Khulna University
Life Science School
Forestry and Wood Technology Discipline

Author(s): Md. Abdur Rakib

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Supervisor(s): Dr. S. M Feroz, Forestry and Wood Technology Discipline, Khulna University

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Distribution and Habitat Preference of Tiger (Panthera tigris L.) in the Sundarbans Mangrove Forest

BY

Md. Abdur Rakib

STUDENT ID: 120502

FORESTRY AND WOOD TECHNOLOGY DISCIPLINE

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Supervisor

Dr. S. M. Feroz

Associate Professor

Forestry and Wood Technology Discipline

Khulna University

Prepared By

Rakib
28.02.2018

Md. Abdur Rakib

Student ID: 120502

Forestry and Wood Technology Discipline

Khulna University

Dedicated To My Beloved Parents

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List of Abbreviations

ADB	Asian Development Bank
EU	European Union
FAO	Food and Agricultural Organization
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
SEALS	Sundarbans Environmental And Livelihoods Security
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development

Approval

This is to Certify, Md. Abdur Rakib, Roll: 120502, has prepared this thesis entitled **"Distribution and Habitat Preference of Tiger (*Panthera tigris* L.) in the Sundarbans Mangrove Forest"**, 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. (Hons.) degree in Forestry.

28.02.2018

Dr. S. M. Feroz

Associate Professor

Forestry and Wood Technology Discipline

Khulna University

Khulna- 9208

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Abstract

The IUCN most endangered and schedule 1 species is the tiger (*Panthera tigris* L.) under the Wildlife Preservation Act,1974 Bangladesh. Tiger is facing serious conservation problems from illegal poaching, anthropogenic disturbance and habitat destruction in the Sundarbans. The present study was designed to identify the distribution of tiger in relation to habitats (riverside and forest proper), salinity zones (low, moderate and high) and river types (main, secondary and tertiary) of the Sudarbans. Stratified systematic sampling was followed for gathering the presence or absence data of tiger and deer species. Tiger species in tertiary and secondary riversides were approximately two times higher than that in the forest proper. It suggests that riverside is the most preferred habitat for tiger. On the other hand, moderate salinity zone is the most preferred habitat for tiger population. Deer were distributed uniformly over the Sundarbans. Therefore, management of tertiary and secondary riverside and moderate salinity zone is indispensible for the maintenance of high population of tiger species.

Chapter One

Introduction

1.1. Background of the study:

Mangroves are the various types of salt-tolerant plant species that occur in intertidal zones of tropical and subtropical shelterwood coastlines. The largest mangrove wetland in the world is the Sundarbans. The literally meaning of the Sundarbans is the beautiful forest that lies in the coastal region of the Bay of Bengal. Approximately 60% portion of the Sundarbans lies in Bangladesh between 21°30'-22°30'N latitudes and 89°00-89°55'E longitudes. 44% of the total forested area in the country is the Bangladesh Sundarbans. At the mouth of rivers Meghna and Padma joining the Bay of Bengal, Sundarbans is formed. It generates 50% of the total forest revenue in the form of tourism, fishing, honey collection, nipa*(Nypa fruticans* Wurmb*)* leaves for thatching, etc. (Khan, 2004).

A total 245 genera and 334 plant species were recorded in 1903 (According to David Prain). The characteristics of the Sundarbans flora is the abundance of Sundari (*Heritiera fomes* Buch.-Ham.), Gewa (*Excoecaria* agallocha L.), Goran (*Ceriops decandra* (Griff.) Ding Hou) and keora (*Sonneratia apetala* Buch.-Ham.) which grow prominently throughout the Sundarbans. Abundance of dhundul (*Xylocarpus granatum* K.D.Koenig)

or passur (*Xylocarpus mekongensis* Pierre) and kankra (*Bruguiera gymnorrhiza* L.) which distribution is discontinuous. Among palms, Poresia coaractata, Myriostachya wightiana and golpata (*Nypa fruticans*), and among grasses spear grass (*Imperata cylindrical* P. Beauv) and Khagra (*Phragmites karka* Retz.) are well distributed.

According to Bangladesh Wildlife preservation amendment act, 1974, Wildlife means any vertebrate, creature other than human beings and animals of usually domestic species or fish and includes till eggs of birds and reptiles.

Sundarbans is the only mangrove forest where the tiger occurs (Sanderson et al, 2006). The major prey species of the tiger, found in the Sundarbans are spotted deer (*Axis axis* Erxleben) and wild boar (*Sus scrofa* L.) and also purportedly include Rhesus macaque (*Macaca mulatta* Zimmermann), lesser adjutant stork (*leptoptilos javanicus* Horsfield), water monitor lizard (*Varanus salvator* Laurenti), crabs and fishes. Other carnivores found in the Sundarban are leopard cat (*Prionailurus bengalensis* Kerr), fishing cat (*Prionailurus viverrinus* Bennett), jungle cat (*Felis chaus* Schreber) and otter (*Lutra sp.* Brunnich) (Seidensticker and Hai, 1983). Gangetic river dolphin (*Platanista gangetica* Lebeck), Irrawady dolphin (*Orcaella brevirostris* Owen), Indo-Pacific hump-backed dolphin (*Sousa chinensis* Osbeck) and finless porpoise (*Neophocaena phocaenoides* G. Cuvier) etc are the diversified cetacean community found in the waters of Sundarbans. The largest living reptile, the estuarine crocodile is also found in the Sundarbans.

For balancing the environment wildlife plays an important role. To maintain different natural processes of nature, wildlife provides stability. Maintaining the balance of nature, wildlife helps. Food, medicine, timber, fibres, etc are of economic value as wild plant products and meat, medicines, hide, ivory, lac, silk, etc. are of tremendous economic value as wild animal products. To test effect of medicine, some wild organisms are used for scientific experiments. Generally for scientific experiments, monkey, chimpanzee, etc. are used. Diversity in the environment can be conserved by conserving wildlife. An ecosystem with more diversity is more stable which is told according to some scientists. For children as well as adult visiting parks and sanctuaries which is an enjoyable proposition. Thus, wildlife is the best means of entertainment. Diversity in the environment can be conserved by conserving wildlife. An ecosystem with more diversity is more stable which is told according to some scientists. For earning money, wild life can be used. Food, medicine, timber, fibres, etc are of economic value as wild plant products and meat, medicines, hide, ivory, lac, silk, etc. are of tremendous economic value as wild animal products. To test effect of medicine, some wild organisms are used for scientific experiments. Generally for scientific experiments, monkey, chimpanzee, etc. are used. In modern culture wild organisms play a very important role. Wild organisms produces new hybrid variety using wild plants and using wild animals which produces better hybrid variety of animals used for agriculture. It also produces new species of plants and animals.

The Sundarbans forest was declared a Ramsar site by the Convention of Wetlands in 1992 for conserving all flora and fauna. In 1997 three sanctuaries in the Sundarbans were declared as World Heritage Site by the UNESCO. The Sundarbans is the richest habitat in the lower Bengal Basin for a variety of faunal species, the last stronghold of the Royal Bengal Tiger (*Panthera tigris*). Studies (Seidenstiker and Hai, 1983; Salter, 1984; Blower, 1985 and Khan, 1986) revealed that the Bangladesh Sundarbans supports diverse biological resources.

The Sundarbans is contributing in various ecosystem services like soil formation, soil protection, and regulation of hydrological cycle, moisture contents, evaporation, climate and protection of the country from natural calamities (Kathiresan and Bingham, 2001).

In the Sundarbans the number of major wildlife is decreasing day by day. IUCN has been classified as endangered the Sundarbans since 2010. Major wildlife number around 440 in Bangladesh and 163–253 in Nepal. There were previously 67–81 individuals in Bhutan. However, the latest census estimated that 106 wild Bengal tigers are living in the Bangladesh Sundarbans (Prothom Alo Newspaper, 29 July, 2015). Both anthropogenic and natural causes are responsible for major wildlife loss in Bangladesh. The most significant cause of major wildlife loss is direct poaching to supply the increasing demand for tiger products. Moreover, Tiger-Human Conflict (THC) is very high in Bangladesh, which is evident from high rate of human killing. In addition, prey

poaching, unsustainable forest management and climate change induced natural calamities also affect major wildlife population. Though protection exists in the park, there are a few loopholes. The geographical topography with hostile terrain criss-crossed by several rivers and their tributaries, long international border with Bangladesh, fishing trawlers and launches enables poaching and the cutting of wood, affecting the mangrove forests. Lack of staff, infrastructure and lack of funds exacerbate the situation. Unfavourably regulating the salinity regime in the Sundarbans. The combined impact of increased inundation by the sea and increased salinity levels, particularly in the dry season, could affect structure and composition of the forest and thus the distribution of the prey and tigers. Yet, food shortage and habitat destruction are significant that forced tigers to stay in nearby villages. In this study we identify that the distribution pattern of major wildlife species in two major habitat types like riverside and forest proper. So, for protecting the Sundarban forest ecosystem and maintaining the major wildlife population, diversity and distribution of major wildlife in the Sundarbans is necessary.

1.2. Objectives of the study:

(1) To determine the abundance and spatial distribution of Tiger in the Sundarbans.

(2) To know the habitat, salinity and river type preference of Tiger.

Chapter Two

Review of Literature

2.1. Tiger

2.1.1. Classification:

Kingdom – Animalia

Phylum – Chordata

Class – Mammalia

Order – Carnivora

Sub Order – Feliformia

Family – Felidae

Genus – *Panthera*

Species – *Panthera tigris*

2.1.2. Physical Description:

Tigers have a reddish-orange coat with vertical black stripes along the flanks and shoulders that vary in size, length, and spacing. Some subspecies have paler fur and some are almost fully white with either black or dark brown stripes along the flanks and shoulders. The underside of the limbs and belly, chest, throat, and muzzle are white or light. White is found above the eyes and extends to the cheeks. A white spot is present on the back of each ear. The dark lines about the eyes tend to be symmetrical, but the marks on each side of the face are often asymmetrical. The tail is reddish-orange and ringed with several dark bands (Sunquist and Sunquist, 2002;).

Body size and morphology varies considerably among subspecies of tigers. Siberian tigers, also know as Amur tigers (*P. t. altaica*), are the largest. Male Siberian tigers can grow to 3.7 meters and weigh over 423 kg; females are up to 2.4 meters in length and 168 kg. Male Indochinese tigers (*P. t. corbetti*), though smaller than Siberian tigers in body size at 2.85 meters in length and 195 kg, have the longest skull of all tiger subspecies, measuring 319 to 365 mm. Sumatran tigers (*P. t. sumatrae*) are the smallest living subspecies. Male Sumatran tigers measure 2.34 meters and weigh 136 kg; females measure 1.98 meters and weigh 91 kg.

Tigers are powerful animals, one is known to have dragged a gaur bull weighing 700 kg. Tigers have short, thick necks, broad shoulders, and massive forelimbs, ideal for grappling with prey while holding on with long retractible claws and broad forepaws. A tiger's tongue is covered with hard papillae, to scrape flesh off the bones of prey.

All tigers have a dental formula of 3/3, 1/1, 3/2, 1/1. Bengal tigers (*P. t. tigris*) have the longest canines of any living large cat; from 7.5 to 10 cm in length. A tiger's skull is robust, short, and broad with wide zygomatic arches. The nasal bones are high, projecting little further than the maxillary, where the canines fit. Tigers have a well-developed sagittal crest and coronoid processes, providing muscle attachment for their strong bite.

2.1.3. Geographic Range:

The range of tigers once extended across Asia from eastern Turkey and the Caspian Sea south of the Tibetan plateau eastward to Manchuria and the Sea of Okhotsk. Tigers were also found in northern Iran, Afghanistan, the Indus valley of Pakistan, Laos, Thailand, Vietnam, Cambodia, Malaysia, and the islands of Java and Bali. Tigers are now extinct or nearly extinct in most of these areas. Populations remain relatively stable in northeastern China, Korea, Russia, and parts of India and the Himalayan region.

There are eight recognized subspecies of *Panthera tigris*. Siberian tigers, *P. t. altaica*, are currently found only in a small part of Russia, including the Amurussuri region of Primorye and Khabarovsk. Bengal tigers, *P. t. tigris*, are found in India, Bangladesh, Nepal, Bhutan, and China. Indochinese tigers, *P. t. corbetti*, are found in Cambodia, China, Laos, Malaysia, Myanmar, Thailand, and Vietnam. South China tigers, *P. t. amoyensis*, are found in three isolated areas in south central China. Sumatran tigers, *P. t. sumatrae*, are found only on the Indonesian island of Sumatra. Bali tigers (*P. t. balica*), Javan tigers (*P. t. sondaica*), and Caspian tigers (*P. t. virgata*) are thought to be extinct. Those subspecies occurred on the islands of Bali (*P. t. balica*), Java (*P. t. sondaica*), and in Turkey, the Transcaucasus region, Iran, and central Asia (*P. t. virgata*) (Mazak, 2006;).

2.1.4. Habitat:

Tigers live in a wide variety of habitats, suggested by their distribution across a wide range of ecological conditions. They are known to occur in tropical lowland evergreen forest, monsoonal forest, dry thorn forest, scrub oak and birch woodlands, tall grass jungles, and mangrove swamps. Tigers are able to cope with a broad range of climatic variation, from warm moist areas, to areas of extreme snowfall where temperatures may be as low as –40 degrees Celsius. Tigers have been found at elevations of 3,960 meters. In general, tigers require only some vegetative cover, a source of water, and sufficient prey (Mazak, 1981; Sunquist and Sunquist, 2002;).

2.1.5. Distribution and habitat:

In 1982 a sub-fossil middle phalanax was found in a prehistoric midden near kuruwita in Sri Lanka, which is dated to about 16,500ybp and tentatively considered to be of a tiger. Tigers appear to have arrived in Sri Lanka during a pluvial period, during which sea levels were depressed, evidently prior to the last glacial maximum about 20,000years ago. In 1929, the British taxonomist Pocock assumed that tigers arrived in southern India too late to colonize Sri Lanka, which earlier had been connected to India by a land bridge.

Results of a phylo geographic study using 134 samples from tigers across the global range suggest that the historical northeastern distribution limit of the Bengal tiger is the region in the Chittagong Hills and Brahmaputra River basin, bordering the historical range of the Indochinese tiger.

In the Indian subcontinent, tigers inhabit tropical moist evergreen forests, tropical dry forests, tropical and subtropical moist deciduous forests, mangroves, subtropical and temperate upland forests, and alluvial grasslands. Latter habitat once covered a huge swath of grassland, riverine and moist semi-deciduous forests along the major river system of the Gangetic and Brahmaputra plains, but has now been largely converted to agricultural land or severely degraded.

Today, the best examples of this habitat type are limited to a few blocks at the base of outer foothills of the Himalayas including the Tiger Conservation Units (TCUs) Rajaji-Corbett, Bardia-Banke, and the transboundary TCUs Chitwan-Parsa-Valmiki, Dudhwa-kailali and Shuklaphanta-Kishanpur. Tiger densities in these TCUs are high, in part because of the extraordinary biomass of ungulate prey.

The Bengal tigers in the Sundarbans in India and Bangladesh are the only tigers in the world inhabiting mangrove forests. The population in the Indian Sundarbans is estimated as 70 tigers in total (Jhala, Y. V., Qureshi, Q., Sinha, 2011).

India

In the past, Indian censuses of wild tigers relied on the individual identification of footprints known as pug marks — a method that has been criticised as deficient and inaccurate, though now camera traps are being used in many places.

Good tiger habitats in subtropical and temperate upland forests include the *Tiger Conservation Units* (TCUs) Manas-Namdapha. TCUs in tropical dry forest include Hazaribagh National Park, Nagarjunsagar-Srisailam Tiger Reserve, Kanha-Indravati corridor, Orissa dry forests, Panna National Park, Melghat Tiger Reserve and Ratapani Tiger Reserve. The TCUs in tropical moist deciduous forest are probably some of the

most productive habitats for tigers and their prey, and include kaziranga-Meghalaya, kanha-Pench, Simlipal and Indravati Tiger Reserves. The TCUs in tropical moist evergreen forests represent the les common tiger habitats, being largely limited to the areas and wetter parts of the Western Ghats, and include the tiger reserves of Periyar, kalakad-Mundathurai, Bandipur and Parambikulam Wildlife Sanctuary.

During the tiger census of 2008, camera trap and sign surveys using GIS were employed to project site-specific densities of tigers, their co-predators and prey. Based on the result of these surveys, the total tiger population was estimated at 1,411 individuals ranging from 1,165 to 1,657 adult and sub-adult tigers of more than 1.5 years of age. Across India, six landscape complexes were surveyed that host tigers and have the potential to be connected. These landscapes comprise the following:

In the Shivaliks–Gangetic flood plain landscape there are six populations with an estimated population size of 259 to 335 individuals occupying 5,080 km^2 (1,960 sq mi) of forested habitats, which are located in Rajaji and Corbett national parks, in the connected habitats of Dudhwa-Kheri-Pilibhit, in Suhelwa Tiger Reserve, in Sohagi Barwa Sanctuary and in Valmiki National Park;

In the Central Indian highlands there are 17 populations with an estimated population size of 437 to 661 individuals occupying 48,610 km^2 (18,770 sq mi) of forested habitats, which are located in the landscapes of kanha-Pench, Satpura-Melghat, Sanjay-Palamau, Navegaon-Indravati; isolated populations are supported in the tiger reserves of

Bandhavgarh, Tadoba, Simlipal and the national parks of Panna, Ranthambore-Kuno-Palpur-Madhav and Saranda;

In the Eastern Ghats landscape there is a single population with an estimated population size of 49 to 57 individuals occupying 7,772 km² (3,001 sq mi) of habitat in three separate forest blocks located in the Srivenkateshwara National Park, Nagarjunasagar Tiger Reserve and the adjacent proposed Gundla Brahmeshwara National Park, and forest patches in the tehsils of kanigiri, Baduel, Udayagiri and Giddalur;

In the Western Ghats landscape there are seven populations with an estimated population size of 336 to 487 individuals occupying 21,435 km² (8,276 sq mi) forest in three major landscape units Periyar-kalakad-Mundathurai, Bandipur-Parambikulam-Sathyamangalam-Mudumalai-Anamalai-Mukurthi and Anshi-Kudremukh-Dandeli;

In the Brahmaputra flood plains and north-eastern hills tigers occupy 4230 km² (1630 sq mi) in several patchy and fragmented forests;

Bangladesh

Tigers in Bangladesh are now relegated to the forests of the Sundarbans and the Chittagong Hill Tracts. The Chittagong forest is contiguous with tiger habitat in India and Myanmar, but the tiger population is of unknown status.

As of 2004, population estimates in Bangladesh ranged from 200 to 419, mostly in the Sundarbans. This region is the only mangrove habitat in this bioregion, where tigers survive, swimming between islands in the delta to hunt prey. Bangladesh's Forest Department is raising mangrove plantations supplying forage for spotted deer. Since 2001, afforestation has continued on a small scale in newly accreted lands and islands of the Sundarbans. From October 2005 to January 2007, the first camera-trap survey was conducted across six sites in the Bangladesh Sundarbans to estimate tiger population density. The average of these six sites provided an estimate of 3.7 tigers per 100 km^2 (39 sq mi). Since the Bangladesh Sundarbans is an area of 5,770 km^2 (2,230 sq mi) it was inferred that the total tiger population comprised approximately 200 individuals. In another study, home ranges of adult female tigers were recorded comprising between 12 and 14 km^2 (4.6 and 5.4 sq mi)., which would indicate an approximate carrying capacity of 150 adult females. The small home range of adult female tigers (and consequent high density of tigers) in this habitat type relative to other areas may be related to both the high density of prey and the small size

of the Sundarbans tigers (Barlow, A.; Smith, J. L. D.; Ahmad, I. U.; Hossain, A. N.; Rahman, M.; Howlader, A. 2011).

Since 2007 tiger monitoring surveys have been carried out every year by Wild Team in the Bangladesh Sundarbans to monitor changes in the Bangladesh tiger population and assess the effectiveness of conservation actions. This survey measures changes in the frequency of tiger track sets along the sides of tidal waterways as an index of relative tiger abundance across the Sundarbans landscape (Barlow, A.C.D, 2009).

The population size for the Bangladesh Sundarbans was estimated as 100–150 adult females or 335–500 tigers overall. Female home ranges, recorded using Global Positioning System collars, were some of the smallest recorded for tigers, indicating that the Bangladesh Sundarbans could have one of the highest densities and largest populations of tigers anywhere in the world. They are isolated from the next tiger population by a distance of up to 300 km (190 mi). Information is lacking on many aspects of Sundarbans tiger ecology, including relative abundance, population status, spatial dynamics, habitat selection, life history characteristics, taxonomy, genetics, and disease. There is also no monitoring program in place to track changes in the tiger population over time, and therefore no way of measuring the response of the population to conservation activities or threats. Most studies have focused on the tiger-human conflict in the area, but two studies in the Sundarbans East Wildlife sanctuary

documented habitat-use patterns of tigers, and abundances of tiger prey, and another study investigated tiger parasite load. Some major threats to tigers have been identified. The tigers living in the Sundarbans are threatened by habitat destruction, prey depletion, highly aggressive and rampant intraspecific competition, tiger-human conflict, and direct tiger loss.

Nepal

The tiger population in the Terai of Nepal is split into three isolated subpopulations that are seperated by cultivation and densely settled habitat. The largest population lives in Chitwan National Park and in the adjacent Parsa National Park encompassing an area of 2543 km² (982 sq mi) of prime lowland forest. To the west, the Chitwan population is isolated from the one in Bardia National Park and adjacent unprotected habitat farther west, extending to within 15 km (9.3 mi) of the Shuklaphanta Wildlife Reserve, which harbours the smallest population. The bottleneck between the Chitwan-Parsa and Bardia-Sukla Phanta metapopulations is situated just north of the town of Butwal.

As of 2009, an estimated 121 breeding tigers lived in Nepal. By 2010, the number of adult tigers had reached 155. A survey conducted from December 2009 to March 2010 indicates that 125 adult tigers live in Chitwan National Park and its border areas covering 1,261 km² (487 sq mi). From February to June 2013, a camera trapping survey was carried out in the Terai Arc Landscape, covering an area of 4,841 km² (1,869 sq mi)

in 14 districts. The country's tiger population was estimated at 163–235 breeding adults comprising 102–152 tigers in the Chitwan-Parsa protected areas, 48–62 in the Bardia-Banke National Parks and 13–21 in the Shuklaphanta Wildlife Reserve (WWF Nepal, 2010).

Bhutan

As of 2015, the population in Bhutan is estimated at 103 individuals. Tigers occur from an altitude of 200 m (660 ft) in the subtropical Himalayan foothills in the south along the border with India to over 3,000 m (9,800 ft) in the temperate forests in the north, and are known from 17 of 18 districts. Their stronghold appears to be the central belt of the country ranging in altitude between 2,000 and 3,500 m (6,600 and 11,500 ft), between the Mo River in the west and the Kulong River in the east. In 2010, camera traps recorded a pair of tigers at altitudes of 3,000 to 4,100 m (9,800 to 13,500 ft). The male was recorded scent-marking, and the female can also be seen to be lactating, confirming that the pair are living within their own territory, and strongly suggesting they are breeding at that altitude (Sangay, T, Wangchuk, T, 2005).

2.1.6. Ecology and behaviour:

The basic social unit of the tiger is the elemental one of mother and offspring. Adult animals congregate only on an *ad hoc* and transitory basis when special conditions

permit, such as plentiful supply of food. Otherwise they lead solitary lives, hunting individually for the dispersed forest and tall grassland animals, upon which they prey. They establish and maintain home ranges. Resident adults of either sex tend to confine their movements to a definite area of habitat within which they satisfy their needs, and in the case of tigresses, those of their growing cubs. Besides providing the requirements of an adequate food supply, sufficient water and shelter, and a modicum of peace and seclusion, this location must make it possible for the resident to maintain contact with other tigers, especially those of the opposite sex. Those sharing the same ground are well aware of each other's movements and activities (Sunquist and Sunquist, 2002:).

In the Panna Tiger Reserve an adult radio-collared male tiger moved 1.7 to 10.5 km (1.1 to 6.5 mi) between locations on successive days in winter, and 1 to 13.9 km (0.62 to 8.64 mi) in summer. His home range was about 200 km^2 (77 sq mi) in summer and 110 km^2 (42 sq mi) in winter. Included in his home range were the much smaller home ranges of two females, a tigress with cubs and a sub-adult tigress. They occupied home ranges of 16 to 31 km^2 (6.2 to 12.0 sq mi).

The home ranges occupied by adult male residents tend to be mutually exclusive, even though one of these residents may tolerate a transient or sub-adult male at least for a time. A male tiger keeps a large territory in order to include the home ranges of several females within its bounds, so that he may maintain mating rights with them. Spacing

among females is less complete. Typically there is partial overlap with neighboring female residents. They tend to have core areas, which are more exclusive, at least for most of the time. Home ranges of both males and females are not stable. The shift or alteration of a home range by one animal is correlated with a shift of another. Shifts from less suitable habitat to better ones are made by animals that are already resident. New animals become residents only as vacancies occur when a former resident moves out or dies. There are more places for resident females than for resident males.

During seven years of camera trapping, tracking, and observational data in Chitwan National Park, 6 to 9 breeding tigers, 2 to 16 non-breeding tigers, and 6 to 20 young tigers of less than one year of age were detected in the study area of 100 km^2 (39 sq mi). One of the resident females left her territory to one of her female offspring and took over an adjoining area by displacing another female; and a displaced female managed to re-establish herself in a neighboring territory made vacant by the death of the resident. Of 11 resident females, 7 were still alive at the end of the study period, 2 disappeared after losing their territories to rivals, and 2 died. The initial loss of two resident males and subsequent take over of their home ranges by new males caused social instability for two years. Of 4 resident males, 1 was still alive and 3 were displaced by rivals. Five litters of cubs were killed by infanticide, 2 litters died because they were too young to fend for themselves when their mothers died. One juvenile tiger was presumed dead after being photographed with severe injuries from a deer snare. The remaining young

lived long enough to reach dispersal age, 2 of them becoming residents in the study area.

2.1.7. Hunting and diet:

Tigers are carnivores. They prefer hunting large ungulates such as chital, sambar, gaur, and to a lesser extent also barasingha, water buffalo, nilgai, serow and takin. Among the medium-sized prey species they frequently kill wild boar, and occasionally hog deer, muntjac and grey langur. Small prey species such as porcupines, hares and peafowl form a very small part in their diet. Because of the encroachment of humans into their habitat, thy also prey on domestic livestock.

In Nagarahole National Park, the average weight of 83 tiger kills was 401 kg (884 lb). This sample included several gaurs weighing upwards of 1000kg (2200 lb). Gaurs were the most preferred choice of prey by tigers in Nagarahole, making up 44.8% of all tiger kills. Sambar deer were the second most preferred and made up 28.6% of all tiger kills. In Bandipur National Park, gaur and sambar together also constituted 73% of their diet.

Bengal tigers have been known to take other predators, such as leopards, wolves, jackals, foxes, crocodiles, Asiatic black bears, sloth bears, and dholes as prey, although these predators are not typically a part of their diet. They rarely attack adult elephants and rhinoceroses but such extraordinarily rare events have been recorded.

The British-Indian hunter and naturalist Jim Corbett also described an incident of two tigers fighting and killing a large bull elephant. If injured, old or weak, or their normal prey is becoming scarce, they may even attack humans and become man-eaters (Ullasa, K, 2001.).

2.1.8. Reproduction and lifecycle:

Males reach maturity at 4–5 years of age, and females at 3–4 years. A Bengal comes into heat at intervals of about 3–9 weeks, and is receptive for 3–6 days. After a gestation period of 104–106 days, 1–4 cubs are born in a shelter situated in tall grass, thick bush or in caves. Newborn cubs weigh 780 to 1,600 g (1.72 to 3.53 lb) and they have a thick wooly fur that is shed after 3.5–5 months. Their eyes and ears are closed. Their milk teeth start to erupt at about 2–3 weeks after birth, and are slowly replaced by permanent dentition from 8.5–9.5 weeks of age onwards. They suckle for 3–6 months, and begin to eat small amounts of solid food at about 2 months of age. At this time, they follow their mother on her hunting expeditions and begin to take part in hunting at 5–6 months of age. At the age of 2–3 years, they slowly start to separate from the family group and become transient — looking out for an area, where they can establish their own territory. Young males move further away from their mother's territory than young females. Once the family group has split, the mother comes into heat again (Mazak, V, 1981).

2.2. Deer

2.2.1. Classification:

Kingdom – Animalia

Phylum – Chordata

Class – Mammalia

Order – Cetartiodactyla

Family – Cervidae

Subfamily – Cervinae

Genus – Axis

Species – *Axis axis*

2.2.2. Physical Description:

The spotted deer is perhaps the most beautiful of all deer. The weight of adult spotted *deer* is between 35 to 85 kg. Head to body length measures about 90 to 140 cm. The length of tail about 10 to 25 cm. They are about 70 to 90 cm high at the shoulder.

The color of body is bright golden brown with white spots. White spots occur in both sexes and run longitudinally in rows throughout the duration of the animal's life. Males being slightly darker than females.

The head is a slightly lighter shade of golden brown than the body, and the eyes are surrounded by a ring of paler furs. Males have black facial markings. A dark dorsal stripe runs the length of the animals back (Albes,1977; Walker,1964).

The underparts are white or creamy in color. The tail is short, with white underparts. They have white furs on the lower lip and chin.

The legs are short and strong, with white or creamy underparts and light brown or whitish brown outer parts. They have a large, white throat patch which is more prominent in the males.

2.2.3. Distribution:

They found in India, Sri Lanka, Nepal, Bangladesh, Bhutan, and Pakistan. Spotted deer have also been introduced to Argentina, Australia, Brazil, South Africa, USA, and Argentina.

2.2.4. Habitat:

They prefer dense deciduous forests, semi-evergreen forests, and open grasslands. They also prefer heavy forest cover for shade. The highest numbers of spotted deer are found in the forests of India.

Spotted deer is a social animal. They commonly occur in herds of 6 to 30, which may contain 2 or 3 stags. Herds are common and composed of adult females and their young from the present and previous year. Large dominant stags without velvet stay in the center of the herd and are surrounded by the females and their young.

They are herbivores, and feed on various type grasses, herbs, shrubs, leaves, fruits and branches of trees. They also eat their shed antlers as a source of nutrients, and will use mineral licks. They prefer to be near water and will drink in mornings and evenings in hot weather.

2.2.5. Ecology and Behaviour:

Chital are active throughout the day. In the summer, time is spent in rest under shade and the sun's glare is avoided if the temperature reaches 80 °F (27 °C); activity peaks as dusk approaches.

As days grow cooler, foraging begins before sunrise and peaks by early morning. Activity slows down during midday, when the animals rest or loiter about slowly. Foraging recommences by late afternoon and continues till midnight. They fall asleep a

few hours before sunrise, typically in the forest which is cooler than the glades. These deer typically move in a single file on specific tracks, with a distance of two to three times their width between them, when on a journey, typically in search of food and water sources. A study in the Gir National Park (Gujarat, India) showed that chital travel the most in summer of all seasons. When cautiously inspecting its vicinity, the chital will stand motionless and hear with rapt attention, facing the potential danger if any. This stance may be adopted by nearby individuals as well. As an anti-predator measure, chital will flee in groups (unlike the hog deer that disperse on alarm); sprints are often followed by hiding in dense undergrowth. The running chital has its tail raised, exposing the white underparts. The chital can leap and clear fences as high as 1.5 metres (4.9 ft), but prefers to dive under them. It stays within 300 metres (980 ft) of cover (Tak, P.C.; Lamba, B.S,1984).

A gregarious animal, the chital forms matriarchal herds comprising an adult female and her offspring of the previous and the present year, which may be associated with individuals of any age and either sex, male herds and herds of juveniles and mothers. Small herds are common, though aggregations of as many as 100 individuals have been observed. Groups are loose and disband frequently, save for the juvenile-mother herd. Herd membership in Texas is typically up to 15;herds can have five to 40 members in India.

Studies in the Nallamala Hills (Andhra Pradesh, India) and the Western Ghats (western coast of India)showed seasonal variation in the sex ratio of herds; this was attributed to the tendency of females to isolate themselves ahead of parturition. Similarly, rutting males leave their herds during the mating season, hence altering the herd composition. Large herds were most common in monsoon, observed foraging in the grasslands. Predators of the chital include wolves, Bengal tigers, Asiatic lions, leopards, Indian rock pythons, dholes, Indian pariah dogs and mugger crocodiles. Red foxes and golden jackals target juveniles. Males are less vulnerable than females and juveniles.

A vocal animal, the chital, akin to the North American elk, gives out bellows and alarm barks. Its calls are, however, not as strong as those of elk or red deer; they are mainly coarse bellows or loud growls. Bellowing coincides with rutting. Dominant males guarding females in oestrus make high-pitched growls at less powerful males. Males may moan during aggressive displays or while resting. The chital, mainly females and juveniles, will bark persistently when alarmed or if they encounter a predator. Fawns in search of their mother often squeal. The chital can respond to the alarm calls of several animals such as the common myna and langurs.

Marking behaviour is pronounced in males. Males have well-developed preorbital glands (near the eyes). They stand on their hindlegs to reach tall branches and rub the open preorbital glands to deposit their scent there. This posture is also used while

foraging. Urine-marking is also observed; the smell of urine is typically stronger than that of the deposited scent. Sparring between males begins with the larger male displaying his dominance before the other-this display consists of hissing heading away from the other male with the tail facing him, the nose pointing to the ground, the ears down, the antlers upright and the upper lip raised. The fur often bristles during the display. The male approaches the other in a slow gait. Males with velvet antlers may hunch over instead of standing erect as the males with hard antlers. The opponents then interlock their horns and push against each other, with the smaller male producing a sound at times which is louder than that produced by sambar deer but not as much as the barasinga's. The fight terminates with the males stepping backward, or simply leaving and foraging. Fights are not generally serious. Individuals may occasionally bite one another.

Common myna are often attracted to the chital. An interesting relationship has been observed between herds of chital and troops of the northern plains gray langurs, a widespread South Asian monkey. Chital benefit from the langur's eyesight and ability to post a lookout from trees, while the langur benefit from the chital's strong sense of smell-both of which help keep a check on potential danger. The chital also benefit from fruits dropped by langurs from trees such as *Terminalia bellerica* and *Phyllanthus emblica*. The chital has been observed foraging with sambar deer in the Western Ghats.

2.2.6. Diet:

Grazers as well as browsers, the chital mainly feed on grasses throughout the year. They prefer young shoots, in the absence of whose tall and coarse grasses will be nibbled off at the tips. Browse forms a major portion of the diet only in the winter months-October to January-when the grasses, tall or dried up, are no more palatable. Browse includes herbs, shrubs, foliage, fruits and forbs; Another source of nutrition may come from mushrooms which are high in proteins and nutrients and are also found in Sal forests(Moe and Wegge,1994). *Moghania* species are often preferred while browsing. Fruits eaten by chital in the Kanha National Park (Madhya Pradesh, India) include those of *Ficus* species from January to May, *Cordiamyxa* from May to June, *Syzygium cumini* from June to July. Individuals tend to group together and forage while moving slowly. Chital are generally silent when grazing together. Males often stand on their hindlegs to reach tall branches. Water holes are visited nearly twice daily, with great caution. In the Kanha National Park, mineral licks rich in calcium and phosphorus pentoxide were scraped at by the incisors. Chital in the Sundarbans may be omnivores; remains of red crabs have been found in the rumen of individuals.

2.2.7. Reproduction:

Sexual maturity is reached within Breeding takes place throughout the year, with peaks that vary geographically. Sperms are produced year-round, though testosterone levels

register a fall during the development of the antlers. Females have regular oestrus cycles, each lasting three weeks. The female can conceive again two weeks to four months after the birth. Males sporting hard antlers are dominant over those in velvet or those without antlers, irrespective of their size. Courtship is based on tending bonds. A rutting male fasts during the mating season and follow and guard a female in oestrus. The pair will do several bouts of chasing and mutual licking before copulation (Fletcher, T.J.1986).

The newborn is hidden for a week after birth, a period much shorter than most other deer. The mother-fawn bond is not very strong, as the two get separated often, though they can reunite easily as the herds are cohesive. If the fawn dies, the mother can breed once again so as to give birth twice that year. The males continue their growth till seven to eight years. The average lifespan in captivity is nearly 22 years. The longevity in the wild, however, is merely five to ten years.

The chital is found in large numbers in dense deciduous or semi-evergreen forests and open grasslands. The highest numbers of chital are found in the forests of India, where they feed upon tall grass and shrubs. Chital have been also spotted in Phibsoo Wildlife Sanctuary in Bhutan, which has the only remaining natural Sal (*Shorea robusta*) forest in the country. They do not occur at high altitudes, where they are usually replaced by other species such as the sambar deer. They also prefer heavy forest cover for shade and avoid direct sunlight.

Chapter Three

Materials and Methods

3.1. Study site:

The Sundarbans reserve forest is located between N' 21°30' - 22°40', and E' 88°05'-89°55' in the Ganges-Brahmaputra delta which is the south of the tropic of cancer (Iftekhar and Islam, 2004). Interspersed with a maze of tidal waterways, the Sundarbans is composed of vegetated low lying islands with elevations ranging from 0.9-2.1 m above mean sea level (Katebi and Habib, 1989; Iftekhar and Islam, 2004b). Approximately 30% comprises a complex network of water bodies (streams and rivers) and remaining 70% are flat lands with occasional depressions varying considerably in width and depth of the total land area of the Sundarbans. The sub-soil is stratified with alternate layers of clay and sand but is compacted at greater depth and the soils are finely texured silty clay loam (Chowdhury, 1968). Most of the forest areas, the soil p^H range from 7.0-8.0 which is alkaline.10 year average temperature was 26.0°C and mean annual maximum and minimum temperatures vary between 32° and 20°C (Canonizado and Hossain, 1998). Average annual relative humidity ranges from 77% to 80% and the region has high relative humidity. About 1900mm to about 2500 mm, the mean annual rainfall ranges.

The changes in the volume of fresh water flow from upstream rivers are related to the change in spatial pattern of salinity inside the Sundarbans Salinity increases from the east to the west across the whole Sundarbans. Oligohaline (low salinity), mesohaline (moderate salinity) and polyhaline (high salinity) are the three zones of the Sundarbans based on the soil salinity distribution (Siddiqi, 2001).

Sundri (*Heritiera fomes*) is the most abundant tree species in the oligohaline zone, followed by Gewa (*Excoecaria agallocha*) in the mesohaline zone and Goran (*Ceriops decendra*) a typical species of the polyhaline zone zone. These three species occupy about 70 % of the forest. Baen (*Avicennia officinalis* L.), Dhundul (*Xylocarpus granatum*), Passur (*Xylocarpus mekongensis*) and Keora (*Sonneratia apetala*) are also frequently found (Fig.1).

Compared to other mangrove areas, the Sundarbans has a high diversity of mammal species (49), but compared to other major forest types on the sub-continent it is lower (Hussain and Acharya 1994; Iftekhar and Islam 2004b; Gopal and Chauhan 2006). There are no other large terrestrial carnivores apart from tiger. Leopard cat (*Prionailurus bengalensis*), Fishing cat (*Prionailurus viverrinus*), Jungle cat (*Felis chaus*), and Otter (*Lutra sp.*) are the small carnivore community (Seidensticker and Hai 1983). Jackals (*Canis aureus* Linnaeus) are only been observed on the south-east coast.

Chital (*Axis axis*), wild boar (*Sus scrofa*), and barking deer (*Muntiacus muntjak* Zimmermann) are the main ungulate species (Hendrichs, 1975). Swamp deer (*Cervus duvauceli* G. Cuvier), Hog deer (*Axis porcinus* Zimmermann), and Buffalo (*Bubalus bubalis* Linnaeus) are a more diverse ungulate assemblage implied in earlier reports, but these species abundant or widespread is unknown (Curtis,1933; Sanyal, 1983; Seidensticker and Hai,1983; Blower, 1985). Only wild primate species present in the Sundarbansis the Rhesus macaque (*Macaca mulatta*) (Hendrichs, 1975). A total diversity of reptiles (59 species) (Hussain and Acharya, 1994;Gopal and Chauhan, 2006)in which monitor lizards (*Varanus sp.*) and estuarine crocodile (*Crocodylus porosus* Schneider) are the most often seen. Dog-faced water snake (*Cerberus rynchops* Schneider), king cobra (*Ophiophagus hannah* Cantor), and Indian spectacled cobra (*Naja naja* Linnaeus) are the more commonly encountered snakes. Rarely seen Indian python (*Python molurus* Linnaeus) which is also present. A number of fourteen species of turtles and eight species of amphibian have been recorded (Hussain and Acharya, 1994; Das and Nandy, 1999b).

95 species of waterfowl, 38 species of raptor, and nine species of kingfisher as a total of 315 species of birds are found in the Sundarbans mangrove forest of Bangladesh. (Hendrichs,1975; Seidensticker and Hai, 1983; Sarker and Sarker, 1986;Hussain and Acharya, 1994; Naskar and Mandal, 1999). A common site along the riverside is the brahminy kite (Haliastur indus Boddaert) which is widespread. The white-bellied sea eagle (*Haliaeetus leucogaster* Gmelin) is also common near the coast. Species of egrets,

shanks, herons, plovers, curlews, gulls, and terns are abundant among waders and shorebirds. Endangered masked finfoot (*Heliopais personata* G.R. Gray) is also a note of the presence in the Sundarbans. (Neaumann-Denzau et al, 2008).

3.2. Field Survey Method:

The study area comprised of entire Sundarbans excluding the three wildlife sanctuaries and the methodology applied in this study followed the similar methodology adopted in the study of floral biodiversity of the Sundarbans under SEALS project (Islam et al. 2016). A series of line transects (Fig.2 and Fig.3) with positioning of plots on the line at a definite interval were executed to capture maximum diversity within a site. The sampling sites were previously stratified on the vegetation map depending on the available forest types (see Fig. 1). The widely practiced systematic sampling in tropical forest inventory has been applied in the present field survey. Due to systematic coverage of the line transect in a sample site, all rare niches are included. Both on the vegetation map and in the ground two major habitat types such as streamside and 'forest proper' (inner side of forest) were identified for sampling. River track was considered as the main transect line and the lateral transects are established at right angle to the main transect to sample forest proper plots, spaced systematically at a 100-m distance inside the forest. But these lateral transects also have been positioned alternately on either side of the main river transect (river track) at a distance of 2 kilometers (Fig.2 and Fig.3). To capture the maximum diversity of streamside, study plots were also established at a 100-m distance along the main transects. In the case of sampling forest proper, every first plot was positioned on the lateral transect after 100-m distance from the edge of the stream plot to distinguish two different habitat types (i.e. streamside and forest proper).

A nested rectangular plots had been established based on different tree size classes for vegetation survey under SEALS project (20 m x 50m, 10 m x 10 m, 5 m x 5 m, 2 m x 2 m respectively for tree, pole, sapling and seedling) (Islam et al. 2016). Foot prints of tiger and deer were recorded from 20 m x 50m and 5 m x 5 m plots, respectively during the vegetation survey. I used these wildlife data for the present study. The detail of the plot design is shown in Fig. 4.

Following the above sampling design, a total of 210 sample plots had been established. Out of 210 sample plots, 119 plots were in stream side represented by filled circles and 91 were in forest proper represented by filled triangles (Fig. 5). The map of saline zones of the Sundarbans was drawn based on Siddiqi's (2001) salinity data (Fig.6). Green colour indicates fresh water zone (<10ppt) which consists of 23 compartments (Compartment no.- 1,2,3,5,9,10,11,12,13,14,15,22,23,24,25,26,27,28,29,30,31,32,39). Light blue colour indicates moderate saline zone (10-<20ppt) which consists of 16 compartments (Compartment no. : 4,6,7,8,16,17,19,20,21,33,34,35,36,37,38,40). Orange colour indicates strong saline zone (>20ppt) which consists of 16 compartments (Compartment no. : 18,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55). A total of 49, 123 and 38 plots had been established in fresh water zone, moderate saline zone and strong saline zone, respectively.

There are three types of rivers eg. tertiary (10-30 ft), secondary (31-50 ft) and main rivers (>50 ft) considered in the present study (Fig.2 and Fig.3). A total of 98, 96 and 16 plots had been established in tertiary, secondary and main rivers, respectively.

3.3. Statistical Analysis of Survey Data

The entire dataset was examined by using bar diagram to identify distribution and habitat preference of tiger and deer in the Sundarbans mangrove forest. Analysis of Variance (ANOVA) of binomial logistic regression model was applied to test difference of habitat types. Statistical analysis and graphical presentation were performed with the R (Release R-3.4.2 version) statistical package(R core team, 2017).

Chapter Four

Results

4.1. Introduction

Binomial logistic regression modeling techniques have been adopted for preparing the results of the distribution and habitat preference of tiger and deer in the Sundarbans. The first step is to group the independent and dependent variables per plot. We cannot look at the tiger and deer locations as points. Table 1 showed the following independent variables: the vegetation type, habitat type, river type, salinity zone, deer abundance and canopy closure.

The binomial logistic regression model was statistically developed by comparing its distribution predictions with the actual distributions of tiger and deer in the province on the basis of the field data. For example, the output of P- value for range is 0.01078 i.e. $P<0.05$ (Table 1).

4.2. Distribution of Tiger and its frequency for different habitat types

A total of 210 sample plots had been established for investigating footprints of tiger and deer. Footprints of tiger were found in 45 plots and were not found in 165 plots (Fig.7). On the other hand, deer were abundant in 13 plots, few deer were present in 170 plots and absent in 27 plots (Fig. 8).

For habitat type, tiger frequency among samples has high significant difference between riverside habitat and forest proper ($P<0.05$) (Fig. 9). The presence of tiger was higher in the riverside habitat than that in the forest proper habitat. Similarly absence of tiger was higher in the riverside habitat than that in the forest proper habitat.

For salinity type, tiger frequency among samples has no significant variation in three salinity zones ($P >0.05$) (Fig.10). However, in moderate salinity zone, the presence of tiger is the highest. Then the absence of tiger was found to be highest in moderate salinity zone and then lower and higher salinity zones.

For river type, it is shown in Fig. 11 that tiger frequency among samples has significant variation in three river types ($P<0.05$). The highest presence of tiger was found in tertiary river and then in secondary and main river. On the other hand, the absence of tiger data followed a different sequence as higher in secondary and then in tertiary and main rivers.

4.3. Tiger Frequency over deer abundance

Figure 12 showed that there is no significant variation between tiger frequency and deer abundance (P>0.05).When deer were few, the presence of tiger was the highest, but when deer were abundant, the presence of tiger was lower.

4.4. Tiger frequency for different canopy closures

In Fig.13, tiger frequency with canopy closure showed no significant variation (P > 0.05). The presence or absence of tiger is the highest in 70-100% canopy closure, then decrease in 30-70% and 10-30% canopy closures.

Chapter Five

Discussion

The Sundarbans mangrove forest is destroyed severely by human activities. To regain mangrove forest's original state, it is very difficult or almost impossible. Because of the conditions under which the mangrove wildlife species and the ecosystem undergoes are very difficult to restore. For protecting the major wildlife species in the Sundarbans, some efforts, strategies and projects have been made in Bangladesh. In order to conserve the major wildlife species and to maintain the ecological balance, the Government of Bangladesh has established different management action plans and policies. At the same time various non-governmental organizations, Tiger project and International organizations such as USAID, UNDP, UNESCO, FAO, ADB, EU, GIZ and World Bank have engaged themselves in research, management and development processes relating to Sundarbans major wildlife species conservation.

The present study recorded the distribution of tiger and deer on the basis of riverside and forest proper habitat in the Bangladesh Sundarbans. It is found that streamside for secondary and tertiary rivers were approximately two times higher of wildlife species (tiger and deer) than the forest proper (Figs. 9 and 11). In addition, riverside habitat

and eastern part of the Sundarbans represented more tigers and deer abundance in the Sundarbans (Figs. 7 and 8). In this regard riverside habitat may have given special look for the management of wildlife species in the Sundarbans. In different salinity zones in the Sundarbans, the frequency of tiger species is the highest in the moderate salinity zone, but other two salinity zones showed almost similar frequency (Table 1, Fig. 10). These three zones indicating there is no special preferences of tiger species to a particular site and determine no representative faunal variation due to salinity. In river types, the frequency of tiger species is the highest in the tertiary river, then lower in the secondary river and least in the main river. The above information related to distribution and habitat preference of tiger and deer species may enrich the management system and protection technique of major wildlife species in the Sundarbans.

Tigers occur throughout the Bangladesh side of the Sundarbans but their distribution, as indicated by transect methods in riverside and forest proper, varies considerably (Fig.7). There was a conspicuously low distribution of tiger in the north relative to areas further south and west among the study areas (Fig.7). While possibly a response to natural variation in some ecological variable, the low relative tiger frequency among samples in the north-west may also be due to low tiger distribution attributable to human activities (Barlow, 2008).

The mean distance moved for Sundarbans female tigers (1.69 km/day) were greater than that recorded by the similar to Nagarahole (1.7-2 km/day), same means in Panna (1.4 km/day), and less than Chitwan (2.4 km/day) using one location/day (Sunquist 1981; Chundawat et al. 1999; K. U. Karanth pers. comm.). However, the maximum distance moved was 11.3 km/day and the mean movement was 3.6 km/day using all locations. Study found that tiger was distributed in the four range of the Sundarbans (Fig.7). The presence of tiger was found in the Andharmanik of Chandpai range. Tiger was also found in the major kella of the Sarankhola range. Due to illegal poaching and anthropogenic activities, tiger is the least found in the Khulna range. The highest movement of tiger was also found in the riverside of the Sundarbans than in the forest proper (Fig.7). Tigers prefer dense canopy closure which is shown in fig. 14 by green marking which indicates 70% to 100% canopy closure. Blue marking indicates 30% to 70% canopy closure and yellow marking indicates 10% to 30% canopy closure. The most preferred habitat of tiger species was found to be Hetal (*Phoenix paludosa* Roxb.) and tiger fern (*Nephrolepis exaltata* (L.) Schott) dominated forest proper and riverside of the Sundarbans forest. This also suggests that riverside is the most preferred habitat of tiger. Moderate salinity zone is the most preferred habitat and important for maintaining the tiger population. In case of deer abundance, Tigers preferred to stay where few deer were present (Fig.12). Because in these areas, tigers could move easily and hide themselves for hunting. The areas of Sundarbans where deer were absent, tigers did not preferred. Because the most favourable food of tiger is the various species of deer. Sundarbans tiger was not only dependent on deer but also other species (wild

boar, otter etc) for their food habit. When tigers were not found anything to eat then, they even ate grass of the Sundarbans mangrove forest.

On the other hand, present study reveals that the distribution of deer was found to be uniform over the Sundarbans (Fig. 8). But they were abundant in Nandabala, Andharmanik, Mirgamari under Chandpai range. The absence of deer was also found in the Harintana, Terabeka, Kokilmoni etc. (Fig.8).

Chapter Six

Conclusion

A sustainable wildlife management plan should be developed and effectively implemented to conserve Sundarbans ecosystem for present and future generations. It is noted that there is a great shortage of wildlife information in the current existing integrated management plan of the Sundarbans. The information obtained from the current study about the distribution and habitat preference of tiger and deer may enrich the overall management of wildlife in the Sundarbans.

Table 1: ANOVA of generalized linear model considering tiger appearance as response factor with respect to various independent variables

Independent Variable	Degree of freedom	Deviance	Degree of freedom	Deviance	Probability (>Chi)	Significant code
Range	3	11.1817	206	207.04	0.01078	*
Vegetation Type	8	9.4521	198	197.59	0.30561	NS
Habitat Type	1	6.7895	197	190.80	0.00917	**
River Type	2	8.5036	195	182.30	0.01424	*
Salinity zone	2	0.5808	193	181.72	0.74796	NS
Deer Status	1	5.2774	192	176.44	0.02160	*
Deer Status2	0	0.0000	192	176.44		NS
Deer Abundance	5	7.2037	187	169.24	0.20593	NS
Canopy Closure	3	0.4055	184	168.83	0.93911	NS

Significant codes: '***'p< 0.001, '**'p< 0.01, '*'p< 0.05, 'NS' p>0.05.

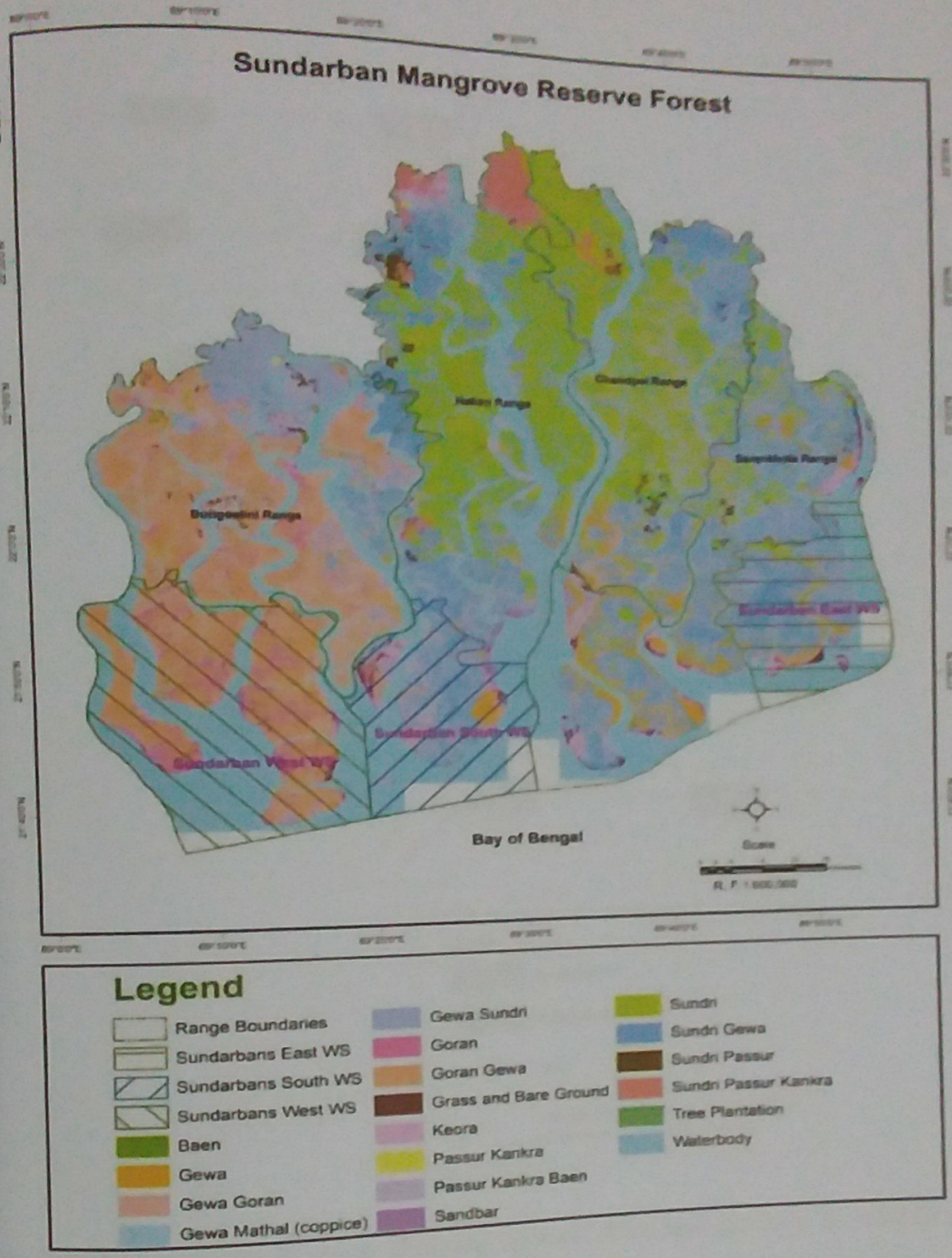

Figure 1: Vegetation map of the Bangladesh Sundarbans Reserve Forest showing major forest types (local names) via colour coding (RIMS-GIS, 2012).

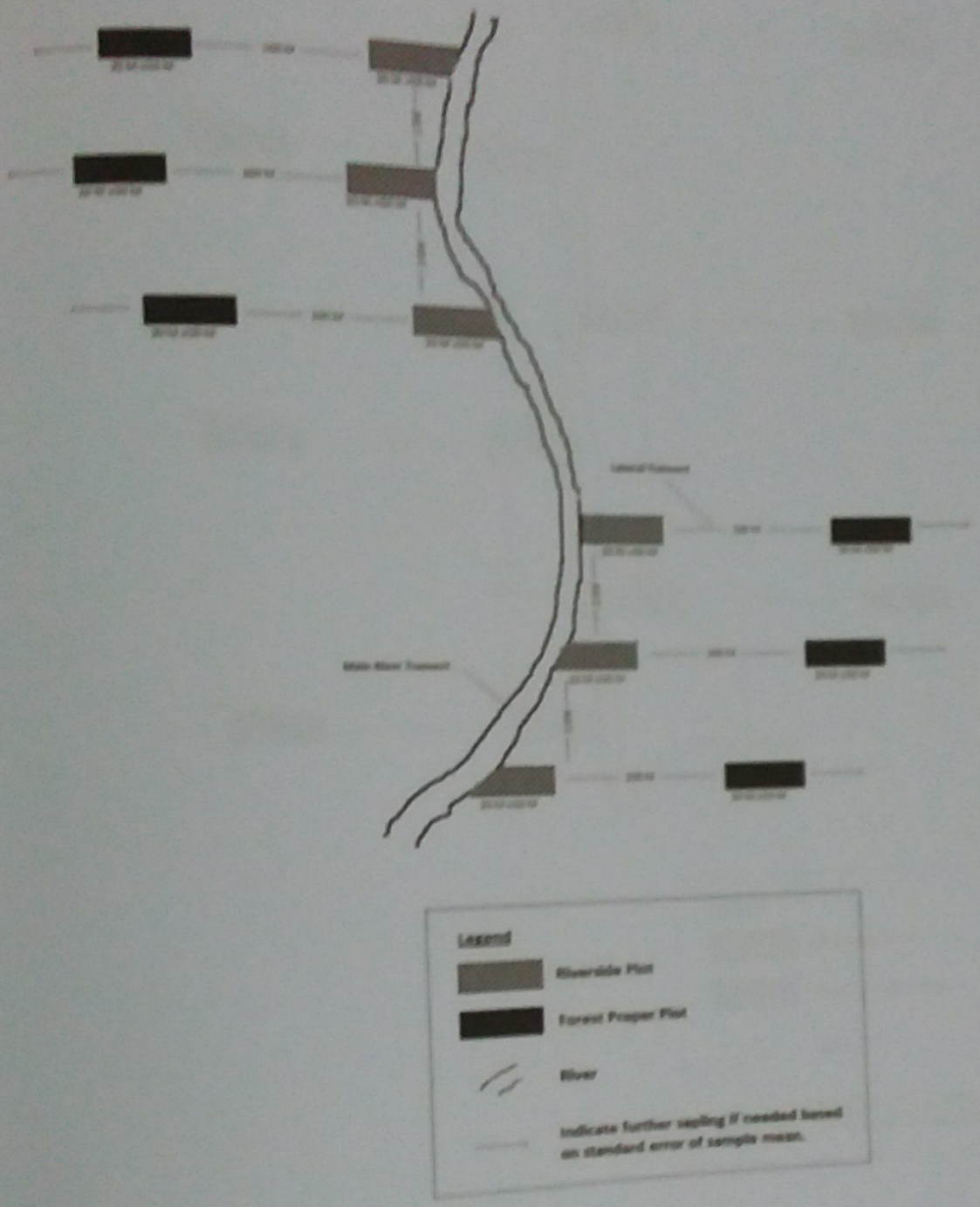

Figure 2: Schematic diagram showing transect lines and position of sampling plots for wide river (main river).

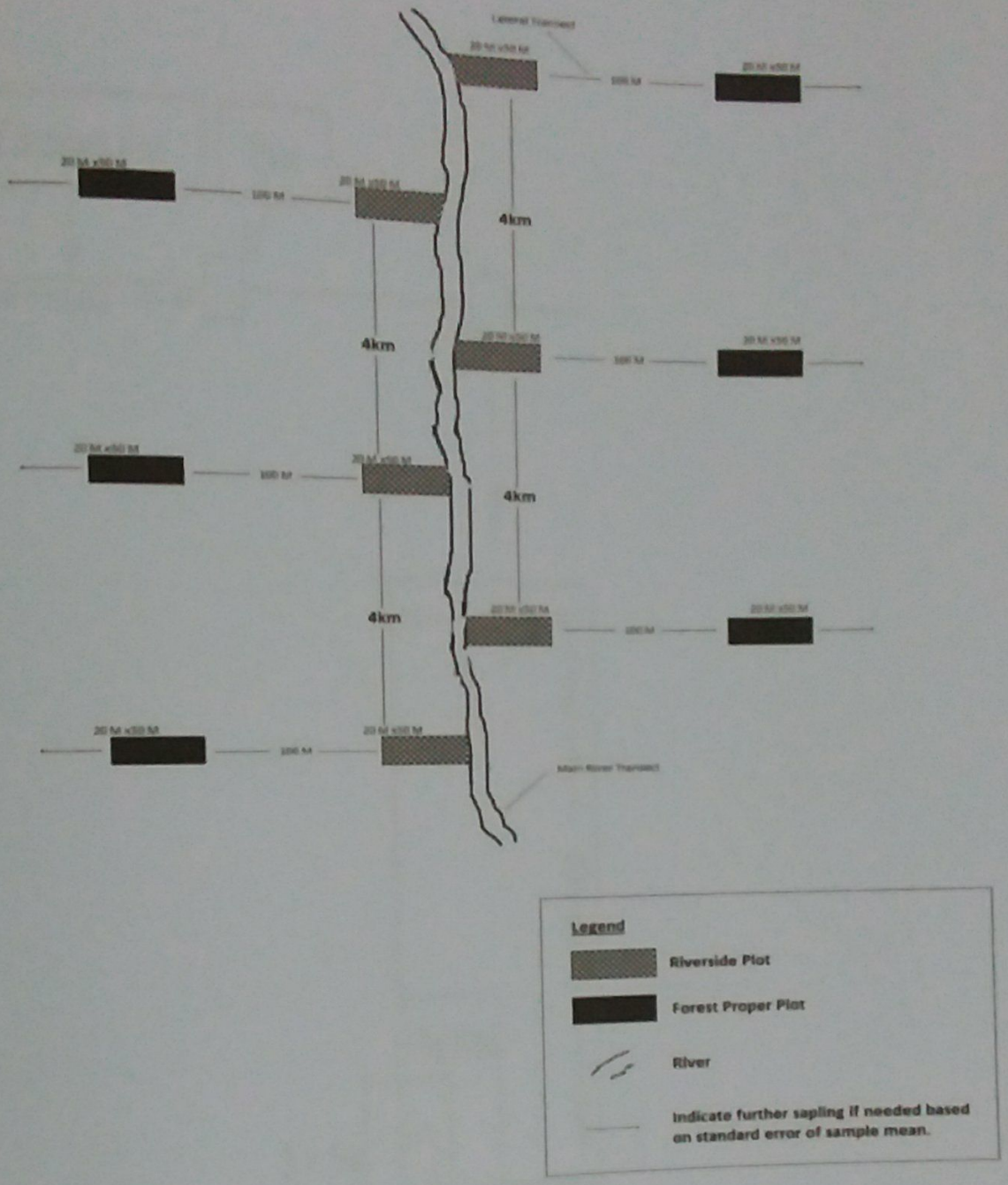

Figure 3: Schematic diagram showing transect lines and position of sampling plots for small rivers (Secondary and tertiary)

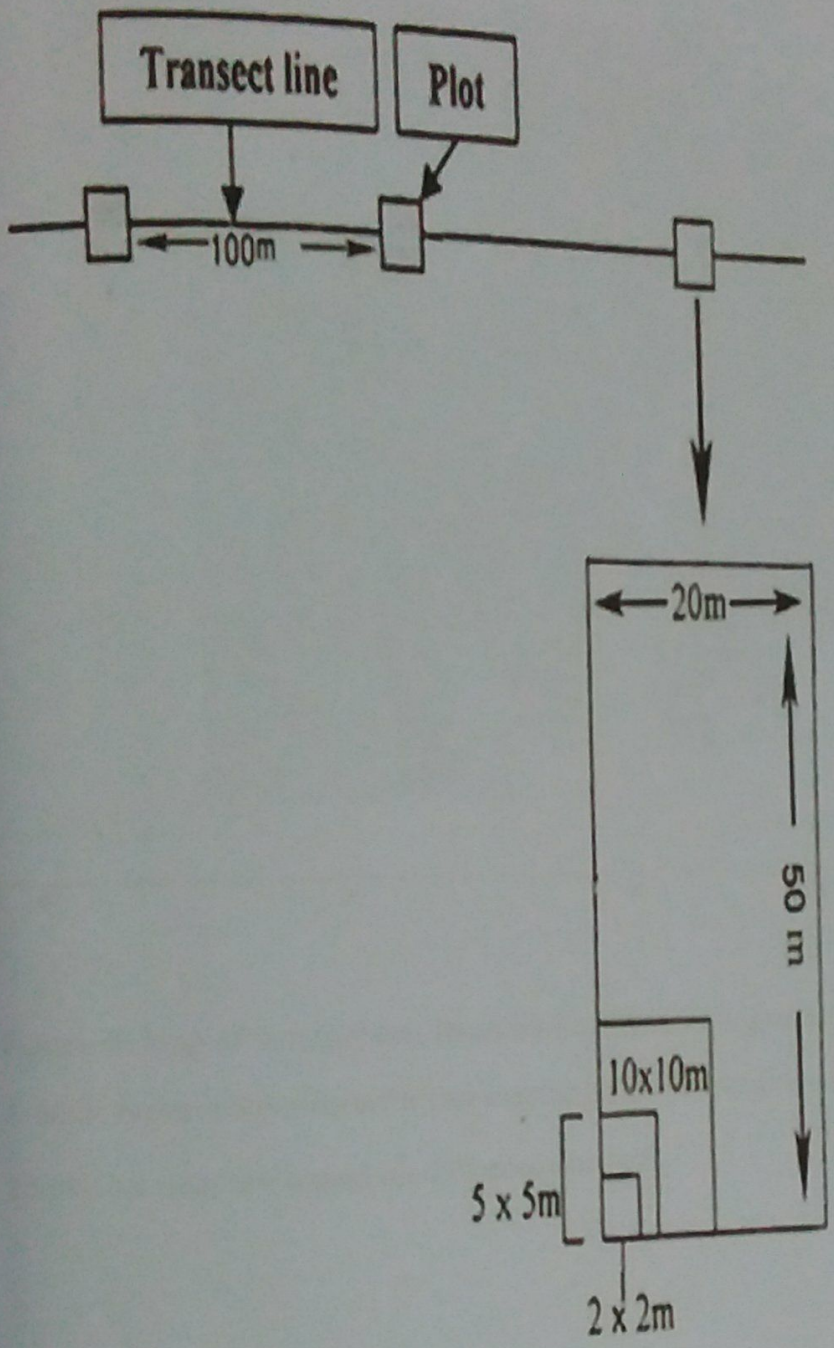

Figure 4: Schematic diagram of nested plot design showing different shape and sizes of plots for enumeration of tiger and deer species.

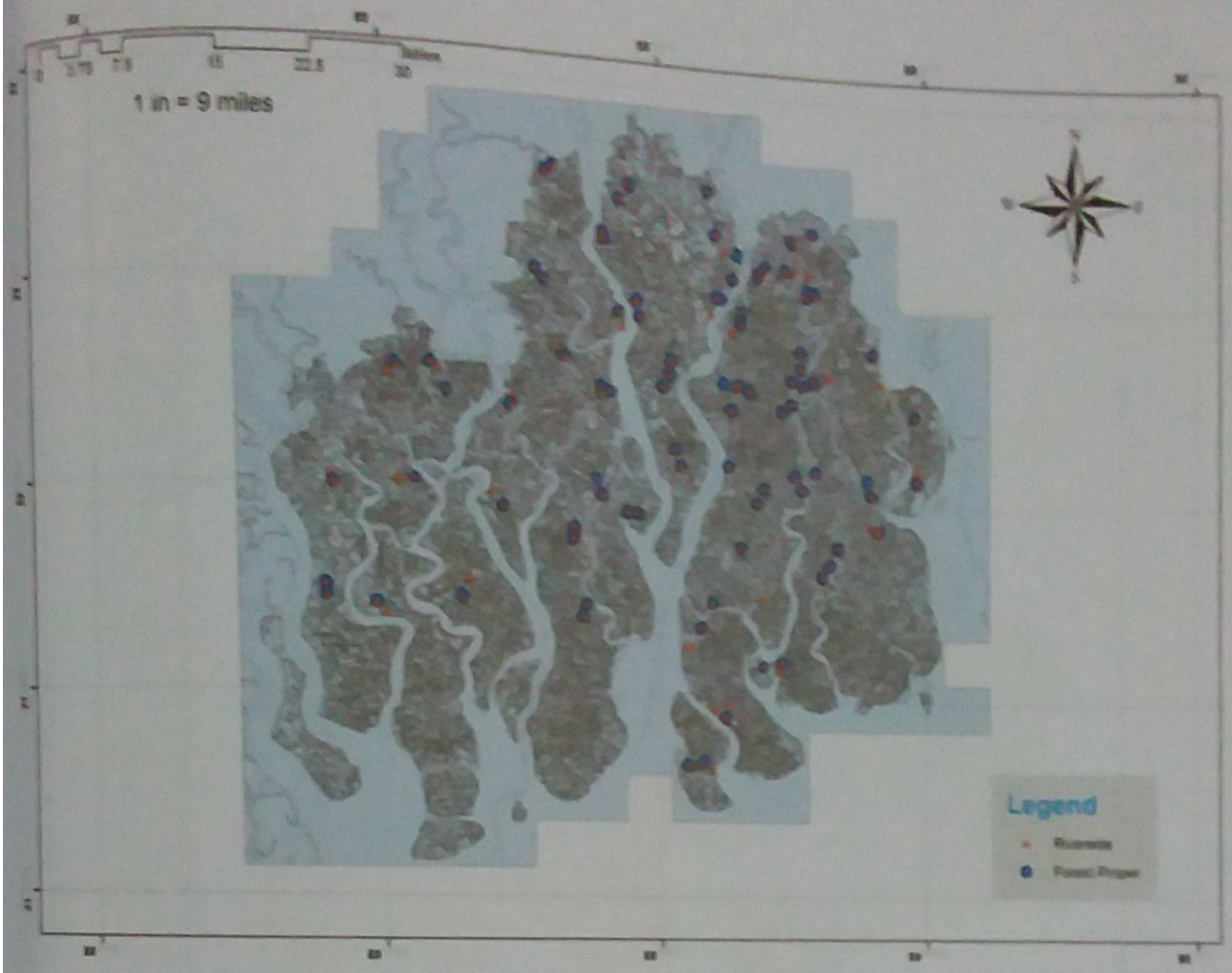

Figure 5: Map of Sundarbans Reserve Forest showing sample plot distribution in two habitat types: riverside with red markings; forest proper with blue marking (Plots shown on map are based on GPS coordinates).

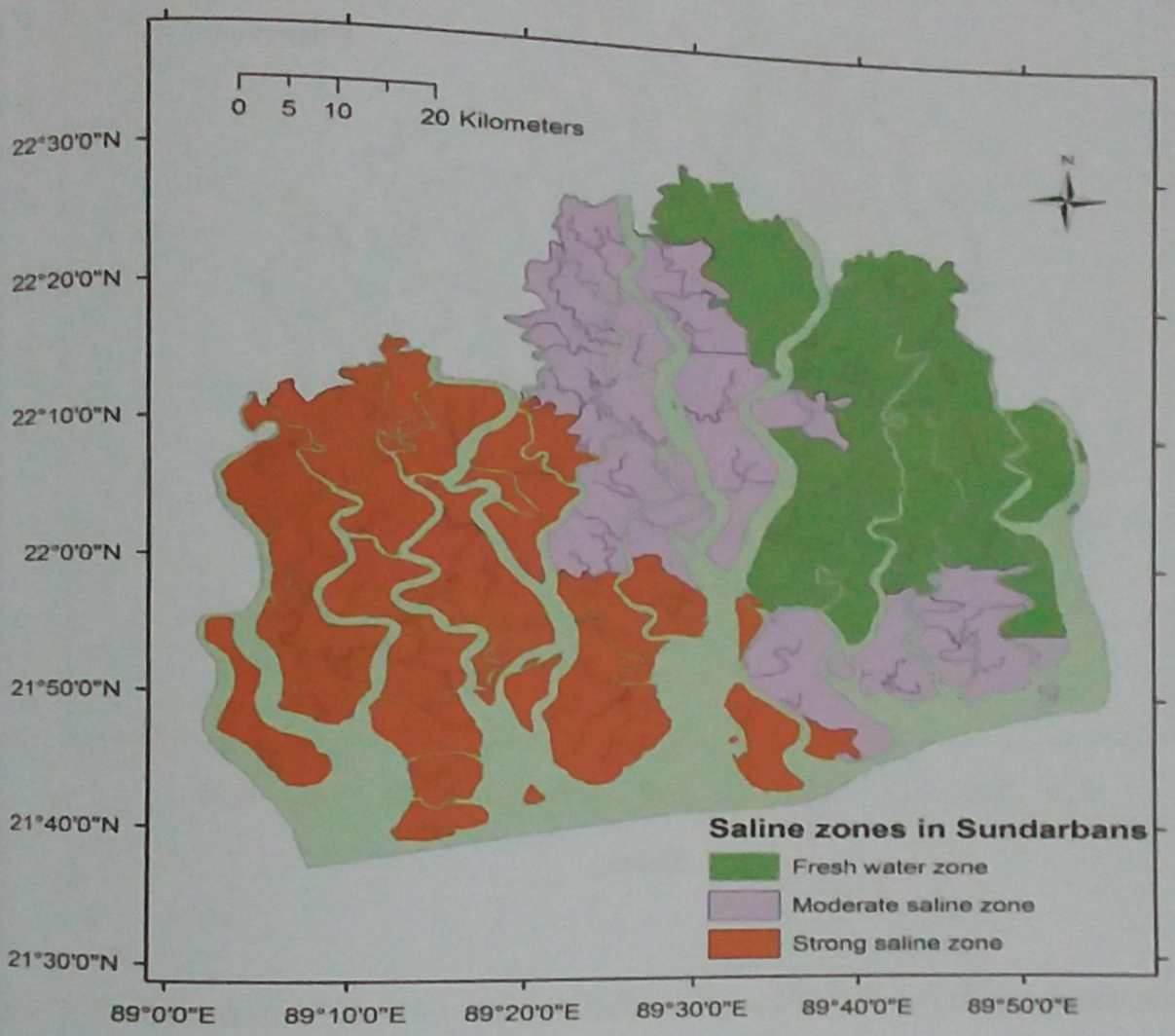

Figure 6: Saline zones in the Sundarbans (Siddiqi, 2001)

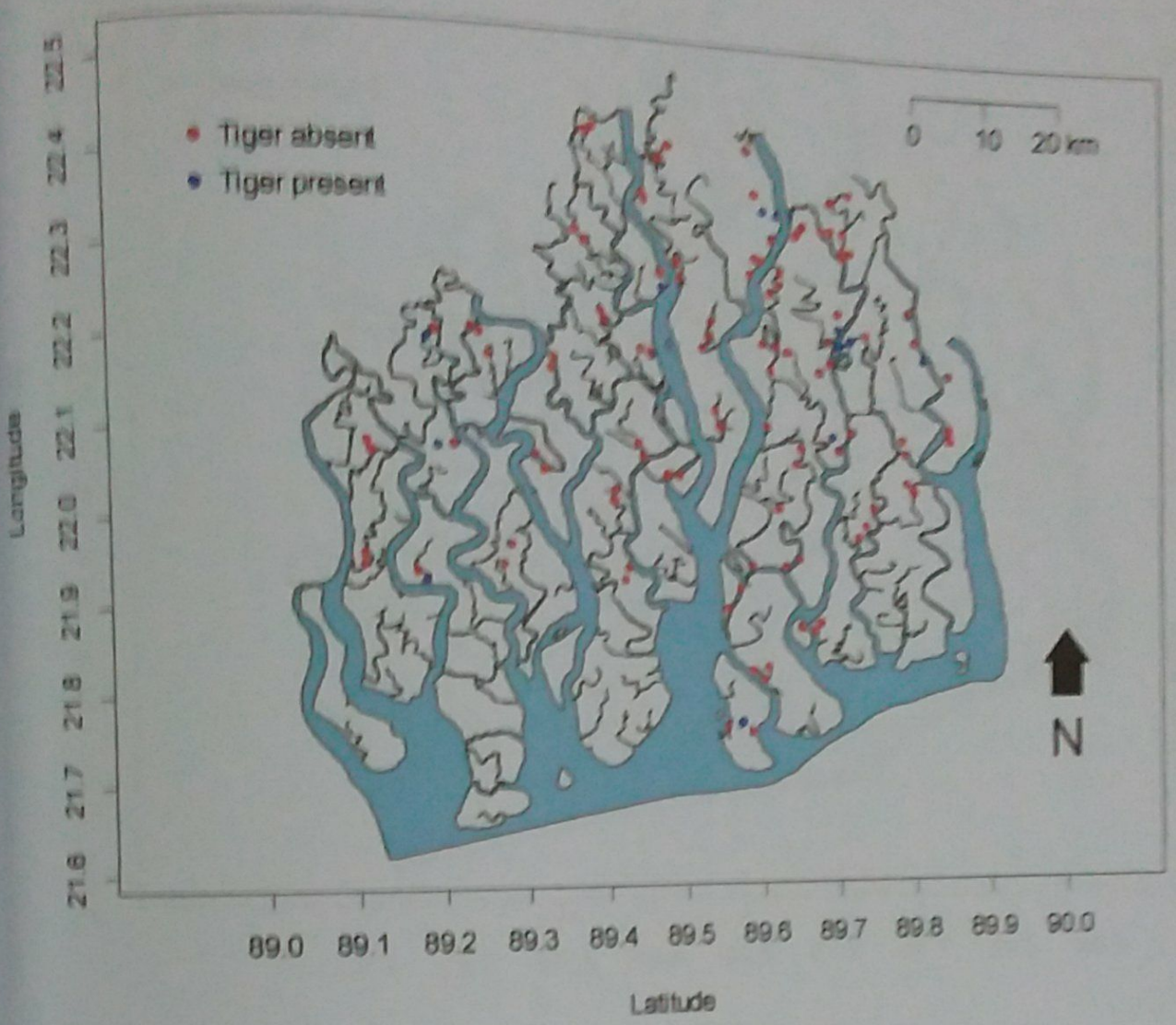

Figure 7: Distribution of tiger in the Sundarbans based on the presence-absence data(Presence: blue circle; Absence: red circle)

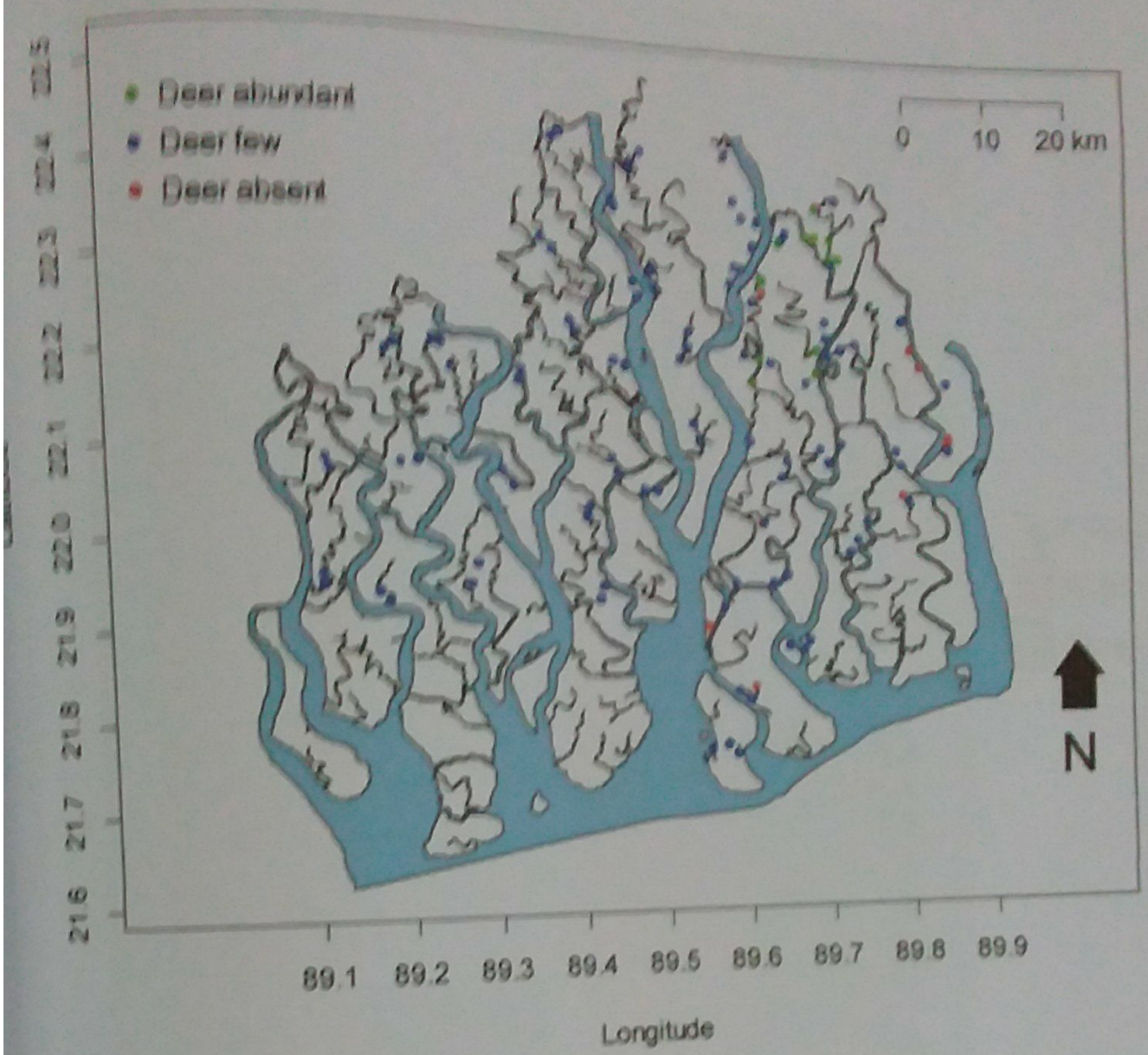

Figure 8: Distribution of deer in the Sundarbans based on the abundance, few and absence data (Abundance: light green circle; Few: blue circle; Absence: red circle)

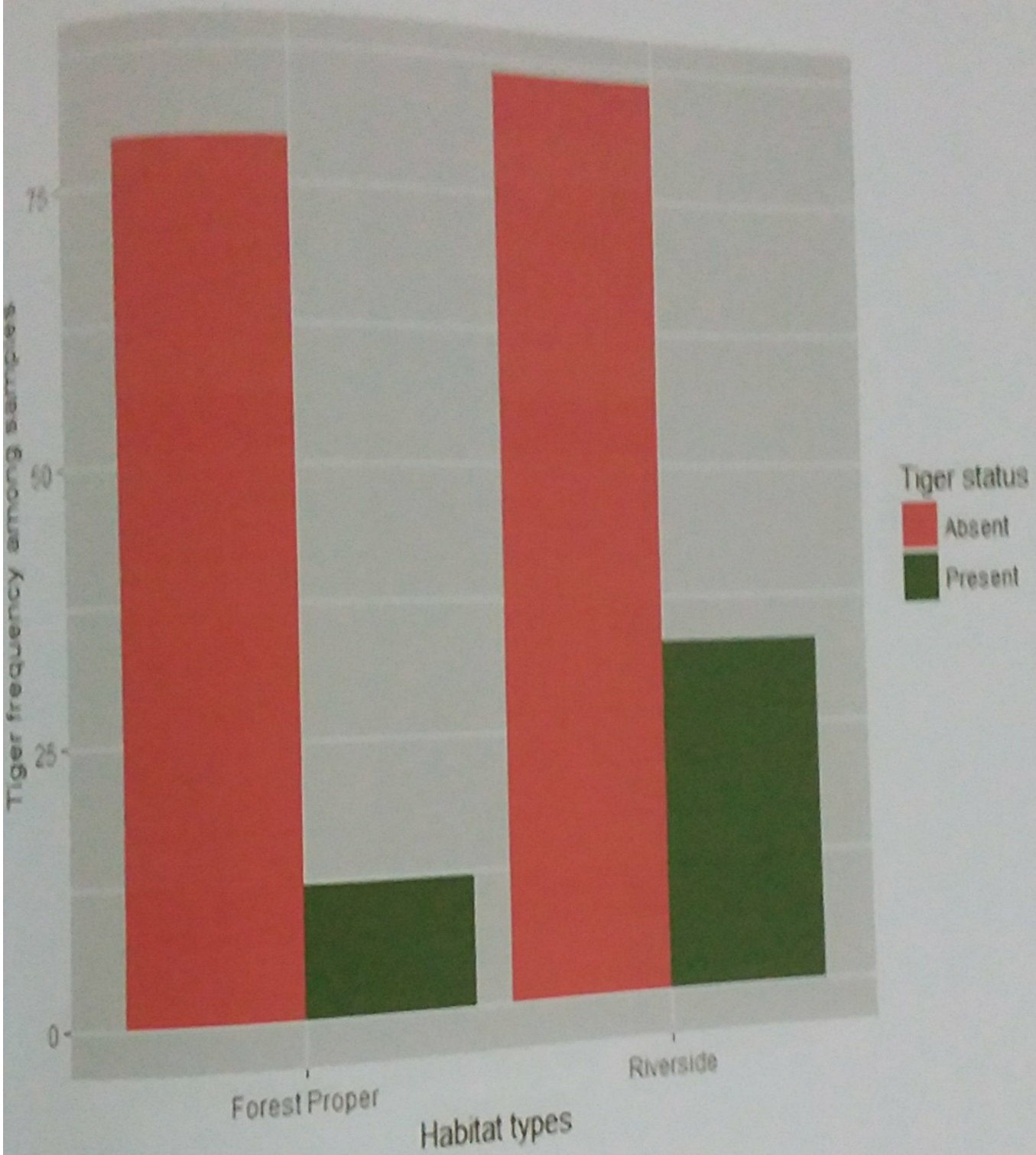

Figure 9: Tiger frequency among samples of two habitat types

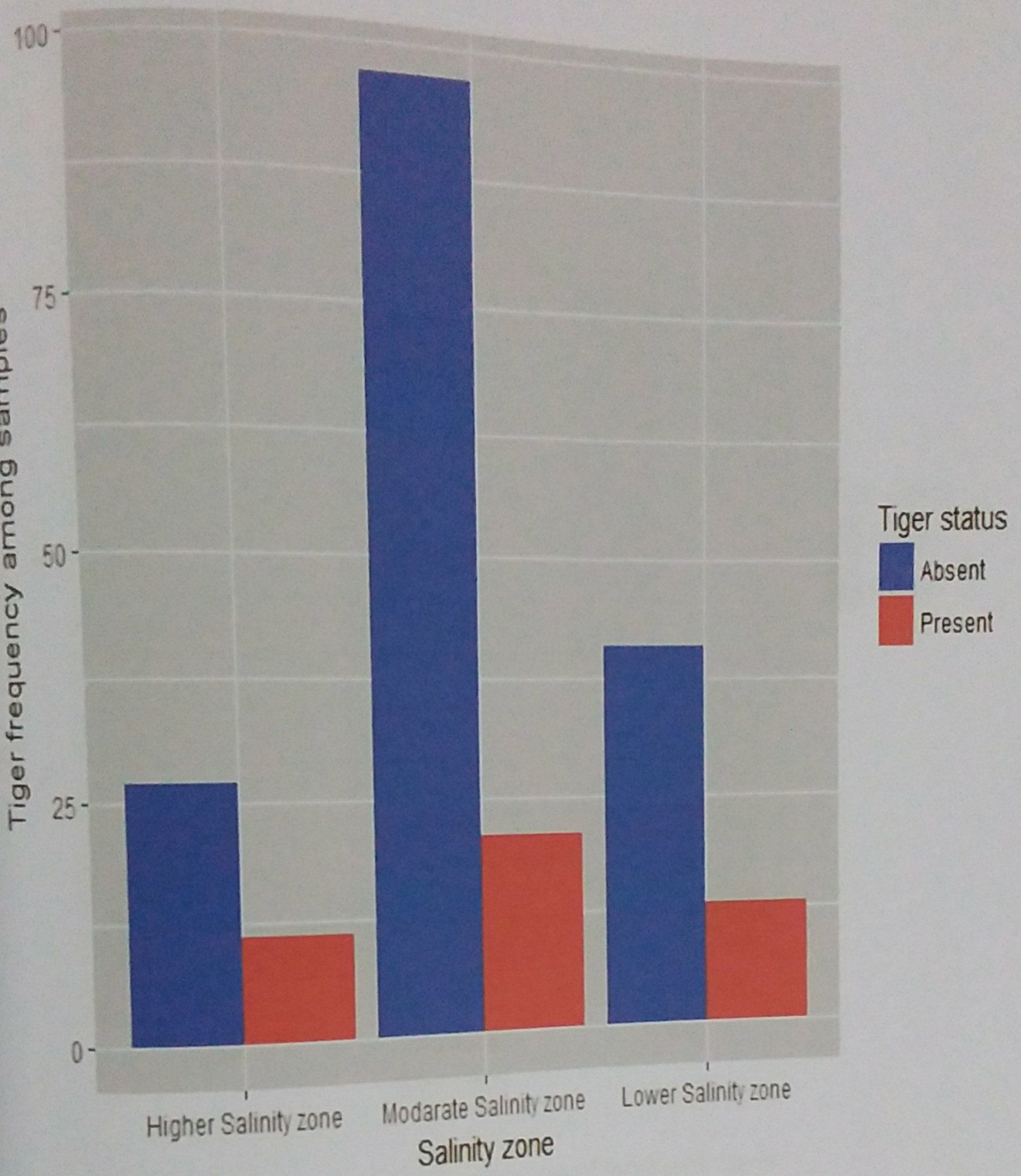

Figure 10: Tiger frequency among samples of three salinity zones

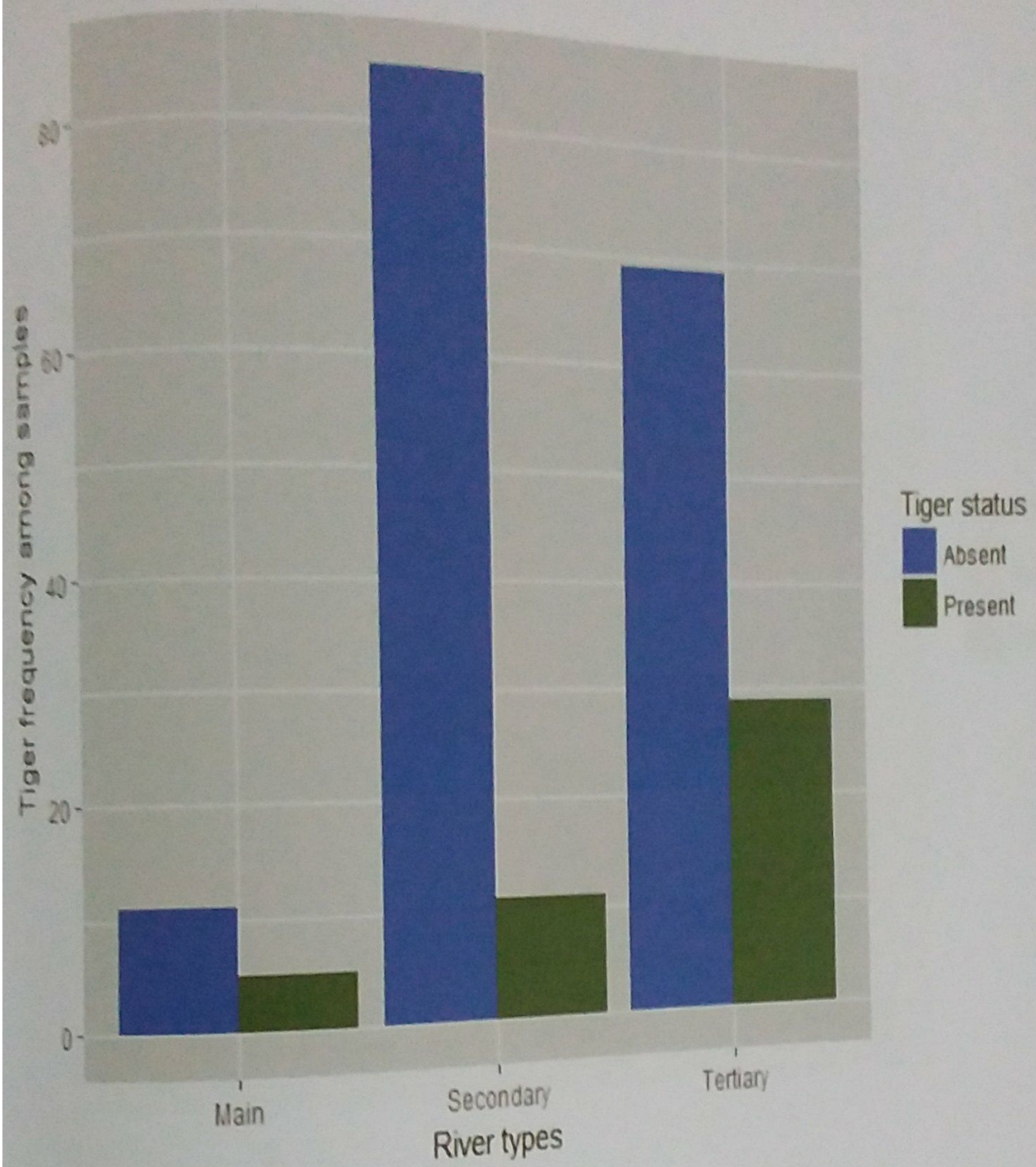

Figure 11: Tiger frequency among samples of three river types

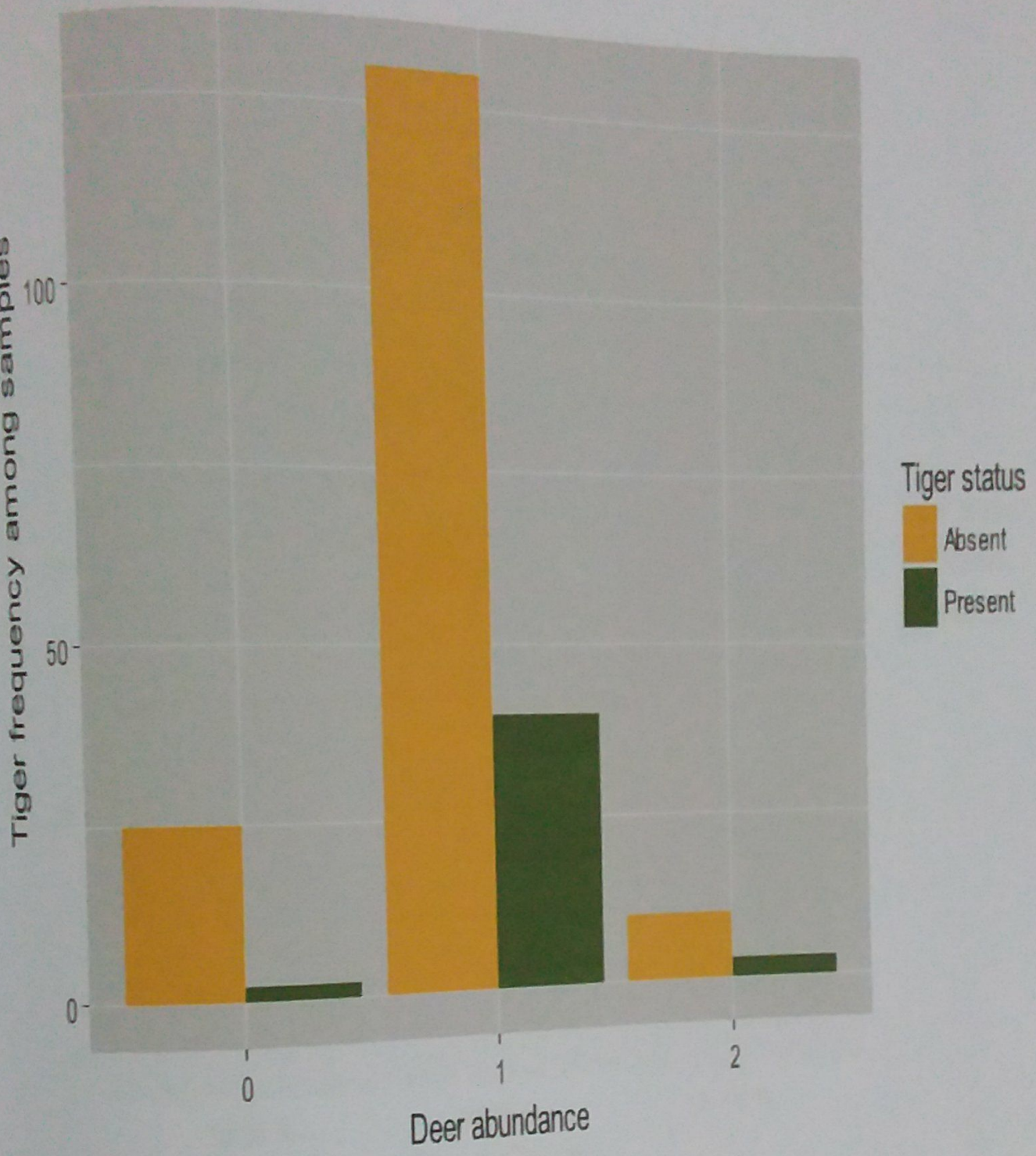

Figure 12: Tiger frequency in relation to deer abundance (Absent=0, Few=1 and Abundant=2)

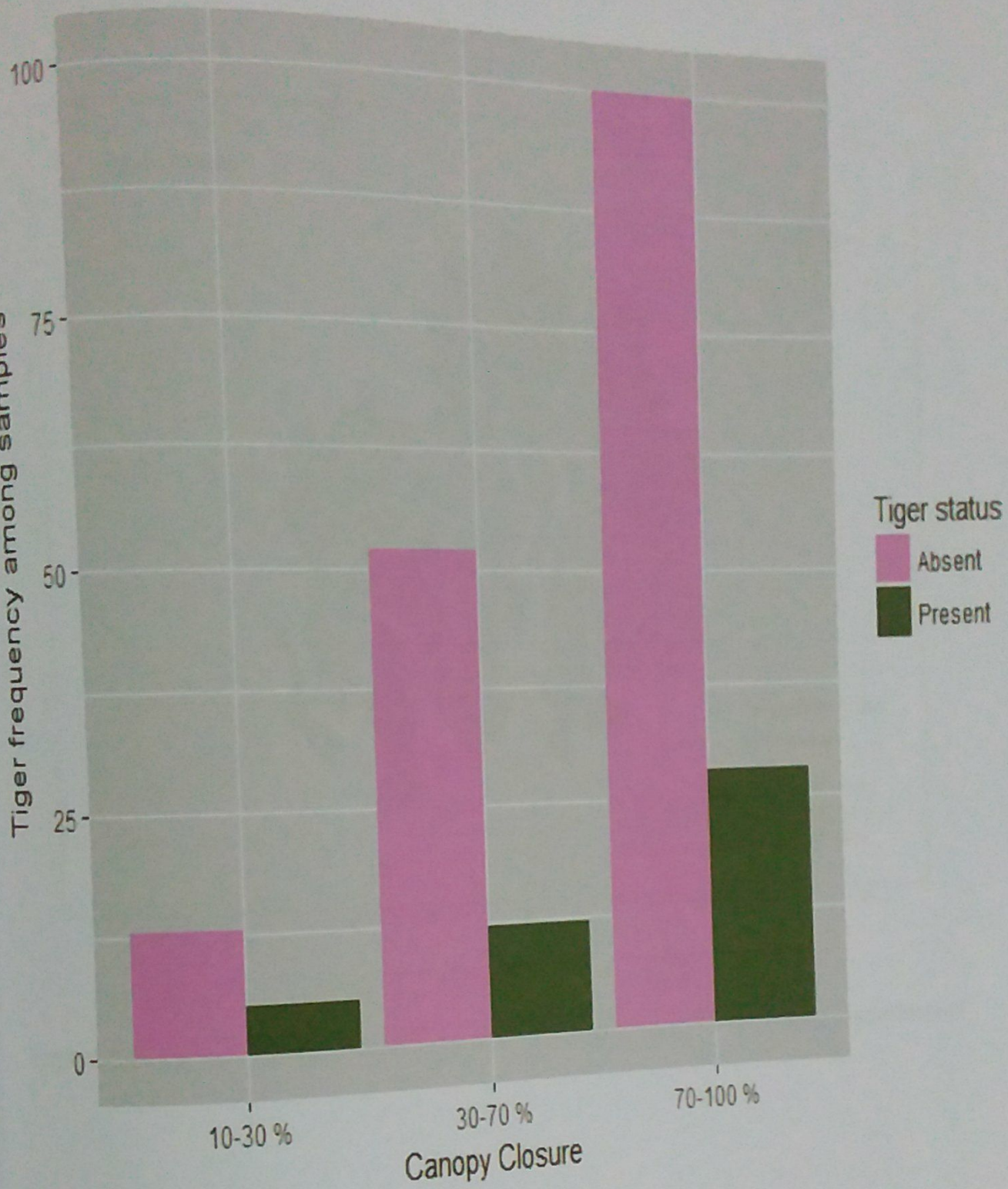

Figure 13: Tiger frequency among samples of different canopy closures

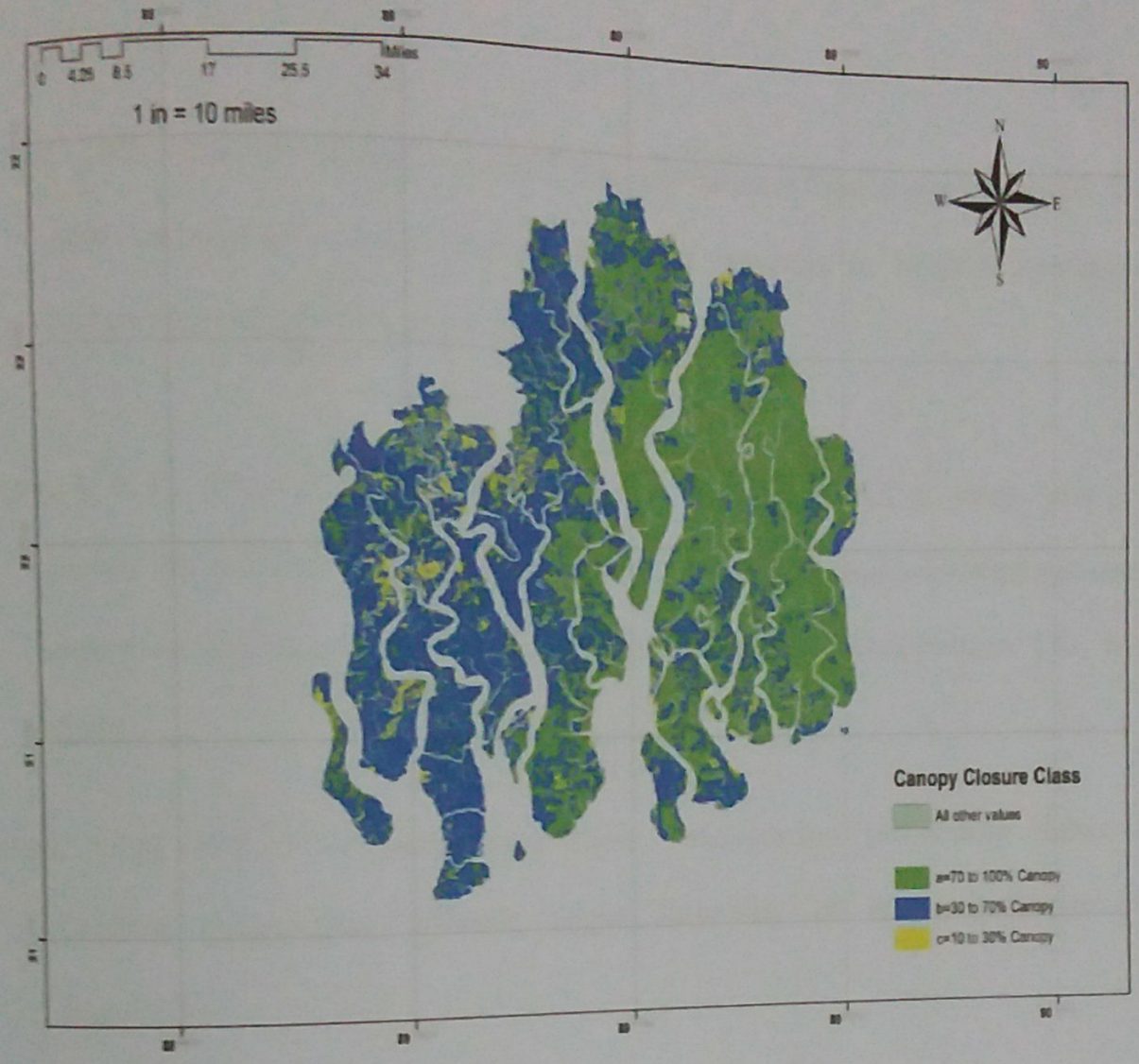

Figure 14: Canopy Closure Class map of the Sundarbans (Source: Forest Department)

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