been carried out. As a result, it is difficult to assess the absolute or relative population density of various important animals. Only a few authors have studied this vast animal resource and they have mainly investigated the species composition. Numbers of existing species in the area and population density of each also varies in the available reports.

The magnificent among the animals on land is Bengal tiger, Spotted deer, Barking deer and Wild boars are there in plenty. Besides that Jungle cat, Fishing cat, Civet cat, Monkey, Bengal fox, Jackie, Water monitor, Monitor Lizard. Snakes are important faunal spp. on the land among aquatic fauna. Estuarine Crocodile. Bateau, (River Terrapin), Marine turtles, Tiger prawns, different types of crabs, Hilsa fish,Vetki, paresetc. are important. In the past, Wild Buffalo, 2 species of deer had already been extinct recently 2 species of amphibians, 14 species of reptiles, 25 species of birds and 5 species of mammals have been recorded as an endangered species by IUCN (Siddiqi 2001)

Table 2.3: Showing the faunal biodiversity in the SRF:

Wildlife	No. of species available in Bangladesh	No. of species available in the SRF Bangladesh	Species biodiversity (%) in the SRF compare to Bangladesh
Amphibians	23	8	34.78
Reptiles	154	35	22.72
Birds	632	186	29.43
Mammals	123	32	26.01
Fishes	325	177	54.46
Shrimps	35	24	68.57
Crabs	11	7	63.63

2.2.10 Mammals

About 42 species of mammals were recorded during the present study. Some important animals are Bengal tiger (*Panthera tigris tigris*), Spotted Deer (*Cervus axis*), Wild Boar (*Susscrofa*), Rhesus Macaque (*Macaca mulatto*) and Clawless Otter (*Lutraperspicillata*). The Sundarbans is one of the biggest reserves of the Bengal tiger. A survey was made in 2005 by Forest Department and they reposed the persona of 423 individuals of tigers. Deer and wild boar constitute the main prey of the tiger. Although that is plentiful, the cause of man-eating behavior of tigers is unknown. An individual tiger requires about 10 sq. km territories for it dowelling (Tamang 1993). These tigers are the top consumers in land and they solely depend on the Spotted Deer (*Cervus axis*), Wild Boar (*Susscrofa*), Rhesus monkey (*Macocamulta*) and Water Monitors (*Varanus Salvator*).

2.3 Spotted Deer:

Deer are a unique group of mammals recognized for their grace and beauty. Deer comprise a distinctive order of mammals. The general structure of deer is in conformity with the structure of Bovine ruminants. Deer are for the most part inhabitants of forest and grassland. With the development of fireams, deer everywhere become more vulnerable. Hungry families

wanted meat. Hides could be sold. Medicines, Magical or Otherwise could be made of certain parts. Deer provide numerous readily utilizable products (meat. hides and antlers) and their population has suffered comic durable reduction from over-exploitation. Conversion of lowland forest areas into agricultural field is a major threat to deer conservation (Dey 2004). There are 17 existing genera under family Cervidae. Asia has 9 (2 extending in Europe) including both primitive and derived forms (Grubb and Gardner 1999). Asia is quite rich with Cervus deer. There are 31 species and 97 subspecies of Cervus deer under of genus Cervus, Allies, Axis, Capreolus, Elaphodus, Elaphurus. Hydropotes, Mazama, Megamuntiacus, Muntiacus and Rangifer in Asia. Most of them are native to China, Indonesia, Philippines, Cambodia, Japan,and Taiwan. In South Asia, there are 7 species and 13 subspecies of Cervus deer are found. The status and distribution of Cervus deer in the South Asia Region are given below (Grubb and Gardner 1999).

Table 2.4: Status and distribution of cervical deer of South Asia Region (Arlettaz, 2003)

Species	Common name	IUCN CITES Status	Countries with range
Cervus axis	Spotted Deer	No	Bangladesh, Nepal India, Srilanka (Introduce to Argentina. Australia. Brazil. the Hawaiian Islands. New Guinea. U.S.A, Yugoslavia)
Axis porcinus	Hog Deer	LR.nt	India, Nepal, Srilanka, Pakistan and Bangladesh (rare and only recorded in Khagrachari area of Chittagong Hill Tracts.)
Cervusd uvauceli	Swamp Deer or Barasingha	EN	India
	Swamp Deer or Barasingha	VU	India and Nepal
	Swamp Deer or Barasingha	CR	India and Bangladesh(extinct)

2.3.1 IUCN Categories

EX-Extinct, CR-Critically Endangered, EN-Endangered, VU-Vulnerable, LR-Lower Risk, Cd-Conservation Dependent, not-Near Threatened, Lc-Least Concern, DD-Data Deficient,

NO- Not Threatened. A distribution map of the Spotted Deer and Barking Deer in the South Asia Region has been developed with the help of Environmental System Research Institute (ESRI I992) digital database (IUCN-Bangladesh, 2000)

2.3.2 Deer Habitat in Bangladesh

There were five species of deer in Bangladesh namely Spotted Deer (*Cervus axis*), Barking Deer (*Muntiacus muntjak muntjak*), Hog Deer (*Axis porcinus*), The Sambar (*Cervus unicolor*) and Swamp Deer or Barasingha (*Cervusdu vauciliranjitsinhi*) (Sarker and Sarker 1988).

They are widely distributed across the Indian Peninsula, Burma, Srilanka, and lndo Malayan countries (Blandford l89l and Prater 1980). According to present information, Swamp Deer and Hog Deer have become virtually extinct. In the middle of 20th century, Swamp Deer and Hog Deer were found in low-lying grassland of Sylhet and the Chittagong Hill Tracts. Due to the destruction of habitat and biotic pressure, they become extinct from Bangladesh. In the year 2003, a pair Hog Deer was collected from Khagrachari area and they were kept in the Dulahazara Safari Park. The Spotted Deer is not threatened in Bangladesh as per IUCN.

Remaining two species. Barking Deer and Samber Deer are also threatened and vulnerable. Samber Deer (*Cervus unicolor* Kerr) populations are also threatened and vulnerable. A few decades back Samber Deer were found in all forests. Now they are confined in the Chittagong Hill Tracts and part of Sylhet Forests. (IUCN-Bangladesh, 2000)

The Spotted Deer (*Cervus axis*) is not threatened or endangered (IUCN Bangladesh, 2000). The Spotted Deer also called Chital locally is considered as the most beautiful of all cervids (Schaller 1967). It is widely distributed in the subcontinent. It is found nearly throughout India, Bangladesh, Nepal and Srilanka. In South Asia the Spotted Deer occurs at the base of the Himalayas, however ascending the mountains beyond the lower spurs, from the neighborhood of the Subtly to Nepal, but not in Sikkim. It is not found in Punjab plains, not in Sind, and only the eastward in Rajputana. It is also wanting in Assam and to the east of the Bay of Bengal, but common in the Sundarbans of Bangladesh and India. In the middle of the l9th century, it was found throughout Bengal, Orissa, the North-west Provinces, Central India, Mysore, Malabar and Srilanka (Blandford 1891 and Prater 1965).

Spotted Deer in the Sundarbans sometimes numbering more than a hundred in a herd can be seen grazing in the meadow-like grasslands. The forests get denser and closed towards the

north and the density of deer population is less in the north. There are 9 different types of vegetation in the Sundarbans Reserved Forest (SRF). But no systematic scientific study has been made on the population status and distribution in the SRF. Hendrichs (I975) estimated 80,000 Spotted Deer in the SRF and he has not provided any basis for the estimation. In I976 several pairs of Spotted Deer were introduced in the Nizam Deep National Park of Noakhali Forest Division, now their population size is about I2000-I3000 and it creates critical situation in the Park and adjacent islands.

The population density, home range, herd composition and activity pattern of the Spotted Deer vary with vegetation, season, biotic pressure, poaching and abundance of predator population. Habitat preference of this species is related to different ecological factors. The habitat requirements study of this species is very complex. No detailed study has been done on the population ecology, status, distribution, habitat preference, dispersal and movement, herd structure and composition in Bangladesh. The SRF is a unique biological unit for the study of spotted deer habitat suitability. The main tiger prey is the Spotted Deer, and there by the study of predator-prey relationship is an important aspect for wildlife management. As we know that prey species depletion is a critical determinant factor of tiger population viability. So continious monitoring and research on population density and distribution of Spotted deer is necessary. So, I tried to find out the population status, distribution, habitat preference, predator-prey relationship home range, activity pattern and conservation measures of the spotted deer in the SRF.

2.3.3 Short Description of the Spotted Deer (*Cervus axis*):

Local Name: Chitra Horin, Chitla.

2.3.3.1 Size

The Spotted Deer is at its best in the Himalayan Foothills in the Jungles of the Teri and in Madhya Pradesh. A well-built stag from these pans stands 90 cm at the shoulder and weighs about 85 Kg. The recording head measures W/ cm. An 85 cm. antler would be good anywhere 80 cm in South India (Hean, 2000)

2.3.3.2 Distinctive characters: The Spotted Deer is perhaps the most beautiful of all deer. Its coat is a bright rufous-fawn profusely spotted with white at all ages and in all seasons.

Old bucks are more brownish in color and darker; the lower series of spots on the Ranks are arranged in longitudinal rows and suggest broken linear markings (Hean, 2000)

The graceful enders have three times, along brow tine set nearly at right angles to the beam and two branch tines at the top, the outer tine, the continuation of the beam, is always longer. It may be noted that old bucks often have one or more false points on the brow antler where it joins the main beam.

2.3.3.3 Distribution

In India, Spotted Deer am found in the Forest at the hase of the Himalayas and practically throughout the Peninsula and Srilanka wherever there is jungle combined with good grazing a plentiful supply of water. It is unknown in the arid plains of the Punjab, Sind, in the large portion of Rajputana, and the countries east of the Bay of Bengal. It is found in Assam in the Goalpara, Kamrup and Darrang Districts. In Bangladesh natural population only found in Sundarban Reserved Forest, Nizum Dip National Park, and Char Kukri Mukri Wildlife Sanctuary.

2.3.3.4 Habits

One always associates Spotted Deer with beautiful scenery, with grassy forest glades and shaded streams. They are seen in herds of ten to thirty, which may contain two or three stags, but assemblages numbering several hundred have been met with. They do not shun the proximity of villages but enter cultivation, and frequently associated with many forest animals, particularly with monkeys. They are less nocturnal than Sambar and feed till late in the interval in some shaded spot.

The time at which the stags shed their antlers varies in different localities. In Madhya Pradesh and south India, it is usually in August and September. The new antlers are in velvet till the end of December. But stags carrying horns in various stages of development have been seen at all seasons. In Madhya Pradesh the pairing season is at its height in May, the rutting stag has a loud harsh bellow and combats between the males for the possession of the hinds are fierce a frequent. In north India, the pairing is said to take place during the winter months. Fawns may be met with at any season. Usually, the mother gives birth to a single fawn. Chital is prolific breeders, an interval of six months may see the production of a new family.

2.4 The Bengal tiger

The Bengal tiger (*Panthera tigris tigris*) is the National Animal of both Bangladesh and India. It is an intimate part of the history and culture of this region. In some archaeological sites, as in Rajaram Roy's Temple in Madaripur, Bangladesh, some terracotta plaques have been discovered which depict the tiger and its prey. Perhaps these were treated as sacred animals in Rajaram Roy's reign. The tiger is admired, feared and respected by humans for its beauty, grace, strength, ruthlessness and other natural and supernatural attributes (Tamang 1993). The tiger is the pride of the fauna of the Sundarbans. Since the tiger is at the top of the ecological pyramid of the mangrove ecosystem, it is also considered as the Flagship or Umbrella Species to conserve the unique biodiversity of the Sundarbans.

The tiger is the largest of the cats (WWF 2001, Sunquist and Sunquist 2002) and is one of the world's most magnificent animals. Of eight sub-species of the tiger Bengal tiger (*P. t. tigris*), Caspian tiger (*P. t. virgata*), Amur tiger (*P. t. altaica*), Javan tiger (*P. t. sondaica*), South China tiger (*P. t. amoyensis*), Bali tiger (*P. t. balica*), Sumatran tiger (*P. t. sumatrae*), and Indo-Chinese tiger (*P. t. corbetti*), the Bengal tiger mainly occurs in India, Bangladesh, Nepal and Bhutan. Of these eight sub-species, three have become extinct since the 1950s (Caspian, Javan and Bali tigers), two are virtually extinct (South China and Indo-Chinese tigers), and from the 100,000-150,000 tigers that might have existed 150 years ago, we are left with 5,000-7,000 animals today (Thapar 1996, WWF 1999). At present, more tigers exist in captivity than in the wild (Nowell and Jackson 1996, Karanth 2001).

There are eight species of wild cats found in Bangladesh of which five are globally threatened (IUCN 2003) and six nationally (in Bangladesh) threatened (IUCN-Bangladesh 2000). According to IUCN Criteria, the Bengal tiger has been categorized as globally Endangered (IUCN 2003) and nationally Critically Endangered (IUCN-Bangladesh 2000).

Table 2.5Status of wild cats (Order: Carnivora, Family: Felidae) in Bangladesh

Sl. no.	Scientific name	English name	Local name	Global status	Local status	Distribution in Bangladesh
1	*Felischaus*Guld	Jungle cat, swamp cat	Ban biral, wab	-	Endangered	Widely distributed
2	*Catopumatemmincki*	Asiatic golden cat, Temminck's cat, Asian golden cat, golden cat	Sonabagh, sonalibiral	Vulnerable	Critically Endangered	South-east and south
3	*Neofelisnebulosa* Griff	Clouded leopard	Gechhobagh, lam chita	Vulnerable	Critically Endangered	South-east and north-east
4	*Panthera pardus Linn*	Leopard, panther	Chita bagh	-	Critically Endangered	South-east and north-east
5	*Panthera tigris Linn*	Tiger, Bengal tiger, royal Bengal tiger	Bagh	Endangered	Critically Endangered	South-west
6	*Pardofelis marmorata* Mart	Marbled cat	-	Vulnerable	Data Deficient	South-east
7	*Prionailurusbengalensis Kerr*	Leopard cat	Chita biral	-	Data Deficient	Widely distributed
8	*Prionailurusviverrinus*Benn	Fishing cat	Mechhobiral, mechhobagh	Vulnerable	Endangered	Widely distributed

2.4.1 Tiger Habitat in Bangladesh

The Bengal tiger was once found in all the forests and even in some village groves of Bangladesh. According to Mitra (1957), tigers were present in 11 of the 17 civil districts of the eastern Bengal (now Bangladesh) until the 1930s. At that time the tiger was treated as a pest and the Government used to pay rewards for killing them (Prater 1940). Tigers were hunted from the deciduous forests of central and north-western Bangladesh, and from the mixed-evergreen forests of the north-east and south-east even during the 1950s- 1960s.

The last tiger hunted or sighted in the deciduous forests of the Madhupur Tract in central Bangladesh was in 1963 (Madhupur in 1963 and Sandhanpur in 1952) and Greater Rangpur (north-west) in 1962 (Banglabandha in 1962, Madhyapara in 1960 and Boda in 1950); in the mixed-evergreen forests of Greater Chittagong and Chittagong Hill Tracts (south-east) in 1984 (Kassalong in 1984, Mainimukh in 1979, Ramgarh in 1960 and Najirhat in 1950) and in Greater Sylhet (north-east) in 1985 (Patharia hill in 1985 and Srimangal in 1962); in the Sundarbans mangrove forest (south-west) tigers had a wider distribution (Khan 2004). At present, the only stable population of the tiger is found in the Sundarbans, but there are vagrant tigers in mixed-evergreen forests in Sangu-Matamuhuri valley and Kassalong-Sajek valley (south-east). According to MacKinnon and MacKinnon (1986), tigers may still occur in Teknaf, located in the extreme southeastern tip of the country bordering Myanmar (Burma).

It was found that the density of the tiger in the Sundarbans varies from north to south, following the density of its prey. Based on the relative abundance of pugmarks, the highest density of the tiger was recorded in the southern Sundarbans characterized by having the mosaic of forests and grasslands (Khan 2004). The grassland pockets are ideal habitats for the prey, and thus provide higher carrying capacity for the tiger.

Wikramanayake*et al.* (1999) classified the Sundarbans and Sangu-Matamuhuri valley as Level I Tiger Conservation Unit (TCU), i.e. these habitats offer the highest probability of persistence of tiger population over the long term. Moreover, Kassalong-Sajek valley has been classified as Level III TCU, i.e. this habitat offers a low probability of persistence of tiger population over the long term due to its small size, isolation from other habitat blocks containing tigers, and fragmentation within its representative major habitat type.

The fates of humans and tigers are intertwined; tigers are an integral part of much of the remaining Asian forest ecosystems, which in turn supply the ecological services essential to our own existence. Tigers are an umbrella species because they need large areas of land to live. Therefore, saving tigers can also help secure the future of the biodiversity that makes up the tiger's forest home. As the top predator, the tiger may help to regulate the number and distribution of prey, which in turn will impact forest structure, composition, and regeneration (Ale and Whelan 2008;Weggeet *al.* 2009). Hence the loss of tigers may reduce ecosystem integrity and ability to adapt to changing environmental conditions.

Irrespective of their use to mankind, as a product of millions of years of evolution, tigers should also be given the chance to exist. The disappearance of tigers from the wild because of human actions would be unpardonable and a sad reflection on our role as guardians of thenatural world. If we can't save the tiger, then this will surely be a signal for the demise of thousands of other species and wild places.

Tigers are categorized as endangered because there are probably fewer than 4,000 individuals left in the wild, and three of the eight subspecies are now extinct (IUCN 2008). The remaining populations continue to be imperiled by poaching, depletion of their prey, and destruction of their habitat. The most recent summary of tiger status worldwide suggests they are living in only seven percent of their former range (Dinersteinet *al.* 2007). The remaining tiger populations are spread across 14 countries, and often in forests too small and isolated for their long-term persistence. The way forward is to identify landscapes that can support tigers, priorities them in terms of their contribution to the species' survival, and then protect those areas (Sanderson *et al.* 2006).

With a relatively large tiger population in the Sundarbans (Barlow 2009) and reports of tigers still present in the Chittagong Hill Tracts, Bangladesh can contribute substantially to the future of the species. As well as the ecological services these tiger landscapes provide, the tiger is the national animal of Bangladesh, the emblem of the East Bengal Regiment which fought for the country's liberation, the logo of the national cricket team and otherwise deeply embedded in the country's culture.

It is distressing to imagine a Bangladesh or a world without wild tigers. With careful planning and concerted effort, that prospect does not have to become a reality. The continuous monitoring and research on population density and distribution of Bengal tigers are

necessary. Find out the population status, distribution, habitat preference, predator-prey relationship home range, activity pattern and conservation measures of the Bengal tiger in the SRF.

2.4.2 Short Description of the Bengal Tiger *(Panthera tigris tigris)*

Although the Bengal Tiger has typical coloring and patterns (light orange or yellow fur with bold brown or black stripes), it is set apart by its being particularly large, second only to the Siberian Tiger. Male Bengal Tigers reach an average weight of 221 kilograms (just under 490 pounds), and females usually weigh around 140 kilograms, which is equivalent to 308 pounds. The male will reach about 2.7 to 3.1 meters in length (about 115 inches) and females grow to approximately 2.4 to 2.6 meters (or 102 inches). This measurement includes the tail, which is around one meter long.

Local Name: The Bengal Tiger

Estimate Remaining Population in the world: < 3,000 (Hemmer, 1971)

2.4.2.1 Size and Physical Characteristics

The tiger (*Panthera tigris*) is the largest among all the living wild cats of the family Felidae. It has an elongated body, short neck, and a compact head with a relatively short muzzle. The legs are stout, and the paws are armed with retractile claws. The total body length of an adult male tiger is between 275-290 cm and that of an adult female is 250-260 cm. The adult male tiger weighs 180-260 kg whereas the adult female weighs 100-160 kg. Tigers have a reddish-brown to rust-brown coat with black stripes and a white underbelly. Variations in coat coloration occur among individuals. White and black tigers are caused by a recessive gene.

2.4.2.2 Habitat and Distribution

In India, the tiger is found practically throughout the country, from the Himalayas to Cape Comorin, except in Punjab, Kutch and the deserts of Rajasthan. In the northeast, its range extends into Burma. Tigers occupy a variety of habitats including tropical evergreen forests, deciduous forests, mangrove swamps, thorn forests, and grass jungles.

2.4.2.3 Behavioral Characteristics

Tigers are usually solitary, except for females with cubs. They are territorial, and males have

discrete territories overlapping those of several females. Male territories are mate oriented while those of females are more resource oriented. Tigers use scent (spraying urine on the trees or other vegetation or deposited on a scrape), scratch (marking on tree trunks with claws) and scrape marks on the ground to maintain contact and advertise their presence to others. During breeding, which lasts about 20 to 30 days, males and females communicate with each other with loud and distinct calls that travel great distances. About 8 different kinds of vocalizations have been documented in tigers from the wild. The gestation period is about three months (90 days). The litter size may vary between 1-6 cubs, but 2-3 cubs are most common. At birth, the tiger cub weighs between 800 - 1500 grams and measures 31 - 40 cm in length. Cubs stay with their mother and siblings until about the age of two when they move on to establish their own territories. During these two years, cubs learn hunting techniques from their mother. Tigers are well adapted to stalking prey rather than running it down. Tigers primarily hunt at night, between dawn and dusk and usually rest during daytime. On an average, tigers and tigresses without cubs kill once in eight days, whereas a tigress with cubs makes kill almost once every five days. However, the rate of kills depends on the number of successful attempts. The prey is killed mostly by a fatal throat bite causing suffocation, strangulation or severance of blood vessels. Sometimes nose bites are applied to suffocate the animal, when an effective throat bite is not an easy task, mainly in case of larger prey. Small prey is killed by a nape bite resulting in broken neck vertebrae or dislocation of the head from the vertebral column.

2.4.2.4 Threats

The tiger population in India is officially estimated to be 1,571 – 1,875. Many of the tiger populations across the nation, particularly those outside protected reserves, face a variety of threats, including habitat fragmentation, encroachment, and poaching and developmental projects. These problems are directly or indirectly linked to anthropogenic factors.

Large development projects, such as mining, hydroelectric dams, and construction of highways are also taking their toll on the tiger's habitat. In the past few years, thousands of square kilometers of forestland have been diverted and destroyed to facilitate such projects. Though mostly outside the protected network, the loss of this vital habitat will have serious repercussions on tiger conservation in India.

2.4.2.5 Conservation

Project Tiger was launched in India in 1973, with the goal of saving the tiger and its habitat in India. With an initial list of 9 Tiger Reserves, this Project went on to cover 28 Tiger Reserves across the country, incorporating an area of 37,761 sq. km. Though this Project tackled various issues over the past 20 years, it had not been able to keep pace with the rapid changes that have changed the tiger landscape and increased human pressures. In 2006, it was replaced by the National Tiger Conservation Authority.

We need to make a concerted effort to combat poaching and habitat loss if this magnificent animal is to survive into the future.

2.5 Sundarbans ECA

A 10 km wide belt in the north and east of Sundarbans forest has been declared as ECA by the Ministry of Environment and Forests with an area of 175,000 hectares. The main objective of this ECA is that provide protection to the Reserve Forest and conservation of its biodiversity. There has been a great deal of change in the land use patterns and agricultural lands have been transferred to get that are developed for fish and shrimp culture.

2.6 History of forest management

The history of the Sundarbans dates to the 12th century. During the Mughal period (12 to 15th century) Raja Basanta Rai took refuge in the Sundarbans from the advancing armies of the Mughal Emperor Akbar. Many of the buildings built by Mughal later fell to the hands of Portuguese pirates, salt smugglers and dacoits in the 17th century. End of 18th century British Govt. brought Sundarbans under Government control and they promoted deliberate conversion to agricultural land. By 1870 about 3000 sq. km forest had been cleaned. In 1878 the forest was declared as Reserved Forest.

2.6.1 International Conventions

At least in 40 environmentally related International conventions, Bangladesh is a signatory. Some forest management conventions are:

Table 2.6: International Conventions

Year	Convention
1950	Int. Convention for the Protection of Birds, Paris, 1950.
1971	Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar, Iran, 1971.
1982	Protocol to Amend the Convention on Wetlands of Int. Importance Especially as Waterfowl Habitat, Paris, 1982.
1972	Convention Concerning the Protection of the World Cultural and Natural Heritage, Paris, 1992.
1993	Convention on Int. Trade in Endangered Species of Wild Fauna and Flora, Washington, 1993.
1979	Convention on the Conservation of Migratory Species of Wild Animals, Bann, 1979.
1992	Conservation of Biological Diversity, Rio de Janeiro, 1992.

2.6.2 Forest management and Policies

The principal policy and legislation related to Sundarbans Mangrove management are:

— The Forest Act of 1927 and its amendments

— The Protection and Conservation of Fish Act, 1950.

— The Embankment and Drainage Act, 1952

— The Wildlife Ordinance 1973 and Wildlife (Preservation) Act, 1974

— The Protection and Conservation of Fish (Amend) Ordinance, 1982

— The Marine Fisheries Ordinance, 1983

— The Protection and Conservation of Fish Rules, 1985.

— The Brick Burning Act, 1991

— The National Forest Policy of Bangladesh, 1994.

— The National Environment Act, 1995

— The Environment Conservation Rules 1997

Table 2.7: SRF Management Act

Year	Act
1974	Wildlife (Preservation) Act
1983	Sundarbans Wildlife Management Plan
1994	Forest Policy
2000	Amendment of Forest Act
2004	Social Forestry Rules
2009-2017	Bangladesh's Tiger Action (440 tigers)
2010-2020	The Integrated Resources Management Plans (IRMP), has been developed for ten-year (2010-2020 with ten strategic programs.

2.6.3: Habitat Suitability Index

A land resource manager uses Habitat Suitability Index to make better decisions on the landscape. If an HSI shows spotted deer prefer wetland habitat types, a land resource manager can preserve these types of habitat. A land resource manager can prohibit the development of infrastructure because an HSI shows the capacity of a given habitat to support spotted deer. HSI can be extrapolated to predict spotted deer in other locations. Spotted deer are found in marshy habitats such as grasslands open ground and moist forests, preferring areas with a good amount of cover for protection, such as cogongrass and young low-growing leaves and buds are plentiful. This species is predominantly found close to permanent sources of water

CHAPTER THREE
MATERIALS and METHODOLOGY

3.1 Study Area

The Sundarbans are the largest single block of tidal halophytic mangrove forest in the world, located in the southwestern part of Bangladesh. It lies on the Ganges-Brahmaputra Delta at the point where it merges with the Bay of Bengal. The forest lies a little south to the Tropic of Cancer between the latitudes 21°30'N and 22°30'N, and longitudes 89°00'E and 89°55'E. With its array of trees and wildlife, the forest is a showpiece of natural history. It is also a center of economic activities, such as extraction of timber, fishing, and collection of honey. The forest consists of about 200 islands, separated by about 400 interconnected tidal rivers, creeks, and canals.

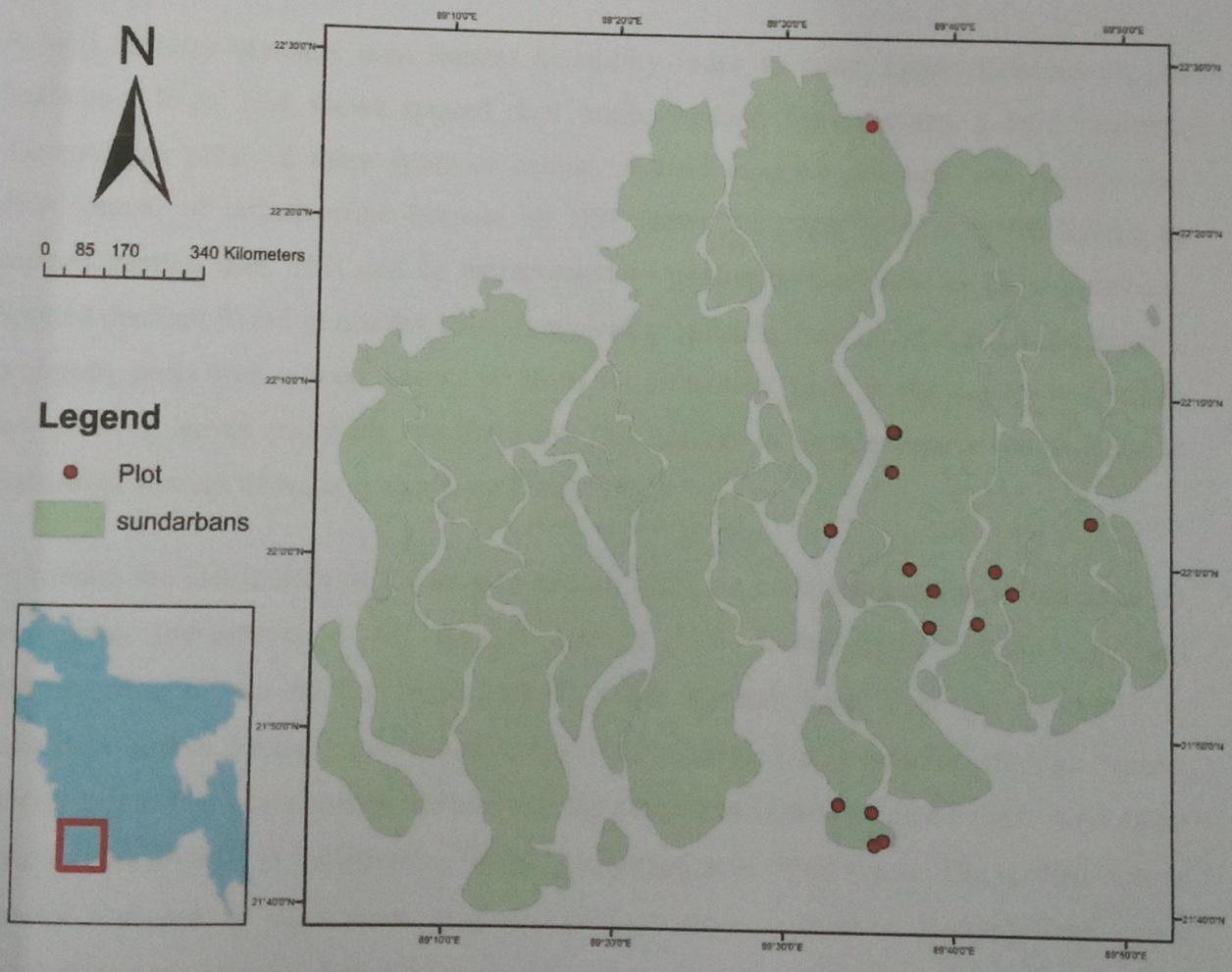


Fig 3.1: Study area

The Sundarbans was originally measured (about 200 years ago) to be of about 16,700 sq km. Now it has dwindled to about 1/3 of the original size. Because of the partition of India, Bangladesh received about 2/3 of the forest, the rest is on the Indian side. It is now estimated to be about 6,000 sq km, of which about 1,700 sq km is occupied by water bodies. The forest lays under two forest divisions, and four administrative ranges viz Chandpai, Sarankhola, and Khulna have 16 forest stations. It is further divided into 55 compartments and 9 blocks. The Sundarbans was declared as a Reserve Forest in 1875. About 32,400 hectares of the Sundarbans have been declared as three wildlife sanctuaries and came under the UNESCO World Heritage Site in 1997. These wildlife sanctuaries were established in 1977 under the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974.

3.2 Methodology

A land resource manager uses Habitat Suitability Index to make better decisions on the landscape. If an HSI shows spotted deer prefer wetland habitat types, a land resource manager can preserve these types of habitat. A land resource manager can prohibit the development of infrastructure because an HSI shows the capacity of a given habitat to support spotted deer. HSI can be extrapolated to predict spotted deer in other locations. Spotted deer are found in marshy habitats such as grasslands open ground and moist forests, preferring areas with a good amount of cover for protection, such as cogongrass and young low-growing leaves and buds are plentiful. This species is predominantly found close to permanent sources of water (Kenny and Smith, 1995)

To predict the distribution of the spotted deer in SRF, we collected existing information on the habitat preferences of the spotted deer in SRF. Comprehensive knowledge and understanding of the habitat requirements of the spotted water deer are necessary to accurately assess habitat quality and proactively manage the population through habitat manipulation. It is also necessary to evaluate the relative influence of each habitat variable on habitat suitability (HS) for effective habitat conservation at Sundarbans. The spotted deer is usually observed at edge areas generally contain more vegetative diversity than either forested or open areas and readily accessible areas. In other words, woody cover and food requirements can be fulfilled by the associated forested area, and herbaceous food and cover requirements can be satisfied by the associated open place.

Water availability is presumably the most critical factor for the deer. Wild mammals generally require a supply of fresh water around their habitat. Although the spotted deer have been reported to prefer areas that are 150–350 m away from water sources, the spotted water deer prefers habitats within 1 km of water.

In addition, topographic characteristics and human disturbance were considered as habitat variables. Habitat destruction mainly occurs because of the harvest of natural resources. Habitat losses and fragmentation caused by humans have become a concern for the recovery and management of Spotted. In this study, the effect of human disturbance on habitat quality was considered in the scale of 0-1(1= High, 0.25=low, 0.5=moderate).

3.2.1 Deer presence/absence database – Fieldwork based:

Along with the datasets described above, extensive fieldwork was carried out for the collection of information related to indicator environmental parameters while considering the presence of Spotted Deer (Axis axis) and predator (tiger) species. Random sampling method has been followed to collect the information on Spotted Deer and predator (tiger) species. After discussing with a local person and forest persons, a wildlife habitat survey sheet was prepared. The data collection sheet was revised with the comments of experts in the fields. During the survey, GPS locations, altitude, vegetation type, inundation height, distance to water, and human disturbance has been noted down. The habitat survey of prey and predator was also done in square plots of 20m x 20m length. Indirect evidence of Deer and tiger likea few pellets per plot and number of pugmarks per plots in the account of fresh or old has been collected. A total of 16 sample plots were laid in the whole area.

Table 3.1: Structural composition in specific species

Species	Relative density(%)	Relative frequency(%)	Relative dominance(%)	Importence value *I v*
Gewa	47.72816788	33.85416667	31.72468285	131.4803513
Sundri	16.33321096	22.39583333	28.45284011	55.68303568
Goran	23.45466766	19.27083333	18.55683166	48.42953843
Keora	6.674178155	9.375	8.584804543	29.38094862
Passur	4.816882371	9.375	5.093899188	21.31766961
Baen	0.721153846	4.166666667	6.380039527	11.25987218
Amur	0.27173913	1.5625	1.206902125	1.89520318

From this table, we can say that most of the cases the dominant species is gewa but whole the forest the dominant species is not gewa, some region the dominant species is gewa. Though the dominant species is gewa it's no relationship with deer. Deer has a relationship with keora and that relationship we shown in the graph.

Table 3.1: Stand structure and composition

Plot no	IVI (Major species)	Average height	Average diameter	Specific density ha-1
1	IVI of gewa= 165.92	20.2 ± 2.12	21.18 ± 2.64	3100
	IVI of Sundri= 93.02	12 ± 6.3	14.51 ± 2.57	2300
	IVI of passur= 41 06	6 1	32 1	100
2	IVI of Gewa= 211.33	5.96 ± o.65	15.11 ± 0.96	7000
	IVI of Goran= 88.66	6 ± 0.3	8.35 ± 0.05	4100
3	IVI of Gewa = 156.23	6.95 ± 0.83	13.22 ± 2.10	3100
	IVI of Sundri= 74.19	5.76 ± 0.36	8.11 ± 1.03	2000
	IVI of Goran= 69.56	6.35 ± 0.45	6.8 ± 0.54	2300
4	IVI of Bain= 96.10	12.4	29.8	100
	IVI of Gewa= 72.24	5.15 ± 0.15	8.6 ± 1.0	300
	IVI of Passur= 131.65	5.77 ± 0.35	10.22 ± 0.79	600
5	IVI of sundri= 147.72	6.2 ± 0.17	6.08 ± 0.25	5900
	IVI of Gewa= 107.58	7.8 ± 0.2	10.47 ±2.77	1900
	IVI of Passur= 78.88	8.4	15.6	1000
6	IVI of sundri= 120.59	9.73 ± 0.42	12.01 ± 1.16	1600
	IVI of Goran= 75.92	5.13 ± 0.07	6.76 ± 0.16	2300
	IVI of Gewa = 103.45	11.95 ± 0.16	7.93 ± 0.84	3700
7	IVI of sundri= 97.52	8.87 ± 0.19	12.77 ± 0.94	2200
	IVI of Goran= 53.46	5.73 ± 0.42	6.66 ± 0.35	1500
	IVI of Gewa= 92.03	10.75 ± 0.45	8.42 ± 0.56	3100
	IVI of passur= 56.97	19.2	31.9	100
8	IVI of sundri= 49.52	7.05 ± 0.35	13.35 ± 8.85	500
	IVI of Keora= 106.27	14.8	119	100
	IVI of Gewa= 113.87	12.87 ± 0.94	15.86 ± 1.35	1600
	IVI of Amur= 30.32	5.6	13.4	100
9	IVI of sundri= 69.13	6.05 ±1.15	7.62 ± 0.83	600
	IVI of Gewa= 230.86	5.4 ± 0.34	7.74 ± 0.36	7300
10	IVI of sundri= 82.26	8.43 ± 3.08	11.01 ± 1.19	1200
	IVI of Gewa= 121.41	6.83 ± 0.87	10.94 ± 1.09	2700
	IVI of passur= 32.50	6.7	14.7	100
	IVI of keora= 63.82	16.2	39.4	100
11	IVI of sundri= 36.37	11.7	8.6	100
	IVI of Gewa= 179.56	9.65 ± 2.40	11.97 ± 1.15	100
	IVI of Baen= 84.05	13.6	49.2	6300
12	IVI of keora= 300	9.27 ± 1.19	42.57 ± 4.98	400
13	IVI of Goran= 126.04	5.62 ± 0.25	7.10 ± 0.25	3800
	IVI of Gewa= 130.91	5.03 ± 0.29	10.64 ± 0.68	1200
14	IVI of Goran= 145.82	5.26 ± 0.41	6,36 ± 0.27	3400
	IVI of Gewa= 154.17	5.82 ± 0.28	14.79 ± 0.60	1500
15	IVI of Goran= 112.98	6 ± 0.26	6.59 ± 0.23	8300
	IVI of Gewa= 149.46	5.25 ± 0.13	9.85 ± 0.72	5200
	IVI of sundri= 37.54	6	9.5	100
16	IVI of Goran= 102.39	5.63 ± 0.42	6.49 ± 0.3	4200
	IVI of Gewa= 114.57	5.63 ± 0.53	7.6 ± 0.72	3400
	IVI of sundri= 83.03	7.2 ± 0.17	10.49 ± 1.7	1000

Source: Field survey, 2018

In the table (3.1) Importance value Index calculated from the field data of Height and DBH

3.2.2 Statistical Modeling:

After preparing the entire database we have used **Ordinary Least Square (OLS) Regression** modeling techniques for habitat suitability analysis of Spotted deer. The first step is to group the independent and dependent variables per plot. We cannot look at the spotted deer locations as points. The table (3.3) must have the number of deer's, Distance of Water body (m), Inundation height, Salinity level, and Pugmarks for each plot. All habitat variables for either analysis of variance or bivariate analysis at a significance level of .05 or less were included in the initial linear regression model.

The probability that a habitat is selected by the species was assumed to be taken in the form of the linear regression model. A binary response variable (y) was defined for each observation, such that y = 1 if observed and y = 0 if not. The linear regression equation estimates the probability that y = 1 if the sample region is the most suitable habitat, while y = 0 if not. The HSI model describing the probability of use conditioned on habitats was defined as follows:

$Yi = \beta 0 + \beta 1 x 1 + \epsilon i$

Where β′= (β0, β1, ...,..., a vector of coefficients. The HSI model is intrinsically bound within the interval from 0 to 1.

Table 3.3: Example of a pre-processed table using OLS.

Plot no	lon	lat	vegetation type	Disturbance	Inundation height	Waterbody	Deer pallets	pugmarks
1	22.745	89.363	Gewa-sundri-passur	0	0	57	0	1
2	22.743	89.36	Gewa-Goran	0.5	0	43	0	0
3	22.744	89.362	sundri-Gewa-passur	0	0.5	27	5	0
4	22.524	89.364	sundri-Gewa	0.25	0	41	2	1
5	22.525	89.362	sundri-Gewa-passur	0	0.5	28	5	0
6	22.529	89.368	sundri-Gewa-Keora	0.25	0	30	3	0
7	22.543	89.366	sundri-Gewa	1	0.25	24	0	0
8	22.504	89.363	sundri-Gewa-Keora	0	0.25	29	5	0
9	22.52	89.361	sundri-Gewa	0	0	25	4	0
10	21.44	89.35	Keora	0	1	20	5	0

3.2.2.1 Ordinary Least Square Regression Model:

Generalized least squares (GLS) is a method for fitting coefficients of explanatory variables that help to predict the outcomes of a dependent random variable. In statistics, ordinary least squares (OLS) is a type of linear least squares method for estimating the unknown parameters in a linear regression model. OLS chooses the parameters of a linear function of a set of

explanatory variables by the principle of least squares: minimizing the sum of the squares of the differences between the observed dependent variable (values of the variable being predicted) in the given dataset and those predicted by the linear function. Geometrically, this is seen as the sum of the squared distances, parallel to the axis of the dependent variable, between each data point in the set and the corresponding point on the regression surface – the smaller the differences, the better the model fits the data. The resulting estimator can be expressed by a simple formula, especially in the case of a simple linear regression, in which there is a single regression on the right side of the regression equation.

Input Feature Class: Plots with aggregated data

Unique ID: Plot No (ex, 1, 2, 3…)

Output Feature Class: Path and name of the output

Dependent Variable: Deer Pellets count

Explanatory Variables: Vegetation Type, Disturbance, Inundation Height, Water body

Output report file: Generates a report file

Table3.4: From the table, we can check the Significance level for each variable

Variable	Coefficient	S. E.	P Value	Signif.codes
(Intercept)	8.277724	1.35170	0.00168	**
Water Body	-0.13604	0.03925	0.01793	*
Inundation Height	0.02519	0.95486	0.97997	
Disturbance	-4.87669	0.77279	0.00147	**

Signif. Codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

Input Feature Class: Plots with aggregated data

Unique ID: Plot_No (ex, 1, 2, 3…)

Output Feature Class: Path and name of the output

Dependent Variable: Pugmarks

Explanatory Variables: Disturbance, Inundation Height, Water body

Output report file: Generates a report file

Table3.5: From the table, we can check the Significance level for each variable

Variable	Coefficient	S. E.	P Value	Signif. Codes
Intercept	0.338589	0.389705	0.402	
Disturbance	-0.330442	0.224739	0.1672	
Inundation height	-0.0858	0.375694	0.8232	
Waterbody	0.016956	0.009239	0.0914	.

Signif. Codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

The HSI model was statistically developed by comparing its distribution predictions with the actual distributions of spotted deer in the province based on the field data (total, 16 observations; 2018). The output of the P-value is 0.00168 that is <0.1. So, it is more than 99% significance and the R-squared value is 0.5237. So Null Hypothesis is rejected, and the alternative hypothesis is accepted.

So, deer number varies with a water body, Inundation height, and Disturbance. Deer number has relation with water body and that is negatively significant, the result is -0.13604. that is not possible because water body with deer has a positiverelation when the water body average more than 40 then the result is positive, but our sample plot is very close to the water body. So the result is negatively significant. Related to the disturbance the numbers of deer are decrease and the result is negative. So, the relation with deer and disturbance are highly negatively significance.

CHAPTER FOUR

RESULT and DISCUSSION

4.1 The HSI model for the deer and tiger of the Sundarbans

The habitat suitability index HSI for deer and predator (tiger) species were prepared by using environmental parameters along with field data. These maps (4.1) were further incorporated to develop the habitat suitability map for Tiger. After overlaying habitat variables on the habitats with shape file data I made a suitable prediction map of SRF. I applied this approach to identify the distribution of potential habitats at a higher resolution, which provided me with feasibility to directly map the target species. Using the OLS method the stepwise with 16 sample data.

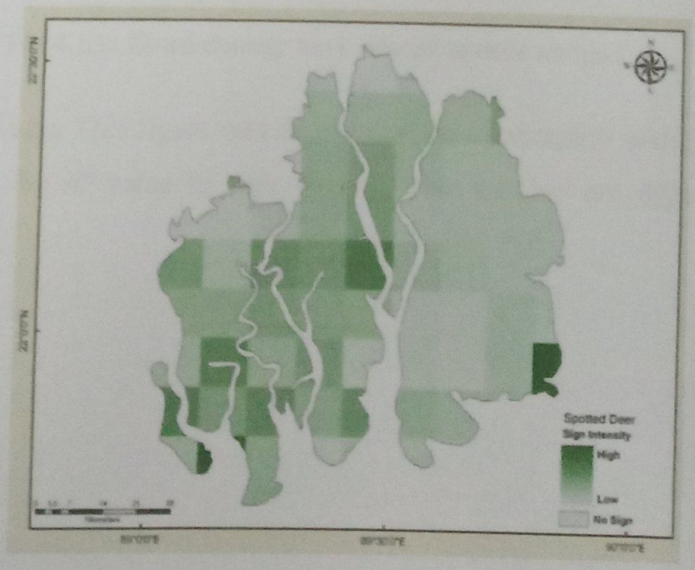
The resulting equation for the habitat variable data is as follows:

$$Y = 8.277724 \times dr - 0.13604x\ wb - 0.02519x\ ih - 4.87669x\ dis$$

Here,

wb = Water body dr = Deer pellets ih = Inundation height dis = Disturbance

The predicted value, Y, denotes the probability of observing spotted water deer in the area, ranging from 0.0 to 1. In this study, the predicted values were regarded as HSI values, describing the suitability of given habitat by combining the interactions of all key environmental variables. The significance of each habitat variable was measured using the Wald statistic ($p<.05$). Of all the habitat variables, dr, pm, wb, ih, dis had the largest impact on the HSI model, indicating that these components are major contributors to the HSI and particularly effective at predicting spotted deer occurrence. It also implied that the deer tend to avoid disturbance and less prefer wetlands and forest areas.



Map 4.1: Suitable Habitats for Spotted deer in SRF

Table 4.1: From the table, we can check the relationship with deer.

Species	Total species no	Density ha-1	Deer no ha-1
Gewa	514	3606.67	220
Sundri	175	1590.91	263.64
Goran	299	3737.5	187.5
Keora	6	200	433.34
Passur	19	380	280
Baen	2	100	200
Amur	1	100	300

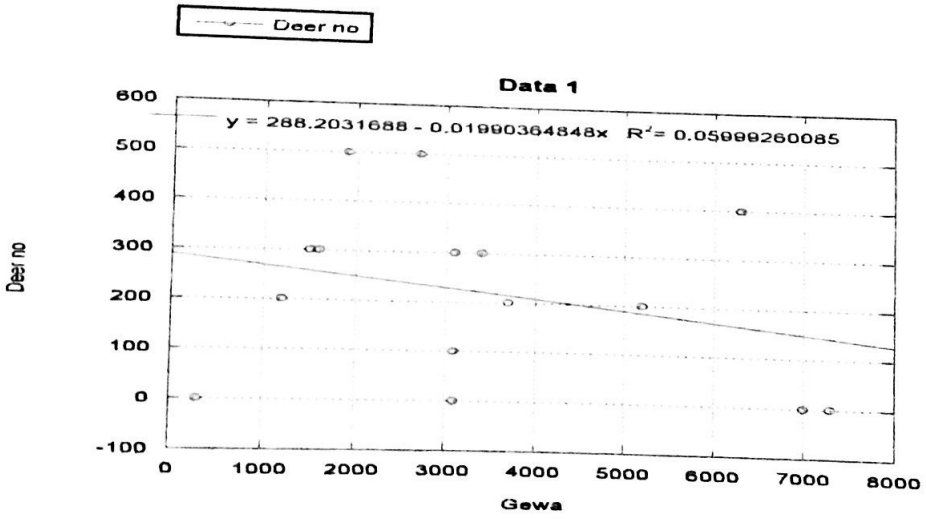


Fig 4.1.1: Gewa density ha-1 related to deer no ha-1

Habitat Suitability Index This figure was shown that the relationship with gewa and deer are significant because the R^2 value is high. So, the deer number are dependent with gewa density.

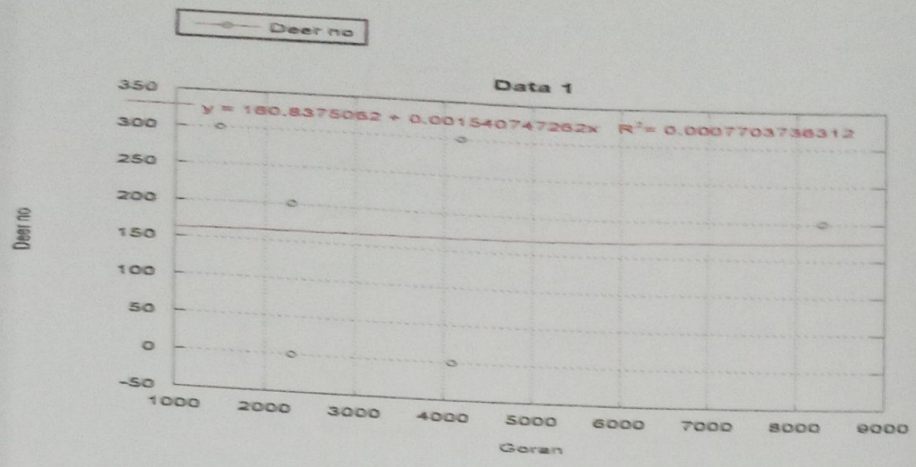


Fig 4.1.2: Goran density ha-1 related to deer no ha-1

From these figures, I could try to identifying the relationship with deer and species, and I saw that goran density are not related to deer number because its R-squire value is very low.

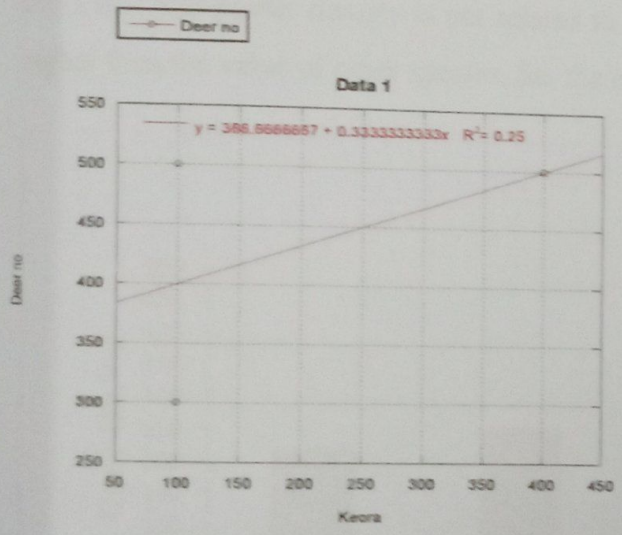


Fig 4.1.3

Keora density ha-1 related to deer no ha-1

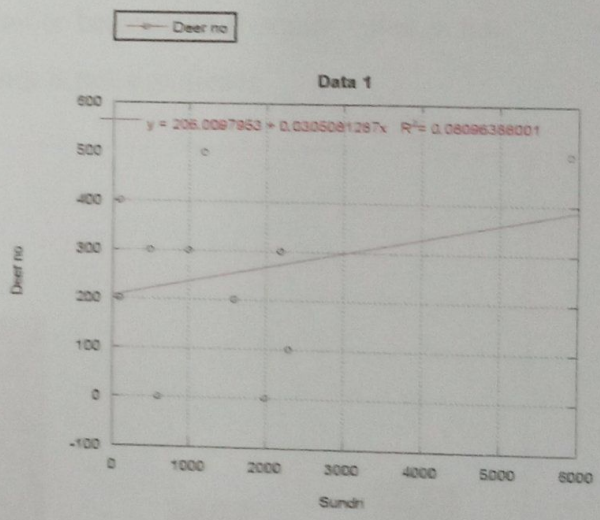


Fig 4.1.4

Sundri density ha-1 related to deer no ha-1

From these figures, I could try to identifying the relationship with deer and species, and I saw that Koera and sundri related to deer number because its R-squire value is higher than the value of other species. So, the deer numbers are dependent with keora and sundri density.

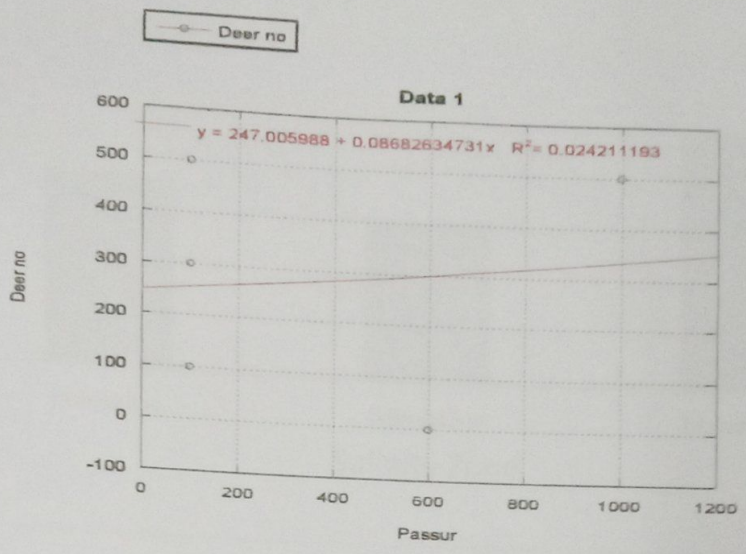


Fig 4.1.5: Passur density ha-1 related to deer no ha-1

From these figures, I could try to identifying the relationship with deer and passur species, and I saw that passur density is not related to deer number because its R-squire value is not higher than the value of other species. So, the relationship is not significant.

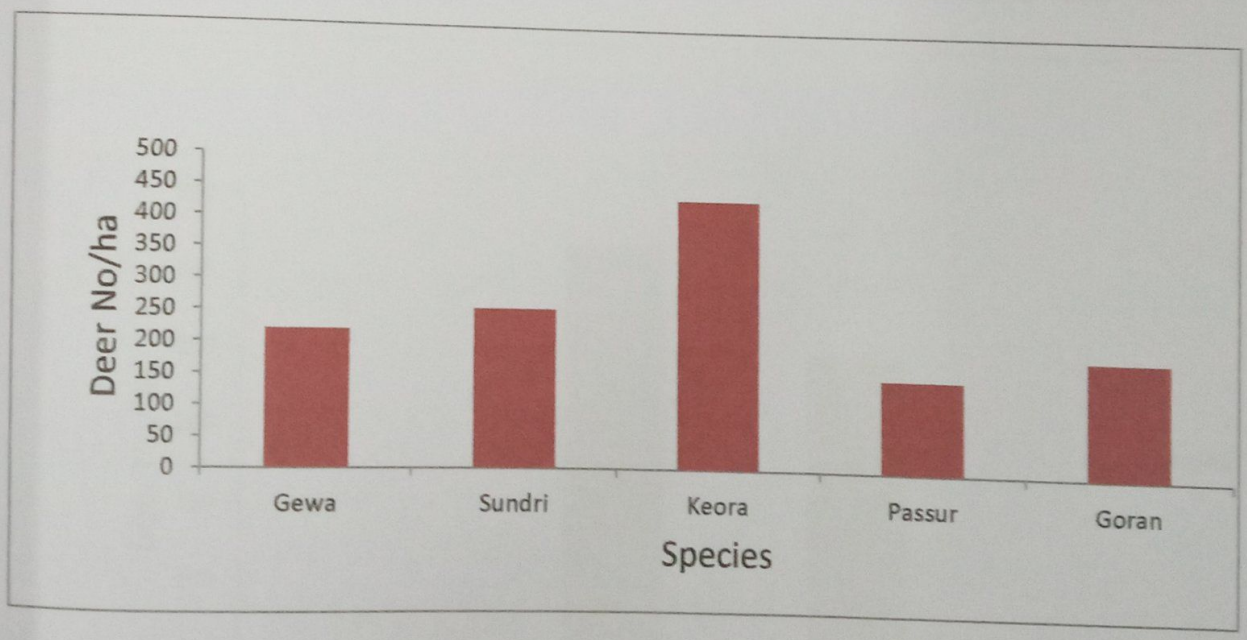


Fig.4.2: Deer No/ha respect to species

In this figure I can see that, deer number is high with respect to keora species and other species are related with deer, but these are low amounts of species because keora are palatable species for deer. So, these area keora densities are high as well as deer density.

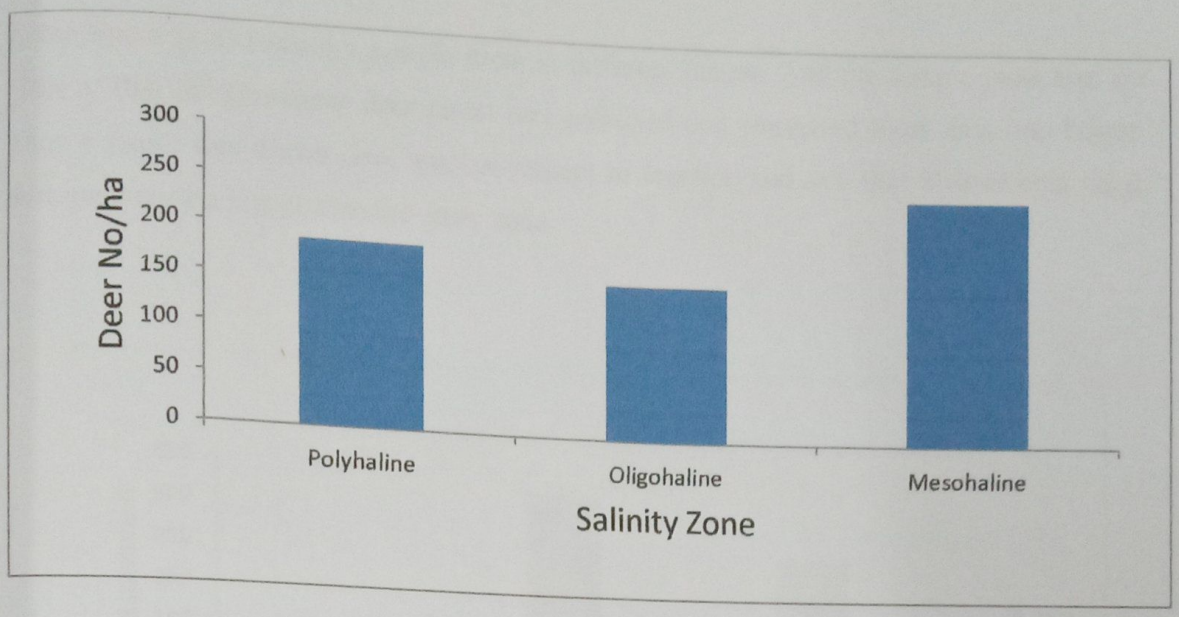


Fig.4.3:Deer no/ha respect to salinity zone

In the sample plot area, I found polyhaline zone, Oligohaline zone and Mesohaline zone.This salinity zone I calculate the species Important Value Index with deer number ha-1. And see that mesohaline and polyhaline zone deer number are higher than the oligohaline zone.

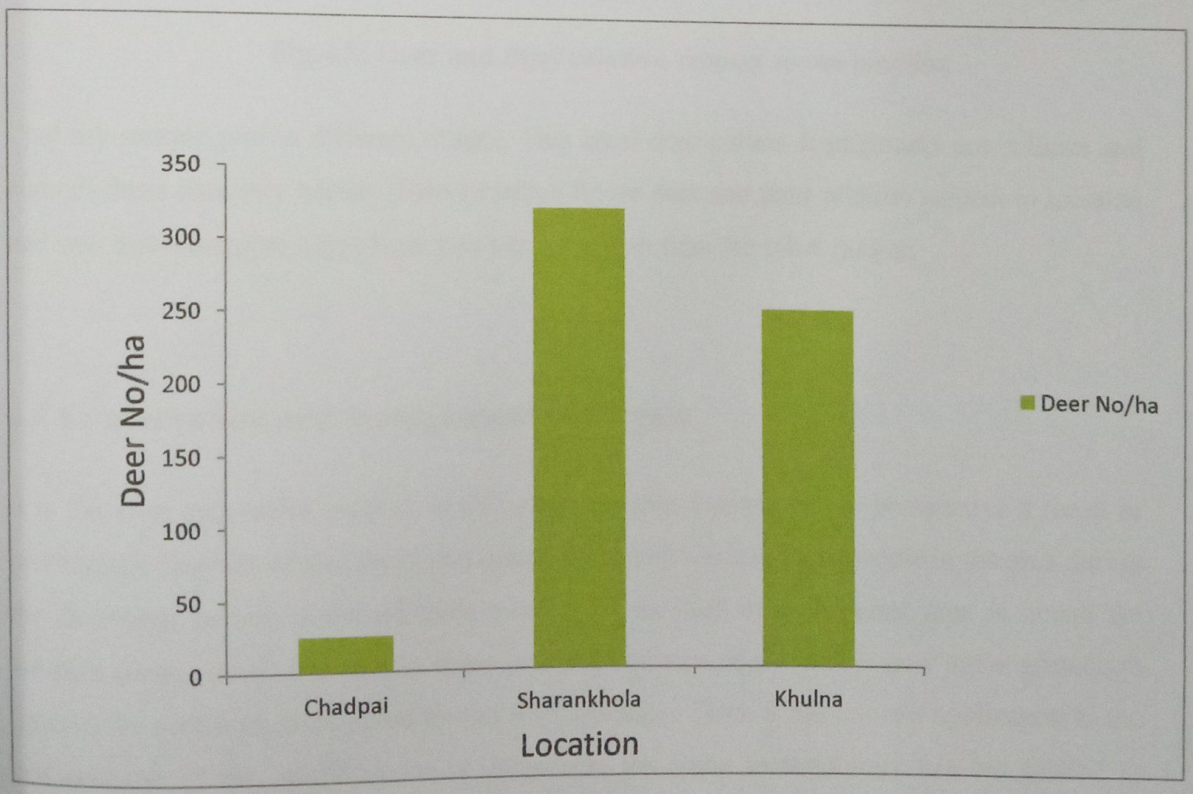


Fig.4.4: Deer No/ha respect to the location

In the figure (4.4) I put my sample plots in different ranges. And the sample plots size are (10m x 10m)m^2.This areas deer pallet was collected and converted these data into hector. Then a figure was drawn deer number respect to location and saw that Sharankhola range deer numbers are higher than the other zone.

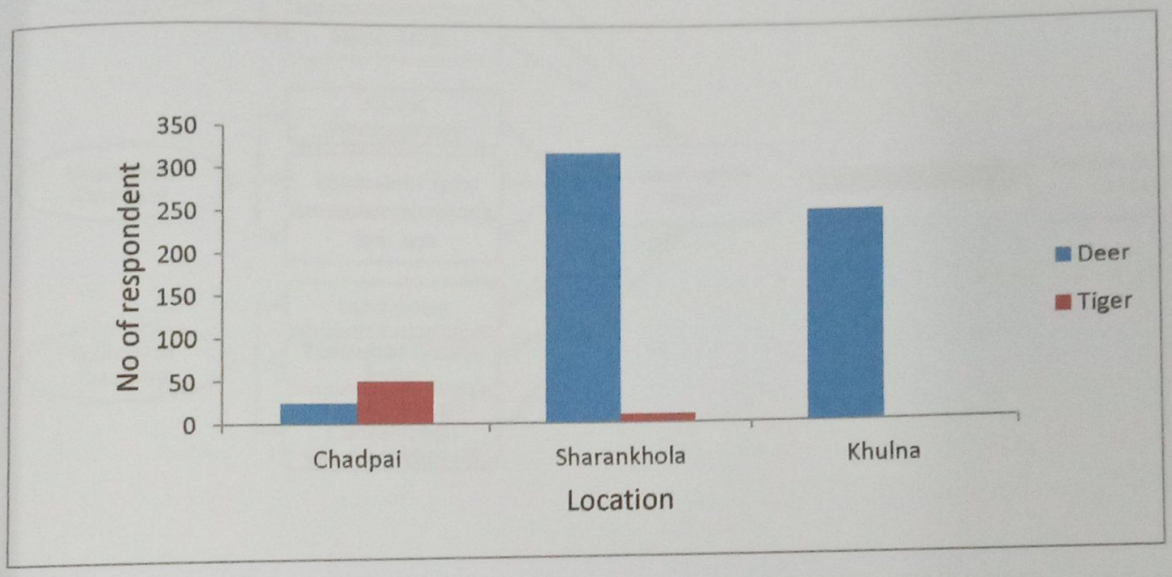


Fig.4.5: Deer and tiger relation respect to the location

I put my sample plot in different ranges. This areas deer pallets & pugmarks are collects and convert these data into hector. Then I made a figure deer and tiger relation respect to location and saw that, chandpai range tiger number are higher than the other ranges.

4.2 Conservation and management strategies:

It is the most successful product of this study is from a conservation perspective a result of preliminary findings of this study and discussions with various local people in the area during the fieldwork period, a considerable portion of the key deer dispersal area is zoned for wildlife conservation. But luckily there is a large portion of the area is now under protection beyond the core area determined by the SRF Division. Thus, it has a direct application to the conservation of the studied species. However, the same methodology can be applied to similar studies on different species. Together with GIS, habitat suitability maps delimit quite well areas highly suitable for each species. A flow chart (Fig 4.1) shown below explains how

this study can be helpful in developing national-level plan to protect highly endangered species from extinction.

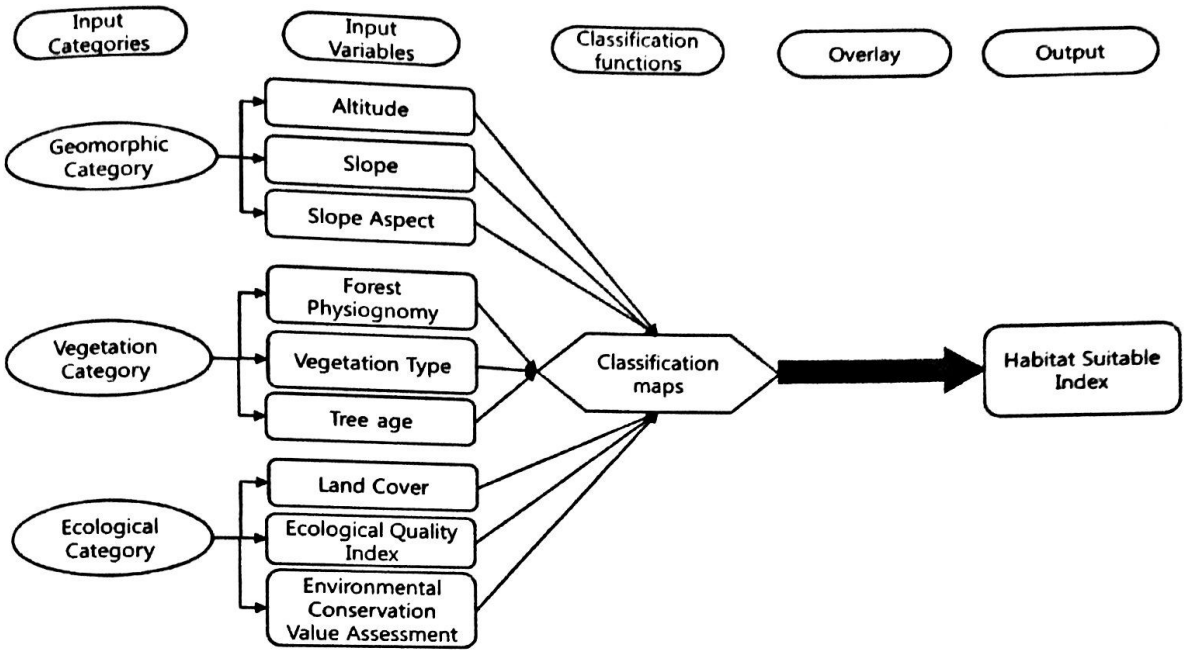


Fig 4.1: Habitat Suitability analysis and conservation – a proposed strategy (Pulliam, 2015)

4.3 Discussion:

The integrated habitat suitability index approach, as produced in this study, is based on the combined use of empirical evaluation models and models based on expertise in the GIS environment. GIS was used to produce the data needed in the models, as a platform to execute the models and in presenting the results of the analysis. However, the suitability models for the case study species were constructed with the GIS. This study showed that several GIS-based approaches and MCE techniques are immediately available for habitat suitability evaluation of a group of species. The biggest advantages of the method are connected to the possibilities to consider habitat factors on different scales, to combine habitat suitability evaluations for several species, and to integrate empirical models and the knowledge of experts.

Most of the earlier habitat suitability models (Map 4.1) have been mainly constructed on a single scale and therefore they are not so suitable as tools in large-scale landscape

management or conservation biology. In our approach, variables on different scales were used in both main phases of suitability modeling. Firstly, to construct the empirical models for case study species, and secondly, to calculate the suitability indices for the species to cover the entire case study area. The suitability models for species were constructed in such a way that they included factors for all the needed scales. In the phase of constructing the empirical models for the deer species. Variables describing vegetation structure and floristic composition were measured within sample areas.

To use the models in habitat suitability evaluation, the needed variables on appropriate scales were calculated overall for the case study area. Most of the variables were connected to the forest compartment scale and the required attributes of the compartments were only transformed to raster format. But there also exist variables, which were connected either to the certain distance around the pixel or to the entire case study area. In those cases, a certain distance around each pixel was recognized and the required landscape characteristics from the surroundings were calculated by spatial analysis and the results were saved as pixel attributes. Furthermore, in the case of the wetness index, the area influencing the value of the index was irregular and it was calculated by spatial analysis functions separately for each pixel. The GIS-based method used in this study enabled the production of the

variables needed in the evaluation process not only on several scales but also in several ways. Especially the variables describing composition (e.g. quantifies of different habitat types) and configuration (e.g. edge length) of the spatial structure of the landscape have gained more and more important in different kinds of ecological considerations.

In most cases, habitat suitability evaluations have been made only for one species at a time (e.g. Brown et al., 1994; Özesmi and Mitsch, 1997; Radeloff et al., 1999; Kobler and Adamic, 2000; Store and Kangas, 2001). It is only in some studies that suitability is considered also from the viewpoint of several species. Wu and Smeins (2000) combined two separate suitability maps in making one maximum-suitability map by choosing the higher of the habitat suitability values of the two species for every pixel. Also, Garcia and Armbruster (1997) took into consideration the needs of several species. They did not actually combine the suitability's of different species, but they did ensure that the suitability of a certain species did not decrease below a given limit when maximizing habitat suitability for another species. The cartographic modeling approach used in this study enables the use of multi-criteria decision-making techniques for combining and weighting da ifferent kind of species and

objectives.

While empirical habitat models are being continuously produced for new species, it is unlikely that we will ever have production models for all the species of interest. Therefore, it is important that the method used in suitability modeling is also capable of handling expert knowledge in evaluations. The case study demonstrates a situation where some of the species of interest have an empirical suitability model and the others do not. The latter could have a suitability model estimated for them based on expert knowledge. In the case study, all the variables in models were first transformed to GIS map layers and then combined by means of cartographic modeling.

Although the research field of modeling expert knowledge has recently been pointed out in many studies (see, e.g. Alho and Kangas, 1997; Kangas et al., 2000), there still exist some incompletely solved crucial problems. From the perspective of this study, the most essential of these were how to effectively utilize the knowledge of many experts, how to treat the differences between the data available and the data needed in the models, how to take account of the sensitivities of the results to the changes of the coefficients, and how to handle the interdependencies between decision variables.

Littleboy et al. (1996) used GIS-based spatial modeling to extrapolate point basic models to form spatial models. In their work, the study area was evaluated according to soil, slope, and rainfall classes and GIS was used to produce a suitability class for each polygon. In many other studies, too, suitability evaluation or modeling has been based on classified criteria (Li et al., 1997; Radeloff et al., 1999; Roseberry and Sudkamp, 1998). The problem with classification is that it can lead to loss of information or in a situation where there is no exact threshold value, or the value is not known with certainty of increasing uncertainty. In the present paper, this problem is tackled by using continuous priority and sub priority functions when evaluating habitat suitability for *S. odora*. This being the case, no classification of continuous attributes was needed and non-linear relationships between habitat suitability and the attributes could be considered.

When evaluating habitat suitability over a large area, some kinds of restrictions are often used to rule out the areas unsuitable for further consideration. Usually, this ruling out is done according to the most essential habitat requirements related to vegetation type (Garcia and Armbruster, 1997; Osborne et al., 2001). In some studies, also the minimum habitat area is

used to rule out habitats patches that are too small (Garcia and Armbruster, 1997). In the case of several species, the process of determining the feasible area is more complicated than in the case on just one species. The easiest solution to this problem is that we do not restrict the area at all. Then all of the areasis included in the consideration, but the worst areas according to the habitat requirements of the group of species are automatically rejected because of their low index values. However, in some cases, this is not enough. For example, it may be appropriate to reject some areas because of their total unsuitability for some important species. One possibility is to restrict the feasible area according to the minimum habitat requirements of the species in the area, and then the feasible area must fulfill the minimum requirements of all the species in the group. If this alternative is used, the habitat requirements of the species must be of the same kind. If the habitat requirements of species are diverse, the feasible requirements must be very general as otherwise, the feasible area will be very small or not exist at all.

CHAPTER FIVE
CONCLUSION

At present wildlife in all types of the forest of Bangladesh under threat (IUCN-Bangladesh 2000). Some of these already avoided wildlife. This creates a higher depletion of the forests. The tiger is the pride of the fauna of the Sundarbans which is also under threat. The Sundarbans is possibly the last hope for the survival of any unique and great population of wildlife. The reasons for such depletion are excessive deforestation or forested lands being brought under monoculture of indigenous and exotic plants or plantation forests comprising commercially viable species and shifting cultivations followed by land grabbing which has changed the composition of local vegetation which in turn has wiped out major forest-dwelling wildlife species from the country. Considering the declining and disappearing status of most wildlife in the country and need to ponder managing or preserving the vast wildlife wealth I still have in the Sundarbans Mangrove Forest in a sustainable manner.

The aim of this study is to develop a method by means of which it is possible to produce geo-referenced ecological information about the habitat requirements of spotted deer and Bengal tiger species. The integrated habitat suitability index approach includes the evaluating of target areas based on habitat factors and combining various suitability indices. Geographic Information System (GIS) was used to analyze the field data. Furthermore, linear regression methods provide the significance level and connecting (standardizing, weighting, and combining) the habitat needs of different species. It is obtaining that the tiger population in the Sundarbans is at risk of extinction. Recently an amendment is also done in the Act and Tiger Reserves are declared under the Wildlife (Protection) Amendment Act, 2006 (Act No. 39 of 2006), Chapter IVB, Section 38V, for giving special attention towards the conservation of tigers. When the prey species are numerous, the number of predators will increase because there is more food to feed them and a higher population can be supported with available resources. As the number of predators begins to increase, the density of the prey population will decrease in response to increased rates of predation. The main advantages of the method were connected to the possibilities for considering the habitat factors on different scales, to combine habitat suitability evaluations for deer and tiger species, to assess the tiger and its prey habitat, and to weight different species in different ways. Thus, the sharankholaand Khulna region are suitable for the deer habitat in various factors (such as food, fresh water and vegetation type), the tiger habitat is also suitable in the chandpai range. The present study will be the benchmark for future conservation of tiger as well as its pr

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