ECOLOGY, DEMOGRAPHY, CONSERVATION AND MANAGEMENT OF GREATER ONE HORNED RHINOCEROS (*Rhinoceros unicornis*) IN CHITWAN NATIONAL PARK, NEPAL

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I feel pleasure in certifying that all work presented in this thesis has been done by *Khagendra Adhikari* under my guidance and supervision. The thesis or any part of it has not been utilized or submitted for any degree or diploma so far.

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DECLARATION

"I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning."

Khagendra Adhikari

Place: Dehradun

Date: 27th March, 2015

Dedicated to

My Parents,

Late Mr. Makar Bahadur Adhikari

and

Late Mrs. Pashupati Devi Adhikari

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Khagendra Adhikari

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Vigne and Martin, 1994; Talukdar, 1995; Menon, 1996a, 1996b; Menon and Kumar, 1998; Talukdar *et al.*, 2007).

Breeding behavior, mother young relationship, social interaction, sexual behavior and reproductive behavior of rhinoceros were also studied profoundly in different protected areas of India (Ali, 1926; Kakati and Rajkonwar, 1972; Lahan, 1974; Buchner and Mackler, 1975; Buchner and Mackler, 1978; Dixon and Macnamara, 1981; Bhattacharya and Goswami, 1987; Bhattacharya, 1991; Yadav, 2000; Hazarika, 2007).

Some researchers gave account of reintroduced rhinoceros in Dudhwa National Park for which individuals were brought from Assam and Nepal (Sale, 1986; Sale and Singh, 1987; Aziz *et al.*, 1988; Sinha and Sawarkar, 1993; Sinha *et al.*, 2005; Singh *et al.*, 2011).

Distribution and range of greater one horned rhinoceros were also mentioned by some writers on their literatures in India (Rao, 1957; Prater, 1971; Rookmaaker, 1980, 1984, 2000; Dutta, 1991). Fecundity and mortality of rhinoceros were given on their articles by Lang *et al.* (1977), Talukdar (2002) and Pluhdcek *et al.* (2007). Diseases cause by helminthes infection, gastrointestinal infection and foot disease were also studied by Bordoloi *et al.* (1990), Chakraborty and Islam (1993).

CHAPTER 2

STUDY AREA AND METHODOLOGY

Chapter 2
Study Area and Methodology

Chitwan National Park (CNP) one of the last strongholds of greater one horned rhinoceros and tigers is situated in a river valley basin or dun, along the flood plains of the Rapti, Reu and Narayani rivers (Fig. 2.1). CNP lies between 27º 16.56’ to 27º 42.14’ north latitude and 83º 50.23’ to 84º 46.25’ east longitude. The mosaic of riverine forests and grasslands along the river flood plains provides excellent habitat for greater one horned rhinoceros. Sauraha Sector identified as a study site (Fig. 2.2) for the present study is one of such site occupied by rhinoceros on the flood plains of Rapti River. Annual flooding of the Rapti River has a role in maintaining grassland and riverine habitats.

Established in 1973, CNP is the Nepal’s first National Park in the southern central *Terai* covering an area of 932 km^2 under the administrative districts of Chitwan, Makwanpur, Nawalparasi and Parsa. In earlier period, the habitats of CNP were well protected as a royal hunting reserve from 1846 to 1950 during Rana regime. An area south of the Rapti River was first proposed as a Rhinoceros Sanctuary in 1958 (Gee, 1959) demarcated in 1963 (Gee, 1963; Willan, 1965) and later incorporated into the National Park.

Substantial addition of area (750 km^2) as buffer zone was made in subsequent year 1996 to enhance management effectiveness of the park. The ecological integrity of the park is further enhanced by notifying Parsa Wildlife Reserve to its eastern boundary of the CNP. Recognizing the significant resource values and commitment of government of Nepal towards conservation, Chitwan National Park was designated as a “World Heritage Site” in November 1984.

2.1 Geology and soils

The Siwaliks are formed by outwash deposits carried from the north and consist of mainly sandstones, conglomerates, quartzites, shales and micaceous sandstones (H.M.G., 1968). The rocks of Siwaliks are Pliocene or Pleistocene in origin. The Chitwan dun valley’s outlets at some time were blocked by rapid tectonic uplift of Siwalik range to the south of the main Himalayan foothills (Carson *et. al.,* 1968). The valley has been much more affected by the Narayani and the Rapti River that have significantly influenced the soils of the valley, almost eliminating the original basin deposits (Carson *et al.*, 1968).

The soils are mainly recent alluvial deposits left by shifting river coarse. Soils on recent alluvial terraces range from sand and coarse loams on new terraces to sandy and silty clay loam on old terraces (H.M.G., 1968). The terraces are composed of layers of boulders and gravel set in a fine matrix. The flood plain terrace has rough gradient from the higher lying boulders and gravels to sands and slits and then to low-lying silt loams and silty clay loams (Berry *et al.*, 1974). Shallow streams have twisted and turned over the valley floor and there is considerable local variation in soil types across the valley floor. Older soils on fans, aprons and ancient river terraces are well drained sandy-loam to loam. Hill soils are sandy-loam to loamy rubble with very stony surfaces.

Surface drainage is very rapid, internal drainage is poor and erosion is severe. Erosion in Churia mainly occurs in south facing slopes than in northern slopes due to poorer vegetation and drier climatic factors.

2.2 Climate

The climate of Chitwan is subtropical and characterized by three climatic seasons, namely hot, monsoon and winter. The hot season extends from March to June, during which maximum daytime temperatures average maximum 35.1˚C and fall to minimum 19.8˚C at night. Relative humidity is low; infrequent aggressive storms with powerful wind, blowing sand, hail and rain occurs in late March to May, that cause severe damage to trees and houses. In this season wind blows southwesterly.

The monsoon extends from July to October, during which wind blows southeasterly. In this season, daytime temperatures remains average 32.8˚C and minimum temperature rarely go below 24.2˚C. Rainfall occurs frequently and relative humidity becomes very high. In 2009, 2010 and 2011, total rainfall in Chitwan (recorded at Rampur Agriculture Station) during monsoon in July to October were 144.6 cm, 173.6 cm and 54.7 cm respectively. The total annual rainfall in 2009, 2010 and 2010 were 190.9 cm, 239.9 cm and 118.3 cm respectively. Nearly 67.9 percent of rainfall occurs in monsoon season alone (Fig. 2.3).

The winter season extends from November to February. In this season, maximum daytime temperatures average about 25.3˚C and fall to 11.1˚C as

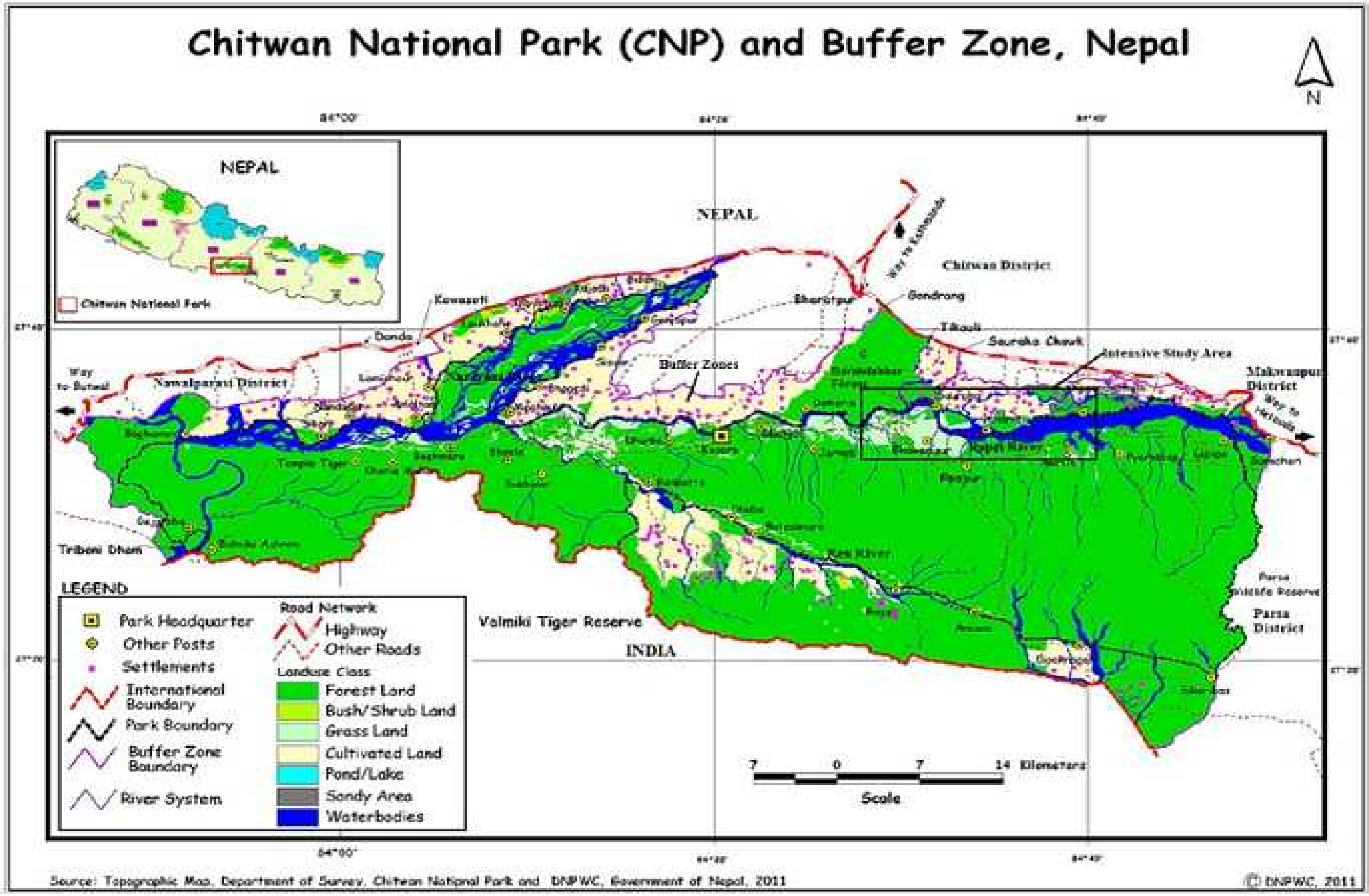


Fig. 2.1: Chitwan National Park (CNP) including intensive study area and its Buffer Zone (DNPWC, 2011).

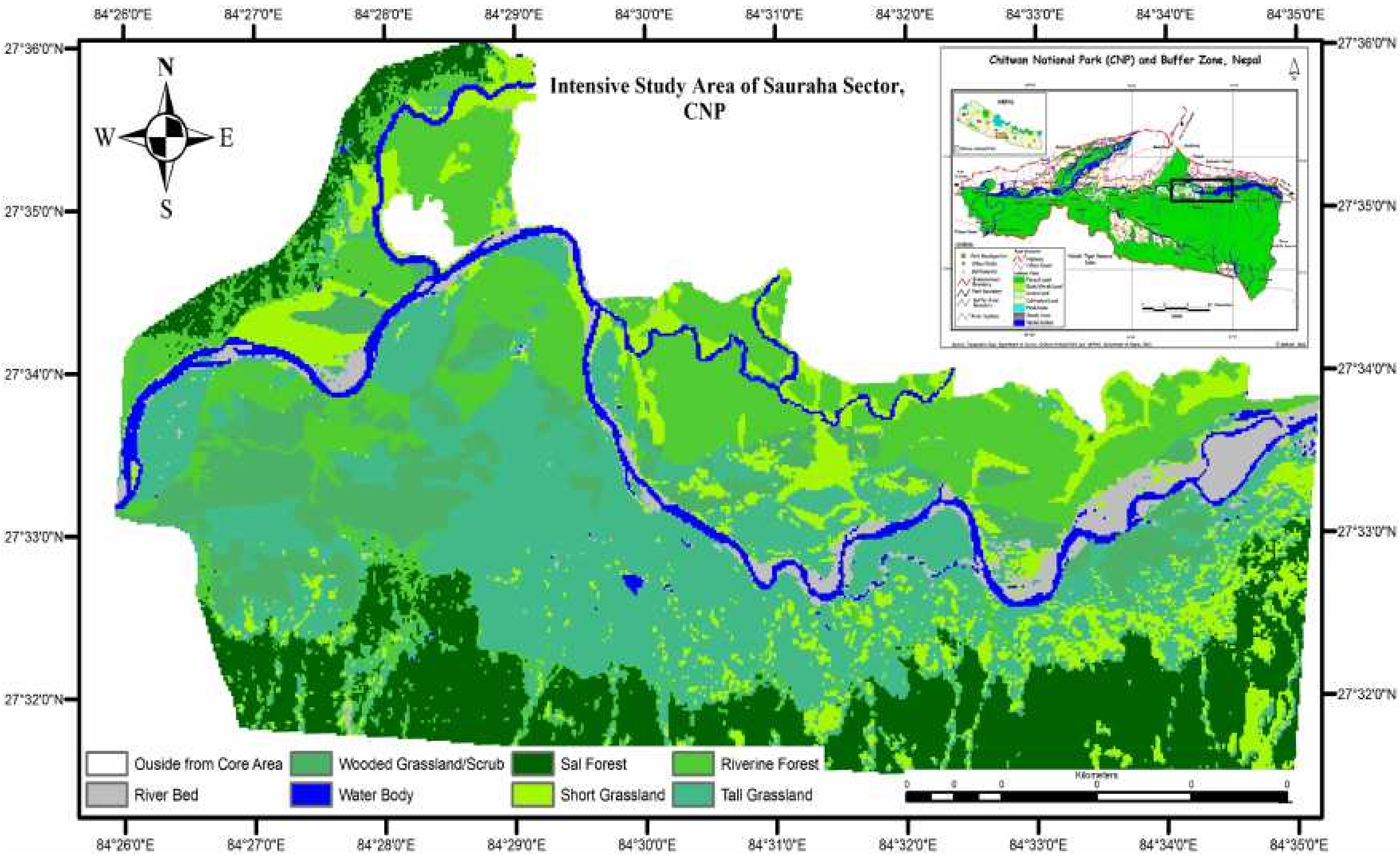


Fig. 2.2: Classified image of intensive study area of Sauraha Sector, Chitwan National Park.

average minimum temperature at night (Fig. 2.4). Nights are very cool with moisture level reaching 100 percent relative humidity (Fig. 2.5); resulting heavy ground fog and dews. Infrequent frosts have also been recorded in winter since few years (Bolton, 1975). Very slight precipitation occurs in the form of rainfall during this season too. In this season wind blows northerly.

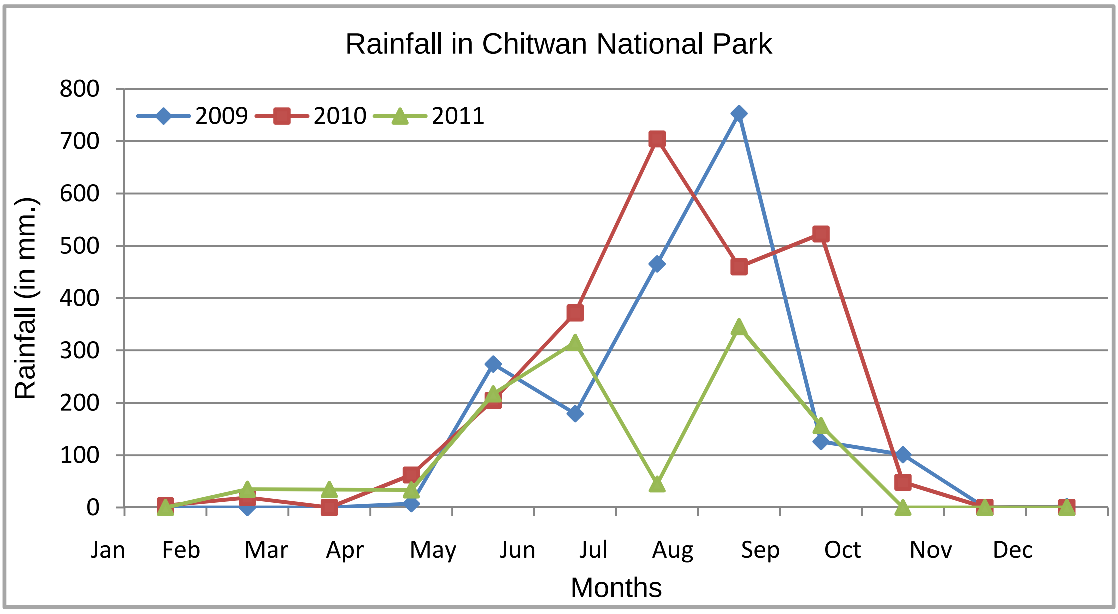


Fig. 2.3: Mean monthly rainfall from 2009-2011 (Source: DHM/GoN).

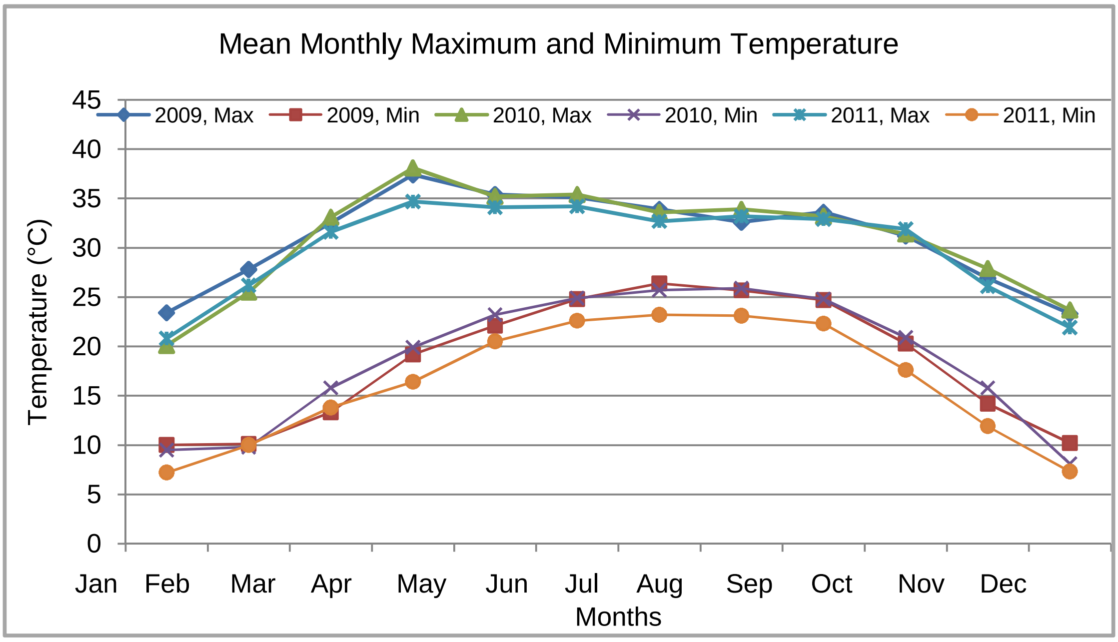


Fig. 2.4: Mean monthly temperature from 2009-2011(Source: DHM/GoN).

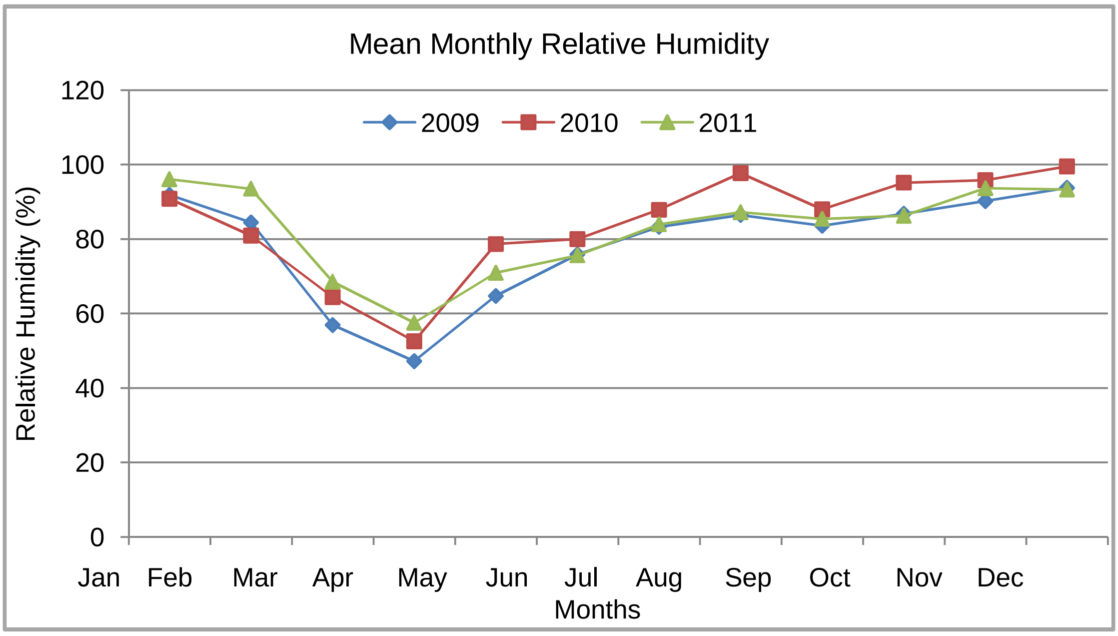


Fig. 2.5: Mean monthly relative humidity from 2009-2011 (Source: DHM/ GoN)

2.3 Hydrology

All rivers and streams of the Chitwan National Park are ultimately drained into the Narayani River. From the Churia hills a number of permanent and seasonal rivers flow northwards into the Rapti River and southwards into the Reu River; both these rivers flow westwards and after their confluence finally submit to Narayani River. Other rivers such as Manahari, Lothar, Amuwa Khola, Khageri Khola, Chamka Khola, Audhori Khola, Bhalu Khola, Harda Khola, Hasta Khola, Dhode Khola traverse through the buffer zone. All these rivers are the tributaries of the Narayani river system. In the hot and dry season, the Rapti and Reu rivers flow at their lowest level below the knee but in the monsoon season water levels rise 2-3 m or more and most of the areas of the flood plains become water logged and inundated for several days.

In the park, permanent standing water forms the lakes (*Tals*) which are abundantly scattered throughout the park and buffer zone. Numerous lakes are found in the adjoining Barandabhar forest of the park, so named as Bishajari Tal (twenty thousand lakes; covering an area about 100 ha), which is the main corridor linking the park to Mahabharat range towards north. There are more than forty lakes, ponds and marshy lakes covering about 114 ha area in the park (Karki, 2011). Some famous lakes are Kamal Tal, Devi Tal, Tamor Tal, Nandan Tal and Lami Tal which are not only a source of water but also an important habitat for wildlife (DNPWC, 2000). Likewise, Khageri canal, Baghmara lake, Kumrose ox-bow lake, Kathar lake, Gaida Tal, Gaida Pokhari, Budhi Rapti Tal, Narkat ghol and Dabdabe ghol are important wetlands in the buffer zone of CNP. Some wallows or ghols are manmade in the park, apart from them mostly are natural found in riverine forest for wallowing and drinking especially to the rhinoceros and other wild animals (Fig. 2.6).

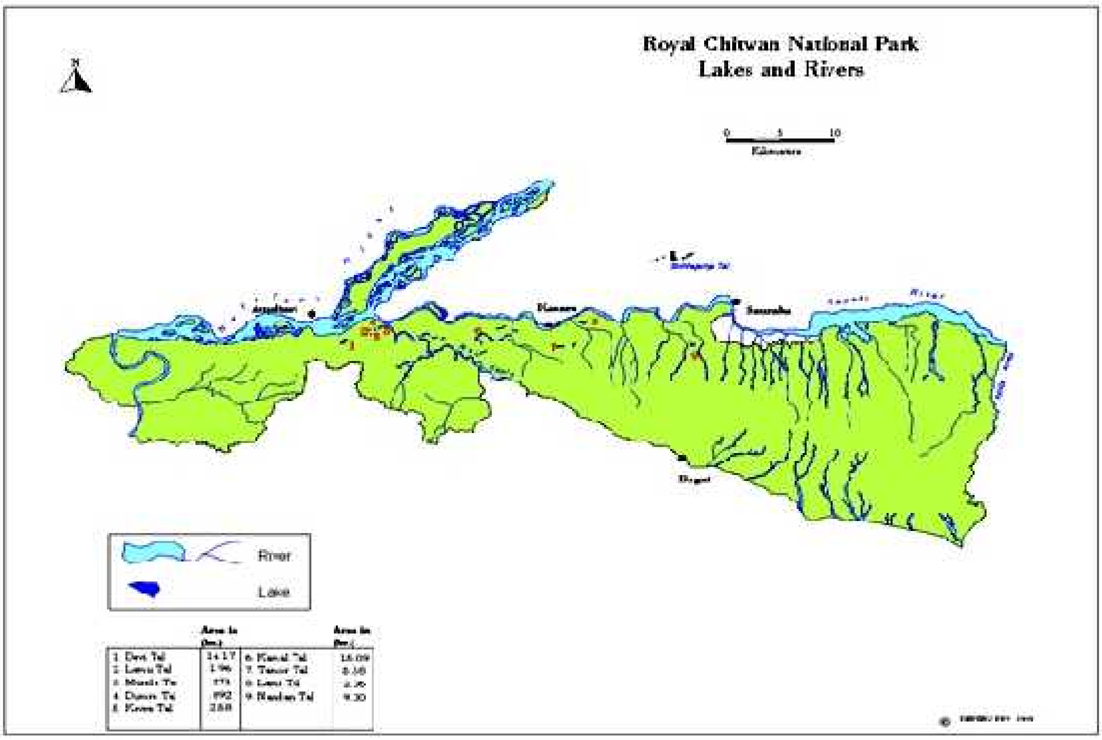


Fig. 2.6: Hydrology and drainage map of CNP (Source: DNPWC and PPP)

2.4 Vegetation

Chitwan National Park has several different habitat types and very rich in floral diversity. The park consists of 577 different species of plants, out of which 3 are gymnosperms, 13 pteridophytes, 415 dicotyledons and 137 monocot and 9 species of orchids.

Chitwan National Park has three basic types of terrestrial vegetation (Fig. 2.7); Sal forest (72.9%), riverine forest (7.54%) and grassland (11.54%); rest of the area covered by river and lakes (2.9%) and exposed surfaces (5.13%) (Thapa, 2011).

2.4.1 Sal forest

Sal (*Shorea robusta*) forest is considered as a climatic climax vegetation of the *Terai* region of Nepal (Champion and Seth, 1968). Sal does not grow on recently formed alluvium or poorly drained soils (Stainton, 1972). Sal generally dominates the forest in almost pure stands 25-40 m tall, or sometimes in association with other species like *Terminalia* species (Combretaceae), *Dillenia pentagyna* (Dilleniaceae), *Syzigium cumini* (Myrtaceae), *Phyllanthus emblica* (Euphorbiaceae), *Bridelia retusa* (Equisetaceae) and *Buchanania latifolia* (Anacardiaceae). The moist area of the Sal forest contains *Cinnamomum tamala* (Lauraceae), *Alnus nepalensis* (Betulaceae), *Catanopsis indica* (Fagaceae), and *Catanopsis tribuloides* (Fagaceae). The pine (*Pinus roxburghii,* Pinaceae) trees occur with Sal on some of the drier ridges of the Churia hills on southern side.

In Sal forest, shrub layer is generally absent, giving the impression of open woodland. In some places, the shrub layer of the Sal forest is composed of species like *Clerodendrum viscosum* (Verbenaceae), *Pogostemon benghalensis* (Labiatae) and *Murraya koinigii* (Rutaceae). The herb layer in Sal forest is composed of species like *Imperata cylindrica* (Graminae), *Cynodon dactylon* (Graminae), *Narenga porphyrocoma* (Graminae), *Ageratum conyzoides* (Compositae), *Arundinella nepalensis* (Graminae), and *Saccharum spontaneum* (Graminae). The area where Sal trees canopy is continuous, the below ground is often bare except for leaf litter and an occasional tuft of grasses.

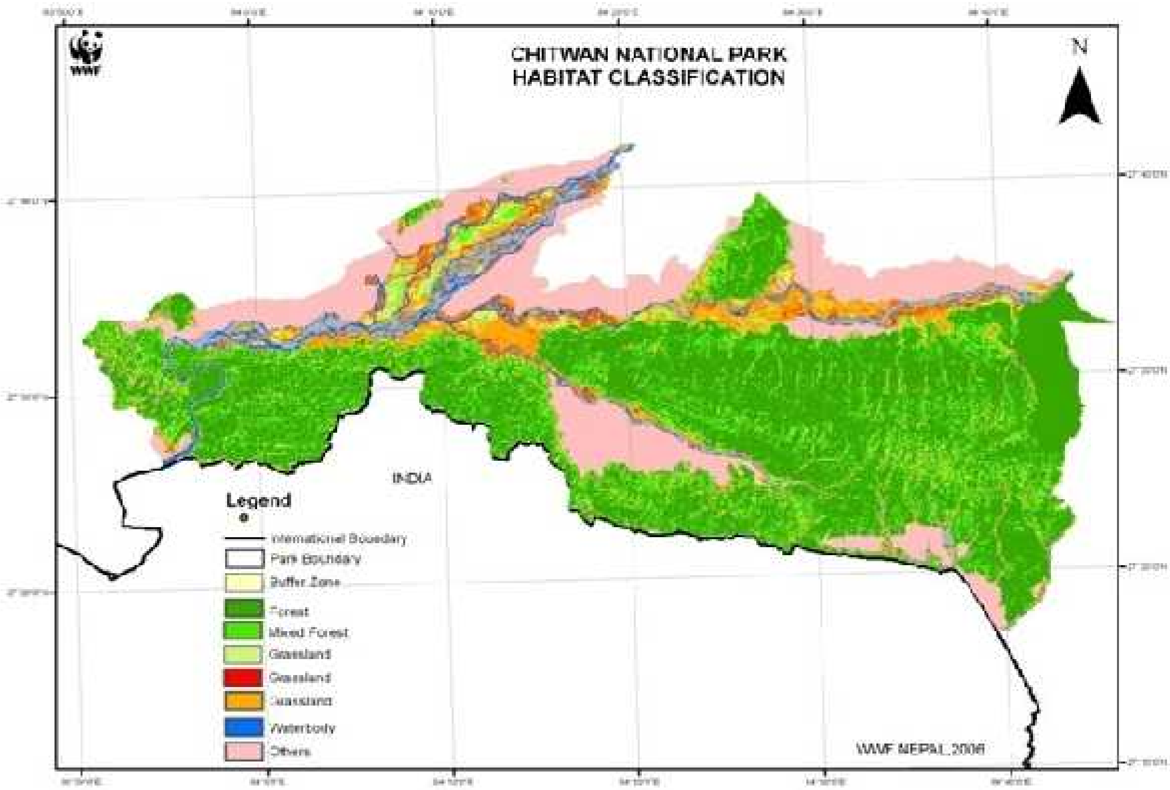


Fig. 2.7: Classified habitat types of Chitwan National Park (WWF Nepal, 2006)

2.4.2 Riverine forest

Riverine forests occur along the streams, lakes and rivers where occasional floodings are essential (Mishra, 1982). It is quite variable in composition and a wide variety of tree associations (Dinerstein, 1975; Sunquist, 1979; Lehmkuhl, 1994). It is the main habitat for wild animals such as rhinoceros, deers and wild boars (Fig. 2.8).

Duration of inundation in monsoon season, river proximity, elevation and soil conditions largely determine the dominance of species composition in the riverine forest (Dinerstein, 1975, 1987). The major tree composition of riverine forest are *Bombyx ceiba* (Bombacaceae), *Trewia nudiflora* (Euphorbiaceae), *Litsea monopetala* (Lauraceae), *Mallotus phillipinensis* (Euphorbiaceae), *Ehretia laevis* (Cordiaceae), *Premna obtusifolia* (Verbenaceae), *Bauhinia malabarica* (Leguminosae), *Dalbergia sissoo* (Leguminosae), *Acacia catechu* (Leguminosae), *Syzigium cumini* (Myrtaceae) and *Ficus racemosa* (Moraceae).

Fig. 2.8: Riverine forest community in Sauraha sector, Chitwan National Park

The shrub layer of the riverine forest consists of species like *Callicarpa macrophylla* (Verbenaceae), *Coffea benghalensis* (Rubiaceae), *Murraya koenigii* (Rutaceae), *Murraya paniculata* (Rutaceae), *Clerodendrum viscosum* (Verbenaceae), *Colebrokea oppositifolia* (Labiatae), *Pogostemon benghalensis* (Labiatae), *Artemisia vulgaris* (Compositae), *Urena lobata* (Malvaceae) and *Maesa sp.* (Myrsinaceae).

The herb layer of the riverine forest consists of species like *Cynodon dactylon* (Graminae), *Imperata cylindrica* (Graminae), *Ageratum conyzoides*

(Compositae), *Saccharum spontaneum* (Graminae) and *Cyperus rotundus* (Cyperaceae).

Fires, overgrazing by domestic animals and feeding habit of large herbivores play role in maintaining structure and composition of riverine forests, grasslands and savannas (Dinerstein, 2003). Riverine forest does not form a continuous belt along rivers and streams, but more commonly appears as a mosaic of patches surrounded by grasslands or intermixed with grasslands. Savanna like habitat conditions prevails where *Bombyx ceiba* has invaded the grasslands. Riverine forest can be further distinguished into following four sub-type communities;

2.4.2.1 *Khair – Sissoo* forest - This type of forest association is dominated by Khair (*Acasia catechu*) and Sissoo (*Dalbergia sissoo*) on the banks of the Rapti, Reu and Narayani rivers on recent alluvium (Laurie, 1978; Lehmkuhl, 1989). *Khair* is the most common species in the drier region. This forest association is a colonized vegetation type when stabilizing through succession produces conditions favorable to other tree species (Laurie, 1978). There is often a dense understory growth of *Pogostemon benghalensis* and a variety of other shrubs, herbs and grasses.

2.4.2.2 *Bombyx – Trewia* forest - This forest type is dominated by Simal (*Bombyx ceiba*) and Vellar (*Trewia nudiflora*) which represent a later stage of succession and appears as a distinct strip in riverine forest. This type of forest is a tropical deciduous riverine forest (Stainton, 1972; Bolton, 1975). This type of association includes species such as *Bauhinia malabarica*, *Murraya koenigii*, *Butea monosperma*, *Ehretia laevis* and *Litsea monopetala, Callicarpa* *macrophylla, Clerodendrum viscosum, Coffea benghalensis, Pogostemon benghalensis, Colebrookea oppositifolia* and *Phyllanthus emblica* are present as understory shrubs. Grasses are present insubstantially except in clearing and at the forest edge. Some species such as *Saccharum spontaneum*, *S. munja, Vetiveria zizanoides, Cynodon dactylon, Chrysopogon aciculatus, Digitera setigera, Paspalidium flavidum* occur in the forest type (Fig. 2.9).

2.4.2.3 *Eugenia* woodland - In damp places along the banks of Rapti, Narayani rivers and its old courses, pure stands of *Syzygium cumini* occur. It is another type of tropical deciduous riverine forest (Stainton, 1972; Bolton, 1975). The understory species of this forest includes *Murraya koeinigii, Colebrokia oppositifolia and Clerodendrum viscosum.*

Fig. 2.9: Savanna grassland with *Bombyx* trees in west Sauraha, CNP

2.4.2.4 Tropical evergreen forest - In some places of the park such as Bagmara to the north-east of the park species associations similar to the Tropical Evergreen Forest are found (Stainton, 1972; Bolton, 1975). This forest includes species like *Albizia lucida, Litsea monopetala, Magnifera indica* and *Ficus sps*. This forest is found mainly in the moist areas and the understory growth in this forest is very poor due to thick and dense canopy which obstruct sunlight reaching to the ground.

2.4.3 Grassland

Grassland occupies about 23 percent area of the Chitwan National Park (Bolton, 1975; Mishra, 1982). At lower elevations on hydric sites, *Saccharum, Narenga* and *Themeda* species form tall grass (4-7 m.) communities and on more well drained soils form Savanna with *Bombyx* (Lemhkuhl, 1989). *Imperata cylindrica*, short grass less than 1 m. height, forms patchy monospecific stands on old agricultural sites (Dabadghao and Shankarnarayan, 1973). Different types of grasslands include species like, *Saccharum spontaneum*, *S. benghalensis*, *Imperata cylindrica, Narenga porphyrocoma, Themeda villosa, Phragmites karka, Arundo donax, Cynodon dactylon, Digiteria setigera, Chrysopogon aciculatus, Andropogon sp. and Paspalidium flavidum.*

In Chitwan National Park, following seven different types grasslands can be distinguished.

2.4.3.1 *Themeda villosa* grassland - This type of grassland is dominated by *Themeda villosa*, a tall grass species which grow up to six meters and is generally found in clearings in the Sal forest and especially on old river-courses.

2.4.3.2 *Saccharum – Narenga* grassland - These grasses grow up to eight meters and are generally found as mixed or pure stands. The dominant species of this grassland are *Saccharum benghalensis* and *Narenga porphyrocoma*. These species are all characteristics of later stages in the succession (Lehmkuhl, 1994). Some short grasses are also found growing under the tall grass canopy.

2.4.3.3 *Saccharum spontaneum* grassland - *Saccharum spontaneum* is one of the first species to invade and colonize the newly formed floodplains and form pure stands which reach a height 2-4 meters. Low-lying stands of *Saccharum* are destroyed by repeated flooding in the monsoon. This type of grassland ranges from less than 100 m to more than 1 km in width (Dinerstein, 2003). *Saccharum spontaneum* is the most preferred grass of rhinoceros due to its nutritious value. This type of grasslands is abundantly found on old agricultural areas of Padampur (Fig. 2.10).

2.4.3.4 *Imperata* grassland - In some places pure patches of short grass species *Imperata cylindrica* are seen. This grassland cover old village sites within the park and grows prolifically in areas where grasslands are burned repeatedly (Sunquist, 1979). *Saccharum spp*. are also found but sparsely scattered and *Imperata* is dominant. It is a valuable thatch grass and is variable in height up to 2 meters or more (Fig. 2.11).

Fig. 2.10: *Saccharum spontaneum* grassland in Padampur Area, Sauraha sector, CNP.

Fig. 2.11: *Imperata cylindrica* grassland in Padampur area, Sauraha sector, CNP.

2.4.3.5 *Arundo – Phragmites* grassland - Along stream beds, floodplains and around lakes species like *Arundo donax* and *Phragmites karka* are commonly found (Sunquist, 1979; Lehmkuhl, 1989). This forms dense stands of grasses that reach a height of almost 7 meters. Other frequent associates of this grassland type are *Saccharum spp*., *Typha elephantia* and *Cyperus spp*.

2.4.3.6 Mixed short grassland - Some raised areas near the riverine forest are covered by short grasses like *Cynodon dactylon* and *Chrysopogon aciculatus* all the year round. Short grasses are quick in germination and can grow both with advent of rains and immediately after the monsoon (Laurie, 1978). Near the edge of the park, short grasslands are protected from livestock grazing. Mixed short grassland includes other species like *Cyperus rotundus, Ploygonum plebujum, Persicaria sp., Ceratophyllum demersum, Eragrotis japonica, Hemortheria compressa, Diablegium sp., Pauzolgia hirta* etc.

2.4.3.7 Wooded grassland and scrub - Due to the succession, the tall grassland and short grassland changed into the wooded grassland or scrub land. The tree species like *Trewia nudiflora, Bombyx ceiba* and *Wendlandia exerta* sparsely distributed in these grassland and covered more than 20% of the canopy (Subedi, 2012). It mainly consists grass species like *Saccharum spontaneum, Narenga porphyrocoma, Imperata cylindrica, Saccharum benghalensis* and *Themeda villosa*. Scrub is formed by heavily grazed meadows dominated by *Imperata cylindrica*, *Chrysopogon aciculatus* and *Cynodon dactylon* with scattered bushes of *Ziziphus mauritinia* and *Callicarpa macrophylla.*

2.5 Fauna

The Chitwan National Park comprises rich in faunal diversity represented through faunal assemblages of 68 mammals, 544 birds, 56 herpetofauna, 126 fishes, 150 species of butterflies as well as several species of invertebrate (Gurung, 1983; Edds, 1986; Shah and Tiwari, 2004; Baral and Upadhaya, 2006; Bhuju *et al*., 2007; Thapa, 2011).

The mammalian fauna include several endangered to common species such as greater one horned rhinoceros (*Rhinoceros unicornis*), tiger (*Panthera tigris*), Asian elephant (*Elephas maximus*), leopard (*Panthera pardus*), sloth bear (*Ursus ursinus*), gaur (*Bos gaurus*), wild dog (*Cuon alpinus)*, hispid hare (*Caprolagus hispidus)*, rhesus macaque (*Macaca mulatta)*, common langur (*Presbytis entellus),* striped linsang (*Prionodon pardicollor*), striped hyena (*Hyaena hyaena)*, dolphin (*Platanista gangetica*), chital (*Axis axis*), hog deer (*Axis porcinus*), Sambar (*Cervus unicolor*), muntjac (*Muntiacus muntjak*), four-horned antelope (*Tetracerus quadricornis)*, pangolin (*Manis pentadactyla) and* Pygmy shrew *(Sorex minutus)*.

The reptilian fauna in the river and riverine habitats are: gharial crocodile (*Gavialis gangeticus*), marsh mugger crocodile (*Crocodylus palustris*), golden monitor lizard (*Varanus flavescens*) and Asian rock python (*Python molurus*), Indian starred tortoise (*Geochelone elongate)* are major reptile species abundantly found in the park. The Maskey frog *(Tomopterna maskeyi)* is another important endemic species traced in the park (Maskey, 1989). The fish fauna documented in the rivers and lakes of CNP consists of *Barilius* spp., *Tor putitora*, *Tor tor, Puntius* spp. etc. species of fishes (Edds, 1986).

The Chitwan National Park is also outstandingly rich in harboring diverse avifauna having more than 544 species including over 22 globally threatened categories. These are bengal florican (*Houbaropsis bengalensis)*, slender-billed vulture (*Gyps tenuirostris*), white-rumped vulture (*Gyps bengalensis*), red-headed vulture (*Sarcogyps calvus*), sarus crane (*Grus antigone*), greater adjutant stork (*Leptoptilos dubius*), lesser adjutant stork (*Leptoptilos javanicus*), Pallas's fish-eagle (*Haliaeetus leucoryphus*), greater spotted eagle (*Aquila clanga*), imperial eagle (*Aquila heliacal*), Indian skimmer (*Rynchops albicollis*), white-throated bushchat (*Saxicola insignis*), Jerdon's babbler (*Chrysomma altirostre*), slender-billed babbler (*Turdoides longirostris*), bristled grass-warbler (*Chaetornis striatus*), greater Indian hornbill *(Buceros bicornis),* swamp francolin (*Francolinus gularis*) (Inskipp, 1989; Baral and Inskipp, 2001; Baral and Upadhaya, 2006; Bhuju *et al*., 2007). Among all the avifauna, more than 266 species are migratory birds, including both winter visitors and altitudinal migrants to CNP.

2.6 Buffer Zone and its management

The buffer zone of CNP was declared in 1996 covering an area of 750 km^2 around the CNP aiming to reduce pressure on park resources through a protective layer to meet the resource needs of local communities (Sharma, 1998). It is formulated under the National Parks and Wildlife Conservation Act, 1973 (amendment in 1993) and Buffer Zone Management Regulations, 1996. To implement participatory management with local people thirty four Village Development Committees (VDCs) and two municipalities of Chitwan, Nawalparasi, Parsa and Makwanpur districts, partly or wholly included. Buffer zone principally covers the cultivated agricultural land (46%) followed by forest (43 %), shrub land (1%), grassland (1%) and river/sand (9%) (DNPWC, 2000). In the buffer zone management, more than 223,260 people with 36,193 households were targeted from various ethnic groups. An inclusion of Tharus- an indigenous people with farming occupation was an important activity under this program (Sharma, 1991; DNPWC, 2000) (Fig. 2.12). This initiative has facilitated in breaking traditional barriers between parks and local people, for promoting conservation (Sharma, 1991; Nepal and Weber, 1993) and also tackle the conflicts with people's help (Sharma, 1998). The buffer zone management also regulated resources utilization to some extent with special development activities for enhancing conservation values of the park (Nepal and Weber, 1993).

The Park channels back 30-50% of its total revenue to the Buffer Zone Management Committee (BZMC), for implementing a development action plans. Out of total allocation BZMC spends 30% for conservation activities, 30% for community development, 20% for income generation and skill development, 10% for conservation education programs and 10% for administrative costs (Buffer Zone Management Guideline, 1996). Twenty two Buffer Zone User Committees and 1779 Buffer Zone User Groups (BZUGs) are formed under the supervision of Buffer Zone Management Committee (BZMC) (Buffer Zone Management Guideline, 1996). Buffer Zone User Committees (BZUCs) undertake activates such as community forestry management, grassland management, conservation awareness, community patrolling, income generation and various anti-poaching activities in their buffer zones (CNPBZ, 2010).

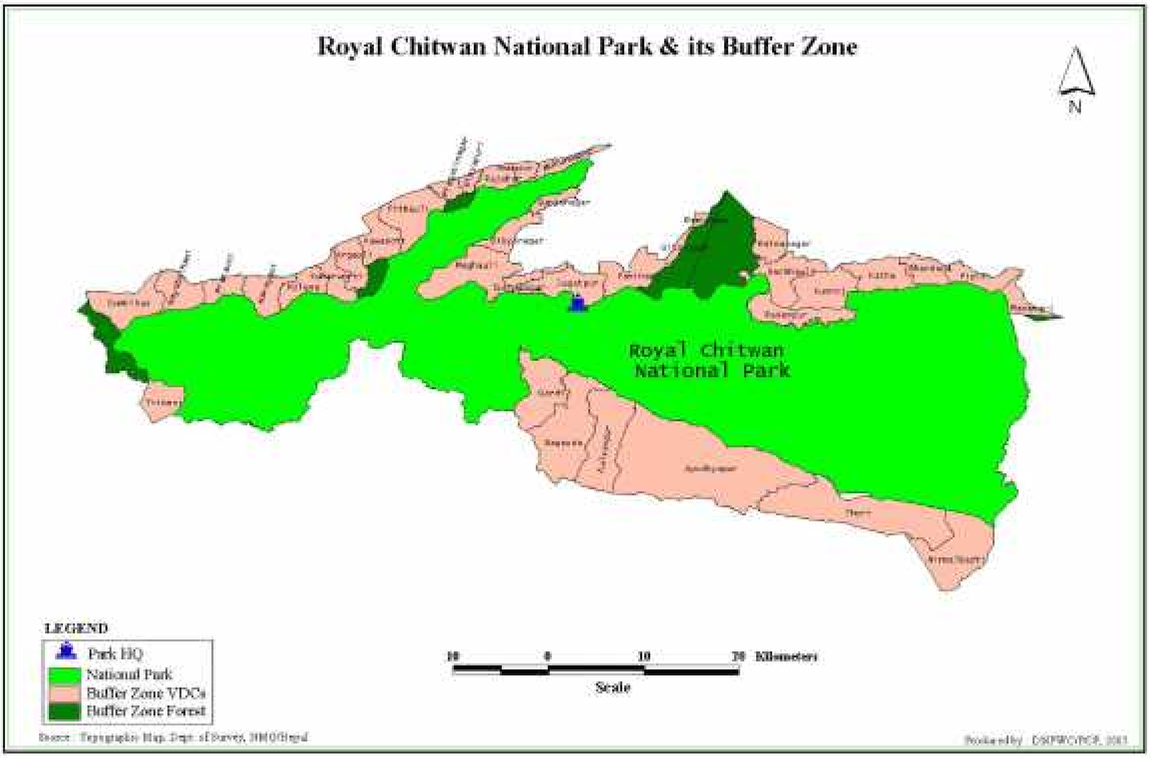


Fig. 2.12: Map showing Chitwan National Park and surrounding Buffer Zone of CNP (DNPWC/PCP, 2005).

2.7 Methodology

2.7.1 Selection of the study sites

Prior to the selection of the study site, I visited most of the parts of the Chitwan National Park frequently. In these recurrent visits, I found several remarkable changes took place after the detailed study carried out by Laurie from 1972 to 1976 in Sauraha area of the park. These are given as - (i) Habitat alteration has occurred; grassland habitat changed into the wooded or forested habitat due to succession and agricultural land changed into the grassland habitat after evacuating the human settlement from Padampur area in 2004. (ii) Among 91 translocated rhinos to different protected areas of Nepal and India, almost all of them were taken from Sauraha sector. In rhino census in 2008, number of rhinos was reduced to 111 from earlier largest count 228 in Dinerstein and Price (1991). (iii) The newly introduced invasive plant species, the *Mikania micrantha* badly impacted the prime rhino habitat in Sauraha area. (iv) During this time period, the Rapti River changed its course effectively. (v) Most of the northern part of the Sauraha sector where human settlements occur was fenced in the later years. (vi) Tourists pressure increased sufficiently in this area and other anthropogenic pressures also exerted.

I visited the Sauraha sector for rapid reconnaissance visit in February and March in the year of 2009. Sauraha sector also known as Eastern sector is the largest among all four sectors of CNP. It lies between south of Rapti River in the north and Churia hill in the south. About 75% area is covered by Sal forest and remaining by riverine forests, grasslands, rivers and riverbeds. I mainly focused to find out rhino occupying habitat in my initial visits and I found rhinoceros rarely went to the south of Sal forest from where Churia elevation starts to rise up. They mainly inhabit in the riverine forests and floodplain grasslands along the Rapti River. So, I selected the intensive study area of 77.1 km^2 including buffer zone community forests, where density, abundance and activities of rhinoceros were high. The intensive study area lies between 27º 31' 20.61" to 27º 36' 3.13'' N latitude and 84º 25' 56.43'' to 84º 35' 9.42'' E longitude.

2.7.2 Preliminary reconnaissance

Before carrying out research, I studied several articles, theses, books and proceedings regarding the rhinos (primarily greater one horned rhinoceros). I made many consultations with the seniors, park authorities and experts to collect preliminary valuable information. After that, I also met with other park personnel, hoteliers, elephant riders, guides and other concerned stakeholders. A preliminary survey was carried out for few days by walking and riding on elephant back to identify the habitat types, major rhino locations and landscape elements. I marked out the major rhino habitat in topo-graphaphic map (1: 25000) in Sauraha sector of Chitwan National Park. This visit helped me to develop general idea for monitoring, observing, evaluating and analyzing the research work.

2.7.3 General methods and data analysis

The research was carried out from 2009 to 2011 in the selected study area of Chitwan National Park. To collect the data in seasonal context, I divided the whole year into three distinct seasons namely hot (March to June), monsoon (July to October) and winter (November to February).

Registry of individual identification (ID) of each rhinoceros and photographic techniques were adopted to collect data to estimate population status of Sauraha sector (Chapter 4; Plates 4.1 to 4.4). I used the Global Positioning System (GPS) locations of each rhinoceros and collected information on my first sighting for estimating abundance and distribution of rhinoceros. I noted sex and age structure of rhinoceros as well as peculiar characteristics of each rhinoceros on the basis of morphological characteristics and later confirmed them on repeated observations. I observed mainly in hot season because it is very suitable for the identification of individual rhinoceros and observing for long time in open grassland where large number of rhinos were engaged on feeding newly sprouted plant shoots. All observations were made on foot, from elephant back and from watch tower.

Scan animal sampling, Ad. Libitum Sampling (Altman, 1974), direct observation and feeding trails observation methods were used to estimate seasonal and annual food and feeding activities of rhinoceros in the study area (Laurie, 1978; Bhattarchya, 1991; Dinerstein and Price, 1991; Patton and Martin, 2007; Hazarika 2007; Hazarika and Saikia, 2006, 2009, 2010 and 2011; Bhatta, 2011; Roy, 2009). I followed ten identified individuals for 10 days in each season from dawn to dusk (6 am to 6 pm) and recorded all the activities, date and duration of time spent. I recorded all plants eaten by rhinoceros in direct and feeding trails observation. Unknown plant species were collected for reference and later verified at the Botanical Department of GoN, Kathmandu.

Habitat preference and habitat utilization pattern of the rhinoceros were studied using ERDAS IMAGINE and Geographic Information System (GIS) (Seidensticker, 1976; Lilesand and Kiefer, 1989; Litvaitais *et al.*, 1996; Porwal *et al.*, 1996; Kushwaha *et al.*, 2000; Gibson and Power, 2000). For this purpose, habitat classification of the study area and habitat used by each rhinoceros were necessary components.

Different landscape elements were identified using differences in plant species composition, land-use pattern and degree of disturbance in the landscape. I selected the intensive study area of 77.1 km^2 which covers the core rhino habitat of Sauraha Sector. I used the latest USGS Landsat Satellite image obtained from the Earth Explorer (www.earthexplorer.com). I used the false color composite (FCC) corresponding to red (R), green (G) and blue (B) with band combination of 5, 4 and 3. Spatial analysis software the ERDAS IMAGINE 9.2 (Leica Geosystems) was used for image processing and Arc GIS 9.3 (Environmental Systems Research Institute, ESRI) for final map preparation. Signature for different category of habitat was prepared with the help of ground truthing points and final supervised classified map was prepared for the analysis of habitat utilization and habitat preference. Prepared classified image was compared for accuracy assessment with Kappa Coefficient value. For the convenience of the data analysis, habitat of intensive study area was classified into seven categories; riverine forest, Sal forest, tall grassland, short grassland, wooded grassland/scrub, water body and river bed.

For estimating home range and habitat use, ten rhinoceros of different age and sexes were individually identified, intensively monitored and fixed all sighting locations in different seasons throughout the year using Global Positioning System (Garmin, Etrex) along with presumptive age, sex and related habitat information (Laurie, 1978; Bhattacharya, 1991; Hazarika, 2007; Hazarika and saikia, 2011). All the data collected by the GPS instruments were transferred and arranged in excel spreadsheets. These locations of sightings were overlaid on a prepared classified map of the intensive study area of the Chitwan NP, and were analyzed individually to determine home ranges of rhinos. To find out the locations of identified individual rhinoceros, 10 days per month was spent to visit each and every corner of the possible rhino habitat using elephant back as well as on foot.

To estimate seasonal and annual home ranges, Minimum Convex Polygon (MCP) (Mohr 1947) and the Fixed Kernel Density Estimator (FKDE) (Worton, 1989; Silverman 1986) methods were used. I used the Home Range Tools (HRT) software version 1.1 of the Home Range Extension (HRE) for Arc View GIS, 9.3 for calculating Minimum Convex Polygons (MCPs) and Fixed Kernel Density Estimations (FKDEs) (Rodgers *et al.* 2007).

To analyze the habitat utilization pattern of rhinoceros, GPS locations of each individual was superimposed on the classified vegetation and the land use map. The habitat use by each individual rhinoceros was analyzed by dividing the used percentage of number of sightings in each landscape element with overall number of direct sighting locations (extracted by Arc GIS 9.3 using Spatial Analysis tool) (Ivlev, 1961).

The used location points of particular habitats and available habitats were extracted and the percentage of both habitat availability and habitat use were calculated. Then habitat preference in relation to seasonal and overall study period was estimated by Compositional Analysis (Aebischer *et al.*, 1993) in Resource Selection Program. Ivlev Electivity Index (Ivlev, 1961) was also used to ensure the habitat preference order.

To facilitate proper data collection, I used several optical tools and equipments. High resolution 10x*40mm (Nikon ST10X40CF HD) binocular facilitated viewing individual rhino's identifying markings and observing food selection and other activities. The Global Positioning System, Garmin, Etrex GPS have been used to collect data with geo-reference in Universal Transverse Mercator (UTM) system. The Sony Cyber-Shot H9 digital camera with an 8.1 Mega pixel CCD image sensor, a Carl Zeiss Vario-Tessar lens with 15x optical zoom had been used for taking photographs and videos. I transferred all the photographs and videos to Acer, Extensa 4620 laptop according to the individual rhinoceros file created on the daily basis. Data captured were transferred to Microsoft XL data sheet in a laptop computer for necessary analysis.

CHAPTER 3

POPULATION STATUS AND DEMOGRAPHY OF RHINOCEROS IN SAURAHA SECTOR, CHITWAN NATIONAL PARK

Chapter 3

Population Status and Demography of Rhinoceros in Sauraha Sector, Chitwan National Park

3.1 Introduction

The performance of an endangered wildlife conservation program is often evaluated by the species population size and net population growth (Hariyadi e*t al.*, 2011). Population density relationship in a habitat plays a vital role in understanding ecosystem diversity and changes in the environmental circumstances. It is therefore essential to analyze the reactive mechanism with careful and continuous monitoring over several years (Schenkel and Hulliger, 1969). Demographic survey of a population is incomplete without mentioning its size and composition. Demographic parameters, mainly age at first reproduction, inter-calving intervals and calf survivorship are most crucial factors in population variations in rhinoceros (Schenkel and Hulliger, 1969; Owen-Smith, 1988). International Union for Conservation of Nature and Natural Resources (IUCN) / Species Survival Commission (SSC) categorized greater one horned rhinoceros as a “vulnerable” species and recommended incessant management concentration for future survival (Talukdar, 2010).

The population of greater one horned rhinoceros is extremely affected by human activities such as habitat alteration and degradation, as well as poaching and over hunting (Blanford, 1888; Prasad, 1975; Dinerstein and Price, 1991; Vigne and Martin, 1991; Adhikari *et. al* 1999; Talukdar, 2002; Martin and Martin, 2006). Threats imposed on them largely are; rapidly shrinking alluvial plain grasslands and massive poaching for its commercially valued horns (Leader-Williams, 1992; Menon, 1996b). This is further intensifying by use of modern weapon, unbelievable value of horn, and the superstitious beliefs put on the body parts have put forth excessive pressure on the survival of this species. In spite of all the odds, the greater one horned rhinoceros still have managed to survive in several protected area systems of Nepal and India, where their populations are reported to be growing.

Large mammalian herbivores or megaherbivores fall into the category of K-selected species, for which demographic patterns are influenced with variation of densities (Owen-Smith, 1988). Population decline have been related to poorer fecundity, delayed puberty and increased mortality in rhinoceros (Laurie, 1978). In future, megaherbivore mammals especially rhinoceros are likely to become more constrained to the reserves, where their conservation demand more knowledge on changes in population densities and demography of populations (Rachlow, 1997).

Until the 1950s, a free ranging population of 1000 rhinoceros survived in the southern lowland *Terai* of Nepal. In following years eradication of malaria, increased poaching and habitat destruction have reduced rhino population alarmingly at Chitawan valley (Caughley, 1969). By the end of 1966, that population reached to the lowest level of 100 individuals, which later on picked up gradually untill 2011; except insurgency period in between from 1996 to 2005 (Martin and Martin, 2006). With implementation of effective conservation efforts (DNPWC, 2011) population again grew as estimated in 2011 to the level of 534 rhinoceros in Nepal including 503 in Chitwan National Park, 24 in Bardia National Park and 7 in Suklaphanta Wildlife Reserve.

Laurie (1978, 1982) carried out population estimation of rhinoceros in Chitwan National Park especially mentioning population of Sauraha sector occupied by 193 animals (including Tikoli and Katar population). He studied by making individual identification (ID) cards and using photographic techniques. Dinerstein and Price (1991) used a register of photographed individual and estimated population of Sauraha subpopulation occupied by 228 rhinoceros. They further included the additional area of Kasara sector within Sauraha subpopulation estimation which was not included by Laurie in previous study.

The purpose of the present study is to understand the demography of rhinoceros in Sauraha sector within Chitwan National Park. This intensive work estimated occupancy of total rhinoceros in Sauraha sector with sex and age categories. Further investigations were accomplished for knowing births, birth rate and natality and mortalities of individuals in Sauraha sector. Comparison of these parameters with previous studies and also with this estimation of rhinoceros in Chitwan National Park in different years will be useful for making several management decisions.

3.2 Methods

I have intensively surveyed and monitored Sauraha sector for knowing occupancies of rhinoceros from April, 2009 to March, 2011 for a period of two full years. The entire sector was subdivided in 11 blocks for recording the habitat and occupancy relationship among the rhinoceros. The methodologies used for individual identification, age and sexing, abundance estimation, births and deaths are as described below:

3.2.1 Identification of individual Rhinoceros

Identification of individual rhino was most important to take record of activities, movements and to estimate population. All individuals were uniquely indentified in my records by following physical features as listed below:

a. Size, length, shape, curvature, rings and grooves on horns,
b. Arrangement of skin folds,
c. Congenital, permanent markings and irregularities in skin folds,
d. Scars on body,
e. Length, shape and cut marks on tail,
f. Cut marks and notch, presence or absence of hair on ears,
g. Size and shape of head,
h. Arrangement of tubercles on the rump.

I took photographs of each and every individual rhinoceros which came across during the survey. For this, I have photographed from front, rear and both side views of each rhinoceros. I have made individual "Rhino Identification Reference Card**"** by drawing its peculiar characters and writing descriptions of identification marks in the data sheets (Fig. 3.1). These cards recorded precise identification for each individual. If any rhinoceros was found to acquire new identification features in repeated observations, the "Rhino Identification Reference Cards" were properly updated with new notes. Photographs and drawings were maintained for all sighted rhinoceros in Microsoft Excel database (Fig. 4.1). In this way the database was built up and minimum population of greater one horned rhinoceros for Sauraha sector of Chitwan National Park was determined.

In the year 2009, I have surveyed Sauraha sector and adjacent forests where rhinoceros occur. I have subdivided Sauraha sector into 11 blocks (Fig. 3.2) which are alienated by clear demarcation of physical boundaries (i.e. rivers and edges) and ecological boundaries (i.e. extensive tracts of Sal forest, riverine forest, savanna, grasslands and agricultural land) (Laurie, 1978; Dinerstein and Price, 1991). I have mostly used riding elephants or on foot survey to record observations, identifications, photographs and registration of rhinoceros. Systematic searches were made in the morning and late afternoon, when animals were most active. I have intensively observed the grasslands east of Khagendramali to the Baghuwaghera on the west which somehow separates the Sauraha population from the west population.

3.2.2 Sex and age categorization

I determined the sex of rhinoceros by observing external genitalia, shape and size of body, horn and neck folds (more prominent in male), mode of urination, accompanying calves and mammary glands. We determined sex easily in the open areas with close observations, but it was difficult in dense vegetation. Modes of urination provided a precise sex determination in young rhinoceros which had not developed peculiar secondary sexual characters (Laurie, 1978, Patton, 2007). Generally adult males have wider horns at the base than adult females (Dinerstein, 2003). Sex of small calves below two years old was difficult to determine and recorded only when frequent observations made was confirmed. If I could not confirm the sex of calves, their record was placed in unknown categories.

Rhino Identification Data Recording Form

Reference ID :……………..   Date of Obs. :……………….

GPS Location (UTM) : Easting / Northing   Sex :   Age :

Calf Position :

<u>Key Identity</u>

Horn :

Ear :

Skin Folds :

Tail :

Remarks :

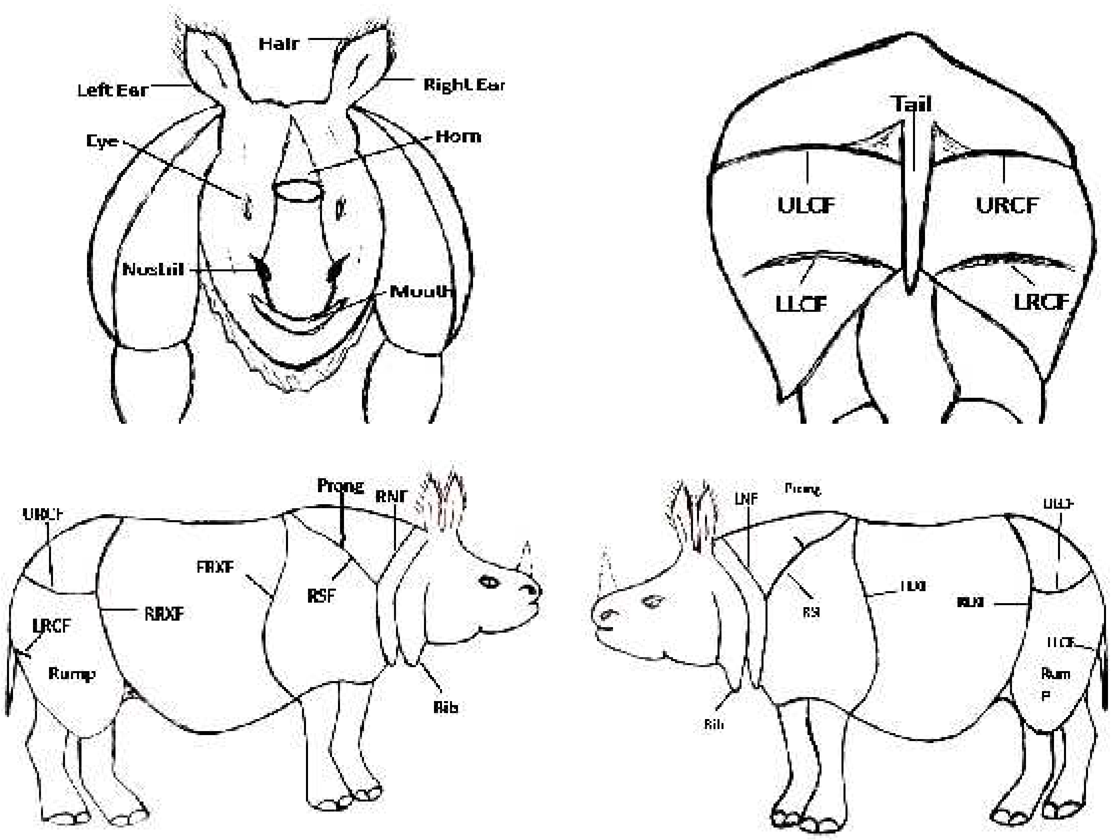


Fig. 3.1: Key physical landmarks for identification of individual rhinoceros.

URCF : Upper Right Corner Fold

LRCF : Lower Right Corner Fold

RRXF : Rear Right Cross Fold

FRXF : Front Right Cross Fold

RSF : Right Shoulder Fold

RNF : Right Neck Fold

P : Prong

ULCF : Upper Left Corner Fold

LLCF : Lower Left Corner Fold

RLXF : Rear Left Cross Fold

FLXF : Front Left Cross Fold

LSF : Left Shoulder Fold

LNF : Left Neck Fold

B : Bib

Each sighted individual was classified into age groups of (i) calves (< 4 years), (ii) sub-adults (4-6 years) and (iii) adults (>6 years) on the basis of shoulder heights, horn size, skin folds, color of skin, size of the body and group associations (with cow) etc. Ages of calves are determined by body size, color of skin, accompanying with mother and little presence of horn. I considered animals to be calves until they separated from the mother, at about 4 years of age.

Sub-adults will be distinguished from adults by body size, horn size and absence of scars on skin. Sub-adults consist of the age class from 4 to ≤ 6 years of age (Dinerstein and Price, 1991).

Adults are also classified into more specific age categories: young adults (6-12 years i.e. breeding F and non-breeding M), intermediate-aged adults (12-20 years) and older adults (> 20 years). Young adults have short horn size with little wear, few scars or body marks and small in body size. Young adult males lacked pronounced secondary neck folds. Intermediate-age adults can be distinguished by horn size and moderate wear, increased amount of facial wrinkles, sign and scars, body size, development of secondary neck folds (in males) and births of more than one calf (for females). Older adults will be distinguished by a combination of extensive facial wrinkles, major scars on the anal skin folds, torn and notched ears, broken and deeply grooved or eroded horns and extensive development of secondary neck and shoulder folds (in males). Male breeders can be identified by observing copulations, tending of estrous females, the sign of fighting among dominant males and behavioral and morphological features. They often squirt urine when closely approached, possess extensive secondary neck folds and are aggressive toward subordinate males (Laurie, 1978; Dinerstein, 2003; Patton, 2007).

3.2.3 Estimation of abundance

The rhinoceros populations of Chitwan National Park are mostly confined to four subpopulations- the Sauraha, the West, the Bandarjhola-Narayani River and the South (Dinerstein and Price, 1991). The Sauraha sector which is northern floodplain of the Rapti River is a span of grasslands extended from east of Kagendramali to the Dudhoura streams in the west. This sector was further divided in 11 blocks where rhinoceros mainly inhabit. Based on physical attributes each block is clearly discernable on ground (Fig. 3.2).

Location of identified rhinoceros through photo files were recorded in hot season (March - June) when the tall grass had been burned and cut off, so, visibility became a maximum. At that time rhinoceros grazed on new shoots for long periods in the open grassland. In other part of the year more search efforts were employed to locate the rhinoceros in relatively tall grassland habitat. But whenever each individual were sighted, their sighting locations were recorded by using handheld GPS. This enabled us to know the relative use of various blocks in Sauraha sector. All individuals were registered separately in the rhino identification profile as hard copy and soft copy in XLS datasheet in computer.

3.2.4 Birth rate and death rate

Records on newly borned calves of rhinoceros in the Sauraha sector were systematically kept and wherever possible tentative birth dates were estimated. All calves born in an annual cycle were recorded and annual birth rate was calculated by dividing it with total number of adult females present in the study zone. Zoo data showed that gestation in greater one horned rhinoceros is about 15.7 months (Laurie, 1978). I assigned birth dates (± 1 month) to calves born during the study in the Sauraha population. I also recorded the death of all rhinoceros in the Sauraha sector during my study period and mortality rate was calculated accordingly.

3.2.5 Use of secondary data of Chitwan National Park

3.2.5.1 Rhino mortality

Official records of Departments of National Parks and Wildlife Conservation (DNPWC) were obtained for mortality data of rhinoceros for Chitwan National Park to compare with the present population study with Sauraha sector. As rhinoceros are considered the property of the king (later national precious property) and the park warden must account for all mortalities by an official inquest; data on mortality are generally to a certain extent accurate. Rhinoceros most often died close to riverbanks, and their carcasses congregate large flocks of vultures, helps to find out the location of dead animals. Elephant drivers, researchers and nature guides also support to find

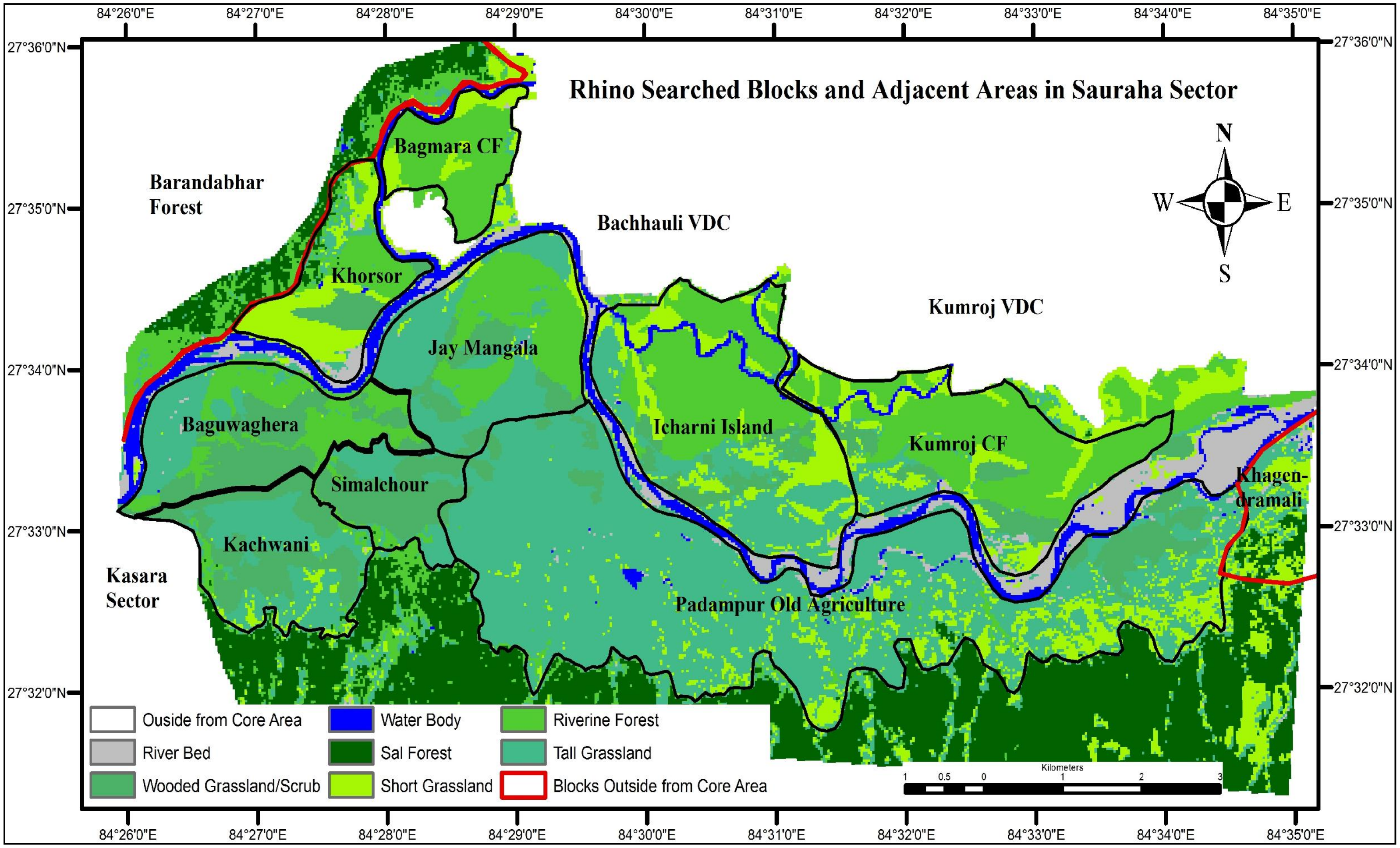


Fig. 3.2: Map showing rhino searched blocks and adjacent areas of Sauraha sector of Chitwan National Park.

the death location. Death rate was calculated by dividing the number of dead individuals by the total number of rhinoceros within that age class.

Detail informations on death of rhinoceros were collected regarding poaching (by gun-shooting, poisoning, electrocution, pitfall, firearm etc) and natural death (old age, tiger predation, infighting, disease, rhino charge, flood and mud sink etc.) from the records of DNPWC. Location, nature, time and date of deaths were recorded categorically for each individual.

Natural mortality is a rare phenomenon for large, long-lived and endangered herbivores (Dinerstein, 2003). In reality, human induced adult mortality is the key problem for the conservation of large mammals. Large mammals are long lived and comparatively slow breeders, so, they suffer rigorous declines in their populations if excessive hunting and poaching occur.

As calves become prey for tigers, most of the calf mortality takes place during the first year of life. The competition for mating with female contributes majority of deaths among adult males. Mortality from disease rarely recorded in rhinoceros. But, the transmission of disease among wildlife is quite serious threat to the existing populations hence transmission options to build up few other populations were undertaken in Nepal.

3.2.5.2 Population growth

Population of rhinos were guessed and estimated since 1950 in Nepal. Early census were only intelligent guess but later rhino counts were done by scientific methodology covering entire possible rhino habitats making individual reference ID cards, total block counts, aerial counts etc. I used the rhino counts data to calculate the annual growth rate (r), for five time periods between 1950 to 2011 as follows; (a) period of low conservation priority, 1950-1966; (b) period of preliminary concern, 1966-1972; (c) period of post park establishment, 1972-2000; (d) period of insurgency, 2000-2005 and; (e) post insurgency period, 2005-2011.

3.3 Results

3.3.1 Population of rhinoceros in Sauraha sector

Data presented in Table 3.1 showed presence of at least 74 rhinoceros in 11 blocks surveyed in the study area. The four blocks particularly Icharni Island, Jay Mangala, Baguwaghera and Bagmara community forest recorded larger number of rhinoceros. However presence of very low number of rhinoceros recorded in Barandabhar, Khorsor, Kumroj, Padampur and Simalchour blocks. The area of the block and occupancy of rhinoceros per unit area found no relationship (r_s = 0.637, d.f. = 9, p = 0.03) (Fig. 3.3). During my study period it was observed that 3 rhinoceros occasionally visited from adjacent sector and travelled in blocks of Baguwaghera, Kachwani, Jaymangala and Simalchour in Sauraha sector. These animals were not recorded and identified in my study site and therefore they were not included in my population count.

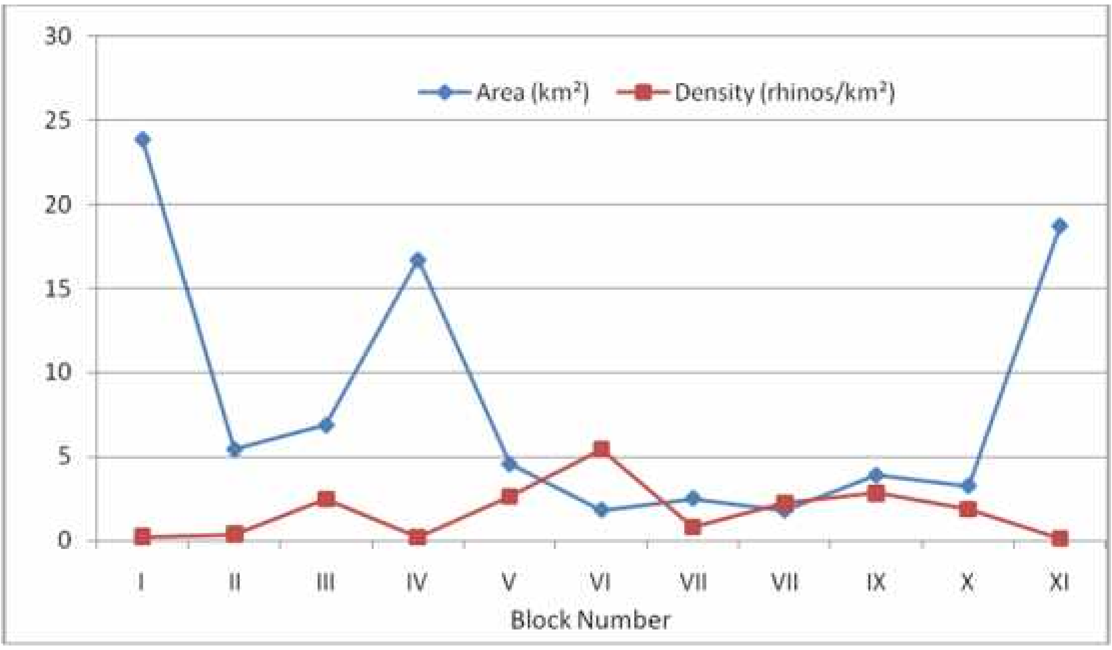


Fig. 3.3: Area and density relationship of rhinoceros in 11 blocks of Sauraha sector of CNP.

3.3.2 Distribution and abundance

Table 3.1 presents data on rhinoceros, their occupied areas in 11 blocks and densities of rhinoceros therein. It can be seen from the Table 3.1 and Fig. 3.4 that Icharni Island registered highest number of rhinoceros (17 or 22.97%) of total population of Sauraha sector. However, in density terms it is not the highest compared to Bagmara community forest block, which though lesser in area terms. It is noteworthy that Bagmara community forest block being the smallest in area (1.84 km^2) had highest density of rhinoceros (5.43 rhinos/km^2). On the contrary, Barandabhar corridor forest block being the largest (18.76 km^2) had lowest density of rhinoceros (0.11 rhinos/km^2). The mean density of rhinoceros in all blocks was 0.83 rhinos/km^2 compared to the range 0.11 – 5.43 rhinos/km^2. The Chi-square test performed on occurrence of rhinoceros in all 11 blocks showed significant difference in their distribution (χ^2 = 37.78, d.f. = 10, p < 0.0001).

The occupancy of rhinoceros in 11 blocks when overlaid on seven habitat types showed greater presence of rhinoceros in tall grassland (26 rhinos; 35.14%) followed by riverine forest (24 rhinos; 32.43%), short grassland (9 rhinos, 12.16%), wooded grassland/scrub (8 rhinos, 10.81%), water body (5 rhinos, 6.76%), Sal forest (2 rhinos, 2.70%) (Table 3.2). The Chi-square test performed on the distribution of rhinoceros in different habitats were significantly different (χ^2= 60.89, d.f. = 6, p < 0.0001).

Table 3.1: Number of Rhinoceros, block size, population density in Sauraha sector of CNP.

Block No.	Block Name	No. of Rhinos	Area of Block	Density/Km²
I	Khagendramali	5	23.89	0.21
II	Kumroj CF	2	5.43	0.37
III	Icharni Island	17	6.87	2.47
IV	Padampur Grassland	3	16.72	0.18
V	Jay Mangala	12	4.58	2.62
VI	Bagmara CF	10	1.84	5.43
VII	Khorsor	2	2.53	0.79
VIII	Simalchour	4	1.81	2.21
IX	Baguwaghera	11	3.91	2.81
X	Kachwani	6	3.28	1.83
XI	Barandabhar Forest	2	18.76	0.11
Total		**74**	**89.62**	**0.83**

Table 3.2: Distribution of rhinoceros by habitat type in Sauraha sector of CNP.

S.N.	Habitat Type	Blocks											No. of Rhinos
		kg	kr	ic	pg	jm	bg	ks	sc	bg	kw	bb	
1	Tall Grassland	3	1	5	2	6	0	0	2	5	2	0	**26**
2	Riverine Forest	1	0	7	0	5	7	0	0	4	0	0	**24**
3	Short Grassland	1	0	2	1	0	3	2	0	0	0	0	**9**
4	Wooded GL/Scrub	0	0	0	0	0	0	0	2	2	4	0	**8**
5	Water Body	0	1	3	0	1	0	0	0	0	0	0	**5**
6	Sal Forest	0	0	0	0	0	0	0	0	0	0	2	**2**
7	River Bed	0	0	0	0	0	0	0	0	0	0	0	**0**
Total		**5**	**2**	**17**	**3**	**12**	**10**	**2**	**4**	**11**	**6**	**2**	**74**

Note: kg = Khagendramali; kr = Kumroj; ic = Icharni Island; pg = Padampur Grassland; jm = Jaymangala; bg = Bagmara CF; ks = Khorsor; sc = Simalcour; bg = Baghuwaghera; kw = Kachwani; bb = Barandarbhar Forest; GL = Grassland

3.3.3 Age and sex analysis

Table 3.3 showed age and sex classes of 74 rhinoceros registered in 11 blocks of Sauraha sector. The demography of the rhinoceros showed composition of 46 adults, 12 sub-adults and 16 calves in the Sauraha sector. The sex ratio in the adult segment was 1:1.3 female whereas in sub-adult segment sex ratio was 1:1.4 female. In my study period, I have recorded four calves from three blocks, being smaller their sex could not be determined. The sexed calves' sex ratio was recorded 1:1.4 female.

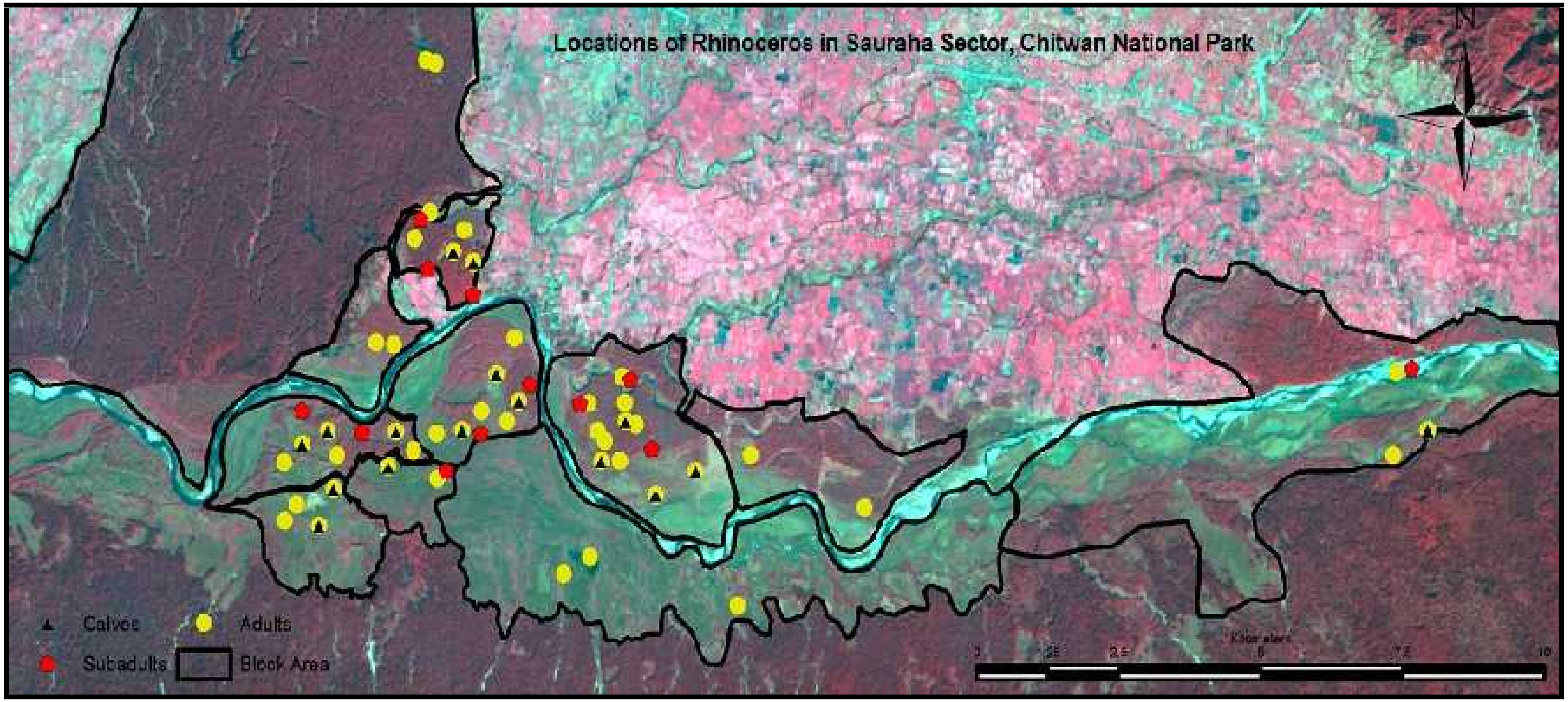


Fig. 3.4: Distribution of Rhinoceros in the Sauraha sector of Chitwan National Park.

Table 3.3: Age and sex-wise status of rhinoceros in Sauraha sector of Chitwan National Park.

B.N.	Block Name	AM	AF	SAM	SAF	CM	CF	CUK	Total
I	Khagendramali	2	1	1	0	0	0	1	**5**
II	Kumroj	1	1	0	0	0	0	0	**2**
III	Icharni Island	4	6	1	2	2	2	0	**17**
IV	Padampur	1	2	0	0	0	0	0	**3**
V	Jay Mangala	2	5	0	2	1	1	1	**12**
VI	Bagmara	2	3	1	2	1	1	0	**10**
VII	Khorsor	2	0	0	0	0	0	0	**2**
VIII	Simalchour	1	1	1	0	0	1	0	**4**
IX	Baghuwaghera	2	4	1	1	0	1	2	**11**
X	Kachwani	1	3	0	0	1	1	0	**6**
XI	Barandabhar	2	0	0	0	0	0	0	**2**
Total		**20**	**26**	**5**	**7**	**5**	**7**	**4**	**74**

Note: AM = Adult Male, AF = Adult Female, SAM = Sub-adult Male, SAF = Sub-adult Female, CM = Calf Male, CF = Calf Female, CUK = Calf Unknown

3.3.4 Birth rate and death rate

In Sauraha sector, rhino population in two years study period gave birth to three calves in the blocks of Icharni Island, Jay Mangala and Baguwaghera. The sex of the calves could not be determined. The annual birth rate estimated on the basis of total females present in Sauraha sector was 5.76%.

I also recorded ten mortalities of rhinoceros (5 adult males, 3 adult females, 1 sub-adult and 1 calf of unknown sex) in Khagendramali, Kumroj, Padampur, Bagmara, Barandabhar and Baguwaghera blocks in two years study period. The death rate recorded annually was 6.75% of the population (74).

3.3.5 Population and demography of rhinoceros in Chitwan National Park

Table 3.4 presents data collected from various sources on the estimates of rhinoceros in Chitwan National Park from the year 1978 to 2011. This Table further include population estimate undertaken by present study between 2009 to 2011 in Suraha sector. Analysis of demographic parameters from earlier estimates to present study have been presented in Table 3.5. It can be seen that sex ratios in adult segment did not vary much in all estimates except the estimates carried out by Laurie (1978) and Dinerstein and Price (1991) where this ratios were more skewed towards female. On contrary, adult male percentage found in current study was higher than the studies carried out by Laurie (1978) and Dinerstein and Price (1991).

Based on the data collected from various sources (Table 3.4 and Fig. 3.5) and by the current study, annual population growth percentage were analyzed and depicted the population growth trend through regression line in Fig. 3.6. It can be seen that of all five periods population growth analysis showed negative growth in two periods i.e. period of low conservation priority, 1950-1966 (-5.46%) and period of insurgency, 2000-2005 (-5.42%). However in other three periods i.e. period of preliminary concern, 1966-1972 (7.83%); period of post park establishment, 1972-2000 (4.43%) and post insurgency period, 2005-2011 (3.29%); the population growth was recorded positive and growing. The highest population growth was recorded in DNPWC estimate in 2011 and in my current study i.e. 7.76% and 5.76% respectively (Table 3.5).

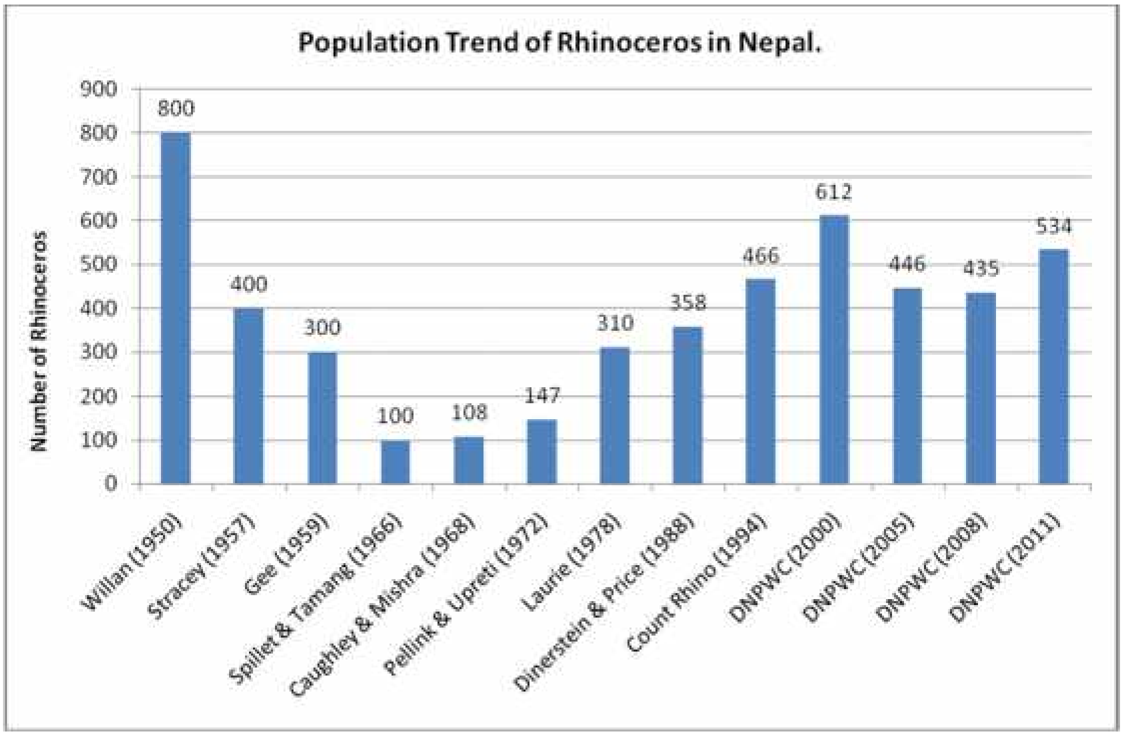
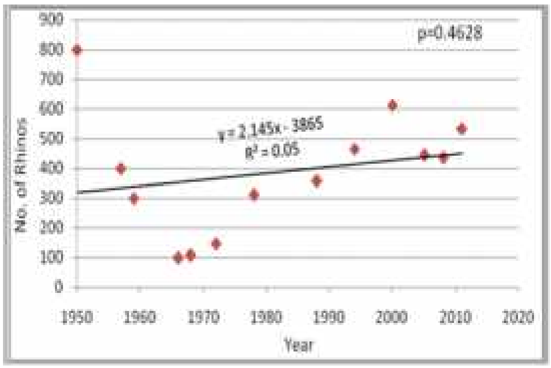
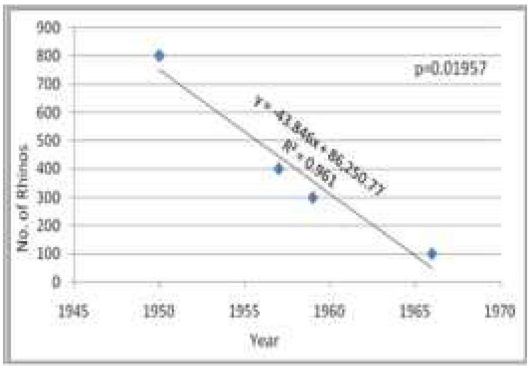


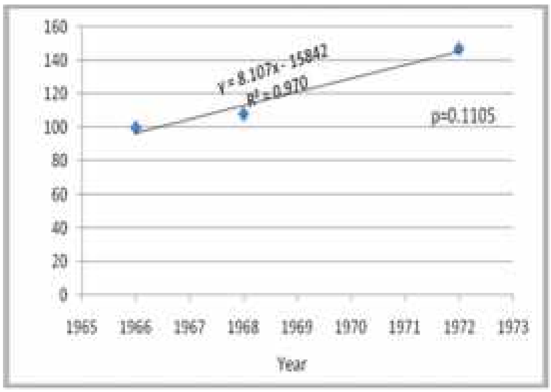
Fig. 3.5: Population trend of greater one horned Rhinoceros in Nepal.



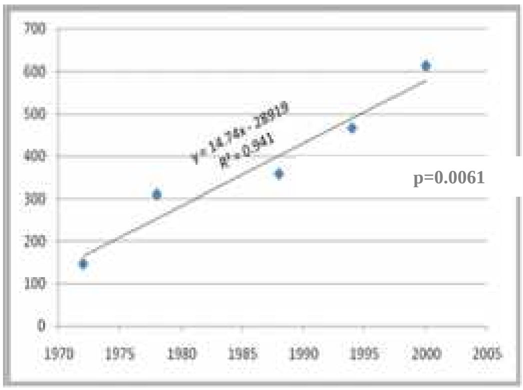
(a) Overall (1950-2011)



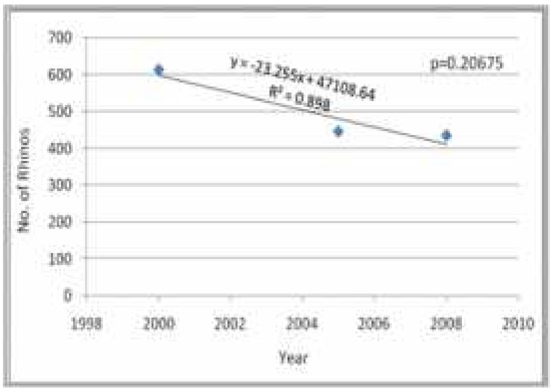
(b) Low conservation priority (1950–1966)



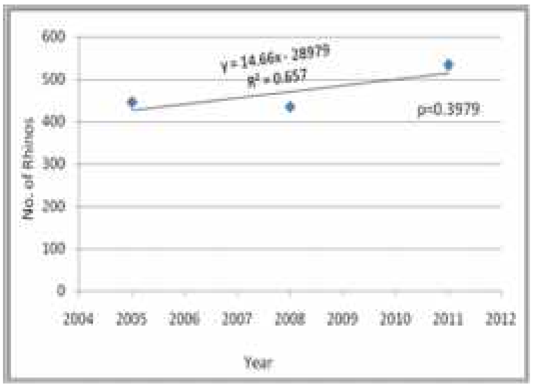
(c) Preliminary concern (1966–1972)



(d) Post park establishment (1972–2000)



(e) Insurgency period (2000–2008)



(f) Post insurgency period (2005–2011)

Fig. 3.6: Showing population increase or decrease trend of rhinoceros, in overall (a) and five stages (b, c, d, e, f) with regression line, p for significance level.

Table 3.4: Population status of rhinoceros in different census years in and around Chitwan National Park.

S.N.	Census Year	Age group	Male	Female	Unknown	Total
1	Laurie (1978)*	Adult	45	73	0	118
		Sub-adult	26	20	2	48
		Calf	26	16	18	60
		Total	97	109	20	226
2	Dinerstein and Price (1991)**	Adult	89	116	10	215
		Sub-adult	17	16	14	47
		Calf	22	18	31	71
		Total	128	150	55	333
4	DNPWC (2000)	Adult	136	186	10	332
		Sub-adult	34	45	8	87
		Calf	57	34	26	117
		Total	227	265	44	536
5	DNPWC (2005)	Adult	113	129	20	262
		Sub-adult	9	25	8	42
		Calf	11	19	38	68
		Total	133	173	66	372
6	DNPWC (2008)	Adult	85	114	78	277
		Sub-adult	8	9	34	51
		Calf	7	8	65	80
		Total	100	131	177	408
7	DNPWC (2011)	Adult	126	157	49	332
		Sub-adult	9	14	37	60
		Calf	10	12	89	111
		Total	145	183	175	503
8	Present study carried out during 2009-2011***	Adult	20	26	0	46
		Sub-adult	5	7	0	12
		Calf	5	7	4	16
		Total	30	40	4	74

* Laurie (1978) only classified the 226 registered individuals out of 310 rhinos.

** Dinerstein and Price (1991) only classified the 333 registered individuals out of 358 rhinos. They carried out population census of rhinoceros from 1984-88.

*** Present study only classified population of Sauraha sector.

Table 3.5: Analysis of demographic parameters of rhinoceros in Chitwan National Park and present study.

S.N.	Demographic Parameters	Laurie (1978)	D. & P. (1991)	DNPWC 2000	DNPWC 2005	DNPWC 2008	DNPWC 2011	Present Study
1	Female: Male ratio	1.22	1.28	1.17	1.30	1.31	1.26	1.33
2	Adult female : adult male ratio	1.93	1.51	1.37	1.14	1.34	1.25	1.30
3	Calf: cow ratio	0.78	0.62	0.63	0.53	0.70	0.71	0.62
4	Adult sex ratio (% M)	34.10	39.90	42.24	46.69	42.71	44.52	43.48
5	Subadult sex ratio (% M)	55.30	54.20	43.04	26.47	47.06	39.13	41.67
6	Adult as % of N	50.90	63.50	61.94	70.43	67.89	66.00	62.16
7	Subadult as % of N	22.80	13.30	16.23	11.29	12.50	11.93	16.22
8	Adult F as % of N	33.50	38.20	34.70	34.68	27.94	31.21	35.14
9	Adult F with calves as % of N	26.30	20.90	21.83	18.28	19.61	22.07	21.62
10	Adult M as % of N	17.30	25.30	25.37	30.38	20.83	25.05	27.03
11	% of adult F with calves	78.60	59.80	62.90	52.71	70.18	70.70	61.54
12	Population growth rate %	2 to 6	4.8	3.88	-6.32	3.22	7.76	5.76

Note: N = total population; M = male; D. & P. = Dinerstein and Price; DNPWC = Department of National Park and Wildlife Conservation

3.3.6 Mortality

The rhinoceros mortality data in Chitwan National Park was meticulously recorded since fiscal year 1998/99 to 2011/12. These data were collected from Chitwan National Park is summarized in the Table 3.6 and depicted in Fig. 3.7. From these, it can be seen that out of total mortality of 356 rhinoceros, 191 (53.65%) mortalities related to natural causes and 165 (46.35%) by poaching. The methods used for poaching either through gunshot (84), electrocution (16), pitfall (2), firearm (5) and poisoning (5) are summarized in Table 3.6. Poaching recorded in the fiscal year 2001/02 and 2002/03 were highest while it was lowest in the fiscal year 2011/12. It can be seen from the Table 3.6 and

3.7 that from the year 1998/99 to 2011/12 there were poaching cases of 165 rhinoceros of which in 116 case horns were removed by the poachers. Other deaths recorded in rhinoceros in CNP were due to old age (25), infighting (20), tiger predation (17), rhino charge (14) and mud sink (12).

The sex and age-wise mortalities of rhinoceros in CNP is presented in Table 3.7 and depicted in Figures 3.8 and 3.9. Out of total 356 mortalities recorded for rhinoceros, 161(45.22%) were males, 132 (37.08%) females and 63 (17.69%) of unknown sexes. According to the age classes mortalities in various segments were adults 152 (42.69%), sub-adults 9 (2.53%), calves 62 (17.41%) and unspecified age class 133 (37.36%).

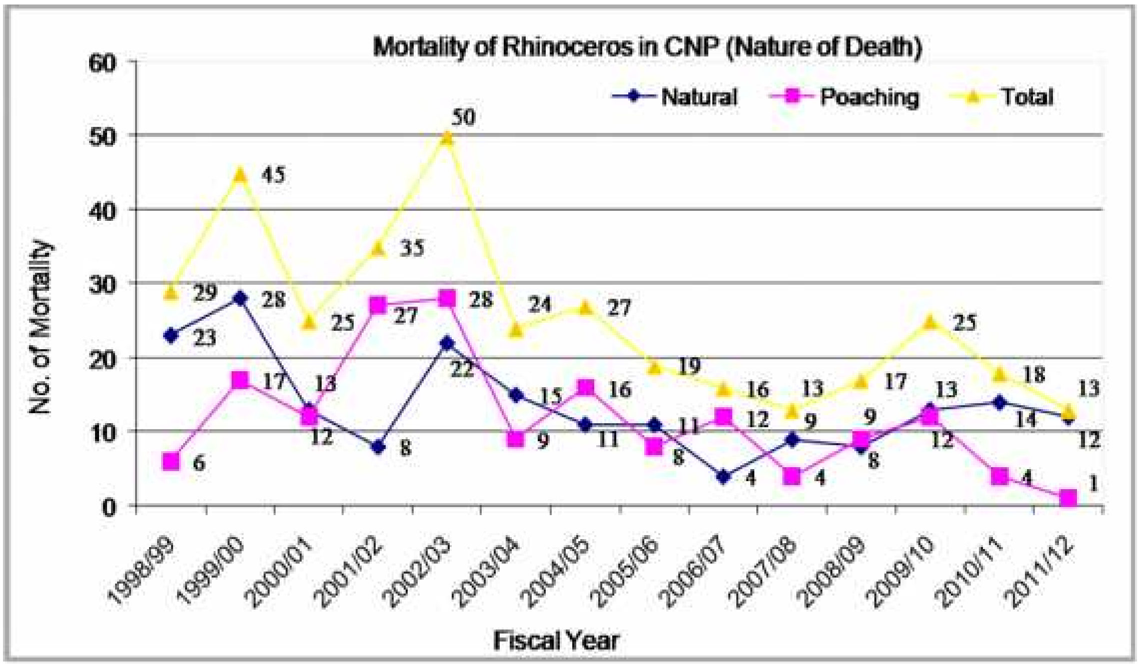


Fig. 3.7: Depicts rhinoceros mortalities during various years in CNP due to natural deaths and poaching.

Table 3.6: Showing rhinoceros mortalities in Chitwan National Park due to natural deaths and poaching from fiscal years 1998/99 – 2011/12.

S.N.	Year	Natural Death										Poaching							Total
		OA	INF	DI	TP	RC	MS	FL	OR	NM	SubTot	GS	EL	PT	FA	PO	NM	SubTot	
1	1998/99	0	6	1	1	1	3	1	1	9	23	0	1	1	0	1	3	6	**29**
2	1999/00	2	2	3	2	5	2	0	0	12	28	1	2	1	5	2	6	17	**45**
3	2000/01	0	3	1	1	2	0	0	0	6	13	6	2	0	0	0	4	12	**25**
4	2001/02	1	2	2	2	0	0	0	0	1	8	10	3	0	0	1	13	27	**35**
5	2002/03	2	1	0	4	1	2	3	0	9	22	22	1	0	0	0	5	28	**50**
6	2003/04	2	1	0	0	0	4	1	0	7	15	0	0	0	0	1	8	9	**24**
7	2004/05	1	2	0	2	0	0	0	0	6	11	11	1	0	0	0	4	16	**27**
8	2005/06	0	0	2	1	2	0	0	0	6	11	5	0	0	0	0	3	8	**19**
9	2006/07	0	0	0	0	2	0	0	0	2	4	9	3	0	0	0	0	12	**16**
10	2007/08	6	1	1	0	0	0	0	0	1	9	1	0	0	0	0	3	4	**13**
11	2008/09	0	0	0	3	1	0	0	0	4	8	7	0	0	0	0	2	9	**17**
12	2009/10	5	1	0	0	0	0	0	0	7	13	10	1	0	0	0	1	12	**25**
13	2010/11	2	0	0	0	0	0	0	0	12	14	2	2	0	0	0	0	4	**18**
14	2011/12	4	1	2	1	0	1	0	0	3	12	0	0	0	0	0	1	1	**13**
Total		**25**	**20**	**12**	**17**	**14**	**12**	**5**	**1**	**85**	**191**	**84**	**16**	**2**	**5**	**5**	**53**	**165**	**356**

Note: OA = Old Age, INF = Infighting, DI = Disease or Illness, TP = Tiger Predation, RC = Rhino Charge, MS = Mud Sink, FL = Flood, NM = Not Mentioned, Sub Tot = Sub Total, GS = Gun Shoot, EL = Electrocution, PT = Pit Fall, FA = Fire Arm, PO = Poisoning

Table 3.7: Showing mortalities of rhinoceros in various age and sex classes and detection of rhinoceros with or without horns in Chitwan National Park from fiscal years 1998/99 – 2011/12.

S.N.	Year	Horn Condition			Sex			AD				SAD(4-6)	CF(<4)	NM	Total
		Removed	Intact	NM	Male	Female	UK	YA(6-12)	IA(13-20)	OA(>20)	NM				
1	1998/99	4	25	0	18	8	3	0	0	0	0	0	6	23	**29**
2	1999/00	10	35	0	20	18	7	0	0	0	2	0	11	32	**45**
3	2000/01	4	17	4	14	8	3	0	0	0	0	0	3	22	**25**
4	2001/02	20	15	0	13	14	8	0	6	2	10	1	4	12	**35**
5	2002/03	21	29	0	14	22	14	0	0	4	12	1	8	25	**50**
6	2003/04	9	13	2	16	5	3	3	2	8	3	1	4	3	**24**
7	2004/05	15	12	0	12	9	6	1	3	6	13	0	2	2	**27**
8	2005/06	7	10	2	9	9	1	0	3	2	8	0	6	0	**19**
9	2006/07	7	8	1	9	4	3	3	2	0	6	1		4	**16**
10	2007/08	4	9	0	4	7	2	0	0	7	3	1	1	1	**13**
11	2008/09	0	5	12	6	9	2	1	2	2	0	1	5	6	**17**
12	2009/10	12	11	2	10	11	4	2	5	9	3	1	4	1	**25**
13	2010/11	2	16	0	10	3	5	1	1	2	6	2	4	2	**18**
14	2011/12	1	12	0	6	5	2	1	0	4	4	0	4	0	**13**
Total		**116**	**217**	**23**	**161**	**132**	**63**	**12**	**24**	**46**	**70**	**9**	**62**	**133**	**356**

Note: All above mentioned data are based on Annual Reports published by DNPWC, Nepal.

NM = Not Mentioned, UK = Unknown, AD = Adults, SAD = Sub Adults, CF = Calf,

YA = Young Adults, IA = Intermediate Adults, OA = Old Adults

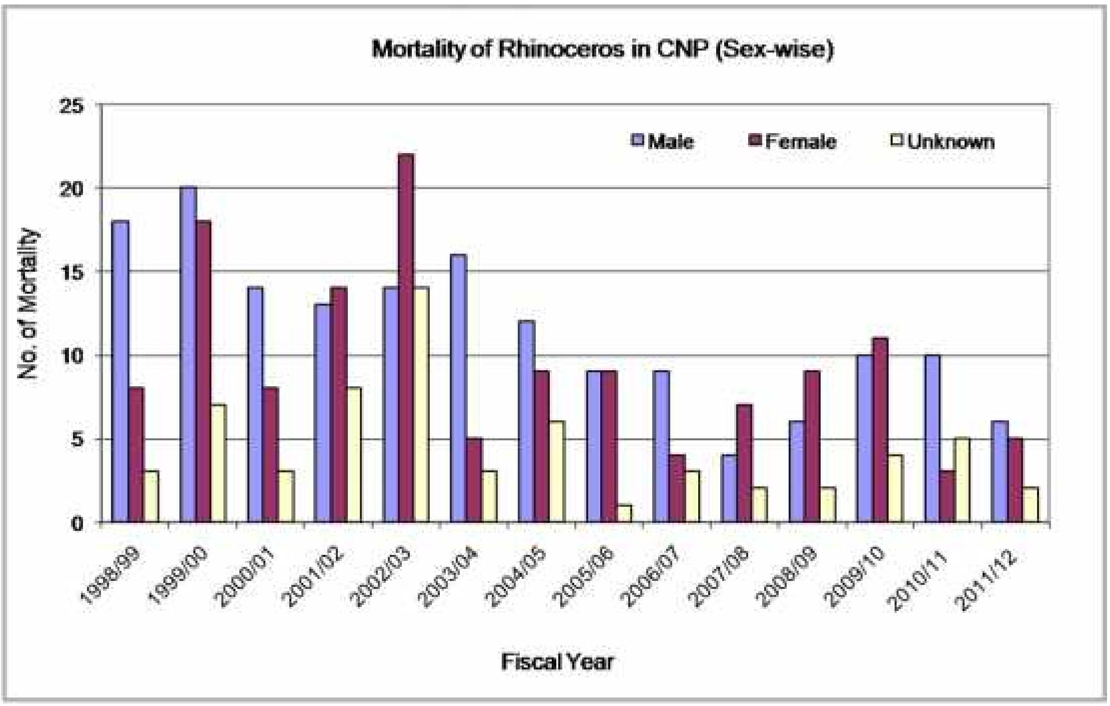


Fig. 3.8: Showing mortality of Rhinoceros sex-wise in Chitwan National Park.

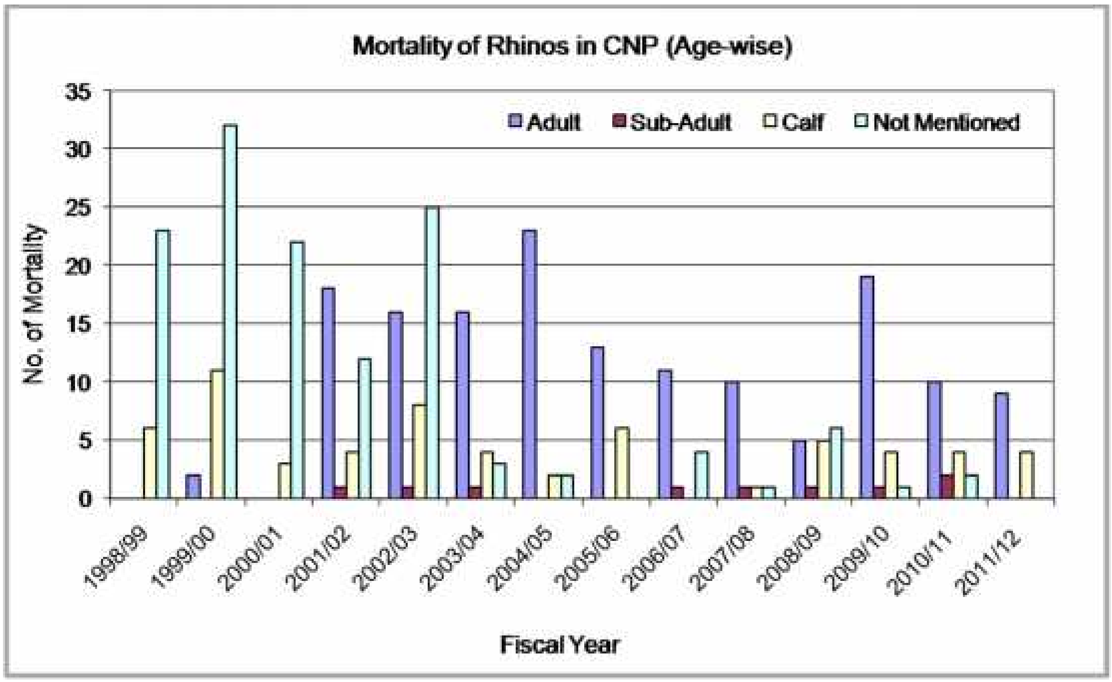


Fig. 3.9: Showing mortality of Rhinoceros age-wise in Chitwan National Park.

3.4 Discussion

The population of rhinoceros in Chitwan National Park has undergone several ups and downs due to intense poaching and anthropogenic factors operating on their habitats (Dinerstein and Price, 1991; Subedi, 2012). In late 1960s, their population dipped as low as 100 animals as estimated by Spillet and Tamang (1966). Political stability and conservation effectiveness through intense protection has reversed the declining processes and allowed the population to rebuild again in later years till now (Adhikari *et al.*, 1999; Dinerstein, 2003).

Detail study on rhinoceros population in Sauraha sector was little known before 1970s. Laurie (1978) first estimated the population of Sauraha and recorded their presence to a size of 193 rhinoceros. His study further revealed that the rate of population increase of rhinoceros in Sauraha sector to be between 2 to 6% per year. Thereafter, more intense and systematic study on Sauraha population was carried out by Dinerstein and Price (1991). According to their study Sauraha population were reported containing 228 registered individuals, constituting 62 – 63.5% of total estimated population for the CNP in 1988. The present study undertaken indicated presence of 74 rhinoceros in Sauraha sector which is much lower than what has been reported by Laurie (1978) and Dinerstein and Price (1991). Further the present population constitutes only 14.71% of total population of rhinoceros in Chitwan National Park (DNPWC, 2011). The estimation carried out by Department of National Park and Wildlife Conservation (DNPWC) in Sauraha sector indicated occupancy of 77 rhinoceros which is very similar to the present study

(DNPWC, 2011; Subedi, 2012). Registering less number of rhinoceros in the present study as well as in the estimate of DNPWC (2011) in comparison to Laurie (1978) and Dinerstein and Price (1991) is noteworthy and probably reflects the earlier translocations wherein several rhinoceros from this sector have been moved away for the recovery program (Mishra and Dinerstein, 1987; Jnawali and Wegge, 1993; Dinerstein, 2003; Sinha *et al.*, 2005) to build population in other protected areas of Nepal. Had this translocation not been there, Sauraha population would have been much larger than what have been reported by Laurie (1978) and Dinerstein and Price (1991). From the year 1986-2003, 91 rhinoceros were translocated from Sauraha sector to protected areas of Bardia National Park and Suklaphanta Wildlife Reserve in Nepal and Dudhwa National Park in India (Jnawali and Wegge, 1993; Dinerstein, 2003; Sinha *et al.*, 2005; Bhuju *et al.*, 2007).

The Bagmara community forest block in the present study had highest density of rhinoceros (5.43 rhinos/km^2) though it was only 1.84 km^2 in size. My finding on the distribution and abundance did not correlate with size of the 11 blocks areas and rhino occupancies. This therefore indicates food resource distribution within the survey blocks. Dinerstein and Price (1991) reported that densities of rhinoceros were positively correlated with the percentage of the block covered by *Saccharum spontaneum* grassland. They further reported that >90% *Saccharum spontaneum* grassland are mostly situated along the river floodplain (Dinerstein unplublished data cited in Dinerstein and Price, 1991). *Saccharum spontaneum* is one of the preferred diet of rhinoceros and its intake constitute could be over 50% of all food biomass (Jnawali, 1995). My study also in agreement with the fact that *Saccharum spontaneum* constitute the staple food of rhinoceros in terms of frequency intake (19.14%; Chapter 4). My study further accounted higher occupancies of rhinoceros in tall grassland habitat (35.14%) followed by riverine forest (32.43%) and short grassland (12.16%). Rhinoceros occupancies in the wooded grassland/scrub were 10.81% mostly in hot season.

My study registered occupancy of 74 rhinoceros in 11 blocks of Sauraha sector constituted by 46 adults, 12 sub-adults and 16 calves. The demographic comparison of sex ratios in the segment of total female to male and adult female to adult male ratios were 1.33 and 1.30 respectively, which are comparable in all estimations of rhinoceros between the year 2000 to 2011 but were lower than the estimates of Laurie (1978) and Dinerstein and Price (1991) (Table 3.5). The lowering of sex ratios are probably related with reduction of population of rhinoceros in Sauraha sector due to several translocations as stated before. The population growth at a rate of 5.76% per annum however compared well with other studies of Laurie (1978) and Dinerstein and Price (1991). The negative growth rate of rhinoceros in CNP was only recorded during the estimates of 2005 when insurgency was in peak. However, moderate positive growth rate were registered in the year 2000 and 2008 estimates i.e. 3.88% and 3.22% respectively.

The mortality through poaching was a serious problem in CNP as well as in Sauraha sector between 2001 to 2005 and 2009 to 2010 when they were exorbitant. Mortality data also indicated that adult rhinoceros were poached excessively due to their bigger size horns which fetch high value in international market (Leader-Williams, 1992; Menon, 1996b). Mortalities in the calf segment do reflect tiger predation, rhino charge and killing of nursing females (Dinerstein, 2003). Sustainability of rhinoceros in CNP and also in Sauraha sector will depend upon the future protection ensured for the rhinoceros and improvement of their habitat condition for registering higher population growth (Rothley *et al.*, 2004). The current population of CNP is still below the park's carrying capacity and can certainly be enhanced through better management and improved anti-poaching efforts.

CHAPTER 4

ACTIVITY PATTERNS, FOOD AND FEEDING HABITS OF RHINOCEROS IN SAURAHA SECTOR, CHITWAN NATIONAL PARK

Chapter 4

Activity Patterns, Food and Feeding Habits of Rhinoceros in Sauraha Sector, Chitwan National Park

4.1 Introduction

The activity pattern of an animal is a key for understanding the potential use of habitat by them for several ecological and behavioral needs (Struhsaker and Leland, 1979). This entails how and where animal allocates its time more on habitat for optimizing their resource uses for growth and survival (Owen-Smith, 1988). Studies on the activity budgeting on large mammals especially on rhinoceros have been undertaken by several authors in Nepal (Laurie, 1978; Dinerstein, 2003; Jnawali, 1995; Subedi, 2012) and India (Bhattacharya and Pal, 1982; Ghosh, 1991; Mary *et al.*, 1998; Hazarika and Saikia, 2011). Importance of activity patterns of rhinoceros such as feeding, wallowing, resting and movement patterns allows understanding of species-specific and site-specific time allocation and are very important tool for designing comprehensive conservation strategies through anti-poaching operations (Maskey, 1998; Adhikari *et al.*, 1999; Talukdar, 2002; Martin, 2004). The activity patterns are often influenced through several biotic and abiotic factors, important among them are availability of food (Laurie, 1988; Dinerstein, 2003), inter- and intra-specific competition (Yadav, 2000), social behavior (Laurie, 1978; Dixon and Macnamara, 1981), poaching (Adhikari *et al.*, 1999; Talukdar, 2002; Martin, 2004), and human disturbances (Sharma, 1991; Nepal and Weber, 1993). Abiotic components such as random climatic factors (Laurie, 1978; Dinerstein, 2003) due to risk of flooding (Baruah, 1998), pollution due to water quality changes (Bhattacharya and Pal, 1982) also influences habitat use so the activity patterns too.

In all animals availability of the food is a basic requirement for survival and maintenance of good health (Owen-Smith, 1988). This is the one activity on which rhinoceros spends more time similar to several other species (Dinerstein, 2003). Being large bodied and coarse feeder, mega-herbivores like rhinoceros requires food in large amount to meet their physiological needs (Sukumar, 1989). The low nutrient selection of food material forces them to eat more food and spent more time to wander and search for food in the habitat (Choudhury, 2005). The distribution pattern of food resources in the habitat are known to guide the occupancy of male and female individuals (Mary *et al.*, 1998). The search for food is a major influencing factor for animal to move and select the habitat.

The *In-situ* conservation program requires good understanding of species and site-specific utilization pattern of food resources over different seasons (Laurie, 1978). Several studies on feeding ecology of greater one horned rhinoceros were carried out in Nepal and India (Brahmachary *et al.*, 1969, 1971; Lahan and Sonowal, 1973; Lahan, 1974; Patar, 1977; Laurie, 1978, 82; Dinerstein, 1989; Bhattacharya, 1991; Ghosh, 1991; Mary *et al.*, 1998; Deka *et al.*, 2003; Bairagee, 2004; Steinheim *et al.,* 2005; Hazarika and Saikia, 2006; Wegge *et al.,* 2006). Apart from that, comparison of feeding ecology (Dinerstein and Wemmer, 1988; Pradhan *et al.*, 2008), feeding habit (Chowdhury, 1966; Clauss & Hatt, 2006;

Kandel and Jhala, 2008), chemical composition of food items (Deka *et al.*, 2003; Banerjee *et al.*, 2001), mineral nutrition and water intake in the captive greater one horned rhino (Clauss *et al.*, 2005b), principal food species (Peet *et al.*,1999; Deka *et al.*, 2003), rhino fodders (Ghosh and Das, 2007), seed dispersal and germination (Dinerstein and Wemmer, 1988), rhino dung analysis (Brahmachary *et al.*, 1971; Jnawali, 1995), diet analysis by comparing the microhistological slides (Jnawali, 1995) were carried out in Nepal and India.

The present study aims at investigating activity budgeting of rhinoceros in Sauraha sector of CNP and attempts to quantify time allocations of rhinoceros for various resource uses in the habitat. I also try to investigate food habits of rhinoceros and their seasonal use pattern. The quantification of food and feeding habits and food preference were also undertaken which might prove useful for conserving the species through effective management planning.

4.2 Methods

The study site, Sauraha sector of Chitwan National Park was surveyed for collecting information on activity patterns, food and feeding habits of rhinoceros from April, 2009 to March, 2011. In three seasons on an average, 10 days per season were utilized for conducting systematic survey to locate and identify the individuals, mostly on elephant back but sometimes even on foot. After preliminary survey in all 11 blocks, highly utilized areas by rhinoceros were stratified to enhance the search efficiency for finding the identified individuals and scan it for larger time for recording related activities food and feeding. From my photo file prepared for all rhinoceros, I have selected 10 individuals which were very distinctive in their physical features. These 10 rhinoceros were initially identified from various blocks of Sauraha sector constituting- 1 from Kumroj CF, 1 from Padampur Agriculture, 4 from Icharni Island, 2 from Jay Mangala and 2 from Bagmara CF. Sample photographic plates for only four individuals with their identifying features are enclosed in Plates 4.1 to 4.4.

During the field visit whenever these 10 individuals were sighted, their GPS locations, habitat types, age-sex and activities were recorded by scanning them for every five minutes interval. The activity budgeting for grazing, browsing, walking, wallowing, resting, standing and drinking were also recorded. The start time and end time of observations were also recorded systematically. All data were recorded in XL sheets for further analysis (Fig. 4.1). The details of the methods used for scan sampling, investigation of the feeding trails and plant identification, activity budgeting and feeding are as given below.

4.2.1 Scan sampling

Continuous *Focal Animal Sampling* (Altman, 1974) was difficult owing to excessive tall grassland and less sight of animal within them. To avoid this, *Scan Animal Sampling* (Altman, 1974) at every five minute interval when animal was properly sighted have been used for collecting data on activity budgeting in various blocks of Sauraha sector. Between two scan samplings, the *Ad. Libitum Sampling* (Altman, 1974) method was also used to record some additional activities.

4.2.2 Examination of feeding trails and plant identification

Data on feeding of 10 identified rhinoceros were collected using feeding trails observation method (Laurie, 1978). Direct observations through *Scan Sampling* and *Ad. Libitum Sampling* (Altman, 1974) was followed to record food consumption using high resolution 10x*40mm (Nikon ST10X40CF HD) binocular. On the basis of grazing and browsing of fresh trail, I have identified the grasses and browse species used by rhinoceros. In grassland habitat, feeding trails survey during winter time is very distinctive with early morning dew. Details of the plant species eaten and their part utilized were recorded systematically. Assistance of the field guides were taken to identify the plants in their vernacular language and later identified through exact botanical name. The recorded plant species eaten by rhinoceros along the feeding trails were properly maintained and added up with inclusion of new food plants. The complete list of 149 food plants used by rhinoceros during my study period compiled and listed in Appendix I. The unidentified food plants were collected and preserved for identification from herbarium maintained by Botanical Department of Government of Nepal, Kathmandu.

4.2.3 Activity budgeting

Activity budgeting of rhinoceros in various blocks of Sauraha sector were accomplished between the diurnal hours starting from 6 AM and continued until 6 PM only. No records of data during evening hour beyond 6 PM were kept due to several logistic limitations. The one way ANOVA tests were used for the test of variance and significance in all data analysis of activities, food and feeding.

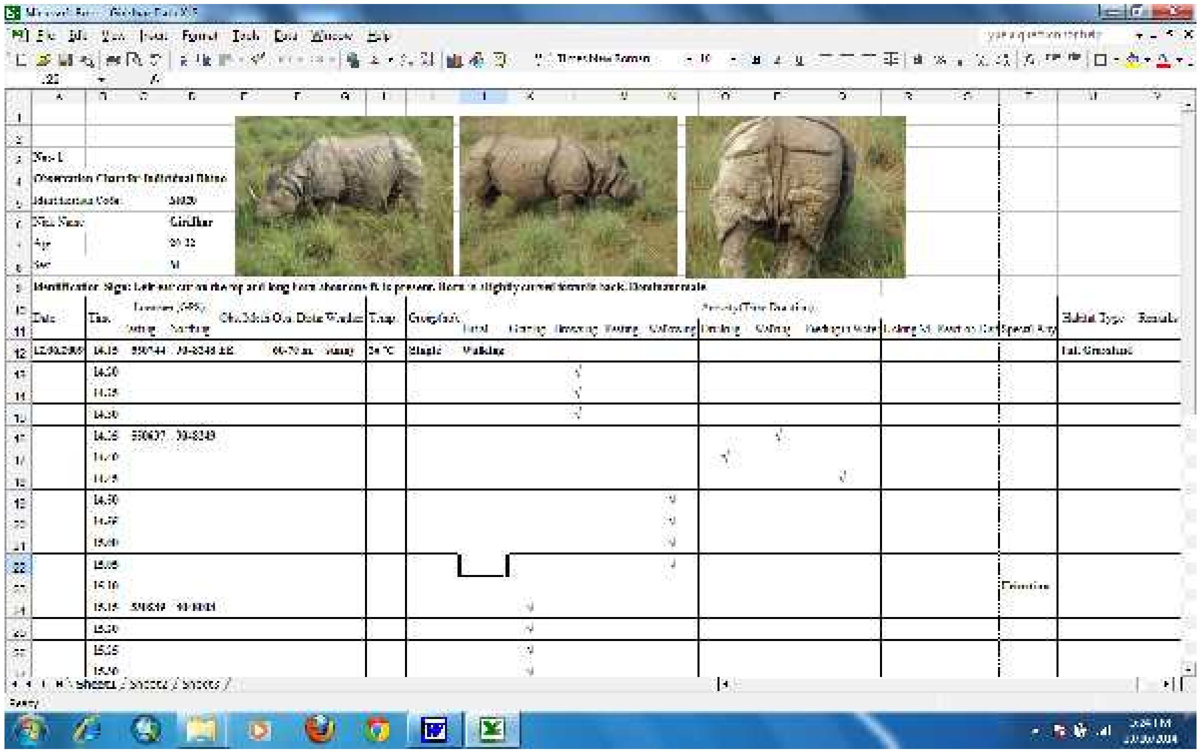


Fig. 4.1: Individual rhinoceros activities data collection XL sheet.

4.3 Results

4.3.1 Seasonal activity

The seasonal activities of 10 identified rhinoceros (5 males and 5 females) were recorded in two annual cycles by recording 720 hours of data categorized into different activity classes. The outcome of the data is presented in Table 4.1 and depicted in Fig. 4.2 which shows their percentage time utilization on various activities in three seasons. It can be seen from the Table 4.1 that during hot season, the grazing activity was higher (41.68 ± 2.98 %; Fig. 4.3) compared to the other two seasons. In contrary to this, browsing activity was found higher (11.87 ±0.81 %; Fig. 4.3) in winter season compared to other seasons. On an average percentage time spent on grazing in rhinoceros was 35.39 ± 2.12 % and browsing was 7.96 ± 0.65 %. In overall terms, the rhinoceros spent nearly 45% time for either grazing or feeding. The other activities which showed higher investment of time is resting followed by wallowing which on average term was found 25.95 ± 1.88 % and 14.62 ± 1.23 % respectively. In remaining other activities such as walking and standing animal spent lower time percentage.

Table 4.1: Percentage time of rhinoceros activities in different seasons in Sauraha sector, CNP. Values after ± are standard errors.

Season/Activity	**Grazing**	**Browsing**	**Walking**	**Wallowing**	**Resting**	**Standing**	**Other**
Hot Season	41.68±2.98	5.10±0.46	6.25±0.35	18.51±1.38	21.26±2.07	5.03±0.36	2.17±0.33
Monsoon Season	37.05±1.59	6.90±0.68	6.57±0.65	23.78±1.75	20.00±1.91	3.78±0.43	1.92±0.20
Winter Season	27.44±1.78	11.87±0.81	14.53±0.65	1.58±0.56	36.60±1.65	6.67±0.65	1.31±0.17
Annual	35.39±2.12	7.96±0.65	9.12±0.55	14.62±1.23	25.95±1.88	5.16±0.48	1.80±0.23

The one way ANOVA tests carried out various activities revealed that grazing ($F_{2, 27} = 9.76$; $p < 0.001$), browsing ($F_{2, 27} = 24.81$; $p < 0.0001$), walking ($F_{2, 27} = 61.12$; $p < 0.0001$), wallowing ($F_{2, 27} = 68.87$; $p < 0.0001$), resting ($F_{2, 27} = 21.62$; $p < 0.0001$) and standing ($F_{2, 27} = 7.71$; $p < 0.01$) were highly significant in different seasons. However, the activities such as drinking water, mineral licking, mating etc. grouped in the category of other activity (Table 4.1) is less significant ($F_{2, 27} = 3.04$; $p = 0.064$) in different seasons.

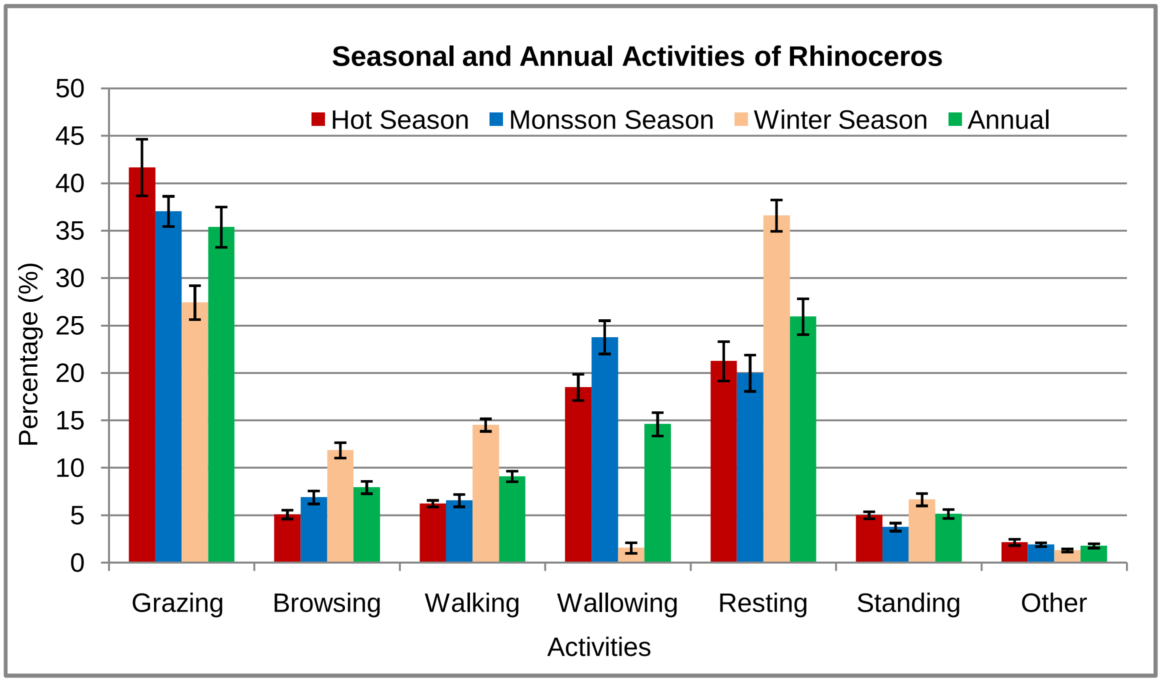


Fig. 4.2: Seasonal and annual activities of rhinoceros (in percentage) in Sauraha sector of CNP. Bars represent standard errors.

In seasonal context, various activities when compared in one way ANOVA tests were found highly significant in hot season ($F_{6, 63}$ = 80.58; p < 0.0001), monsoon season ($F_{6, 63}$ = 103.24; p < 0.0001) and winter season ($F_{6, 63}$ = 144.08; p < 0.0001).

4.3.2 Activity time budgeting

The time budgeting of 10 identified rhinoceros monitored from dawn to dusk (6 AM to 6 PM) in three seasons are plotted in one hour interval categories (Figs. 4.4 to 4.6).

In **grazing,** gradual increase in the activity have been noticed beyond 2 PM and reaches to its peak by 6 PM during hot and monsoon seasons. The grazing activity remains low after 9 AM to 2 PM when the ambient temperature stays higher. On

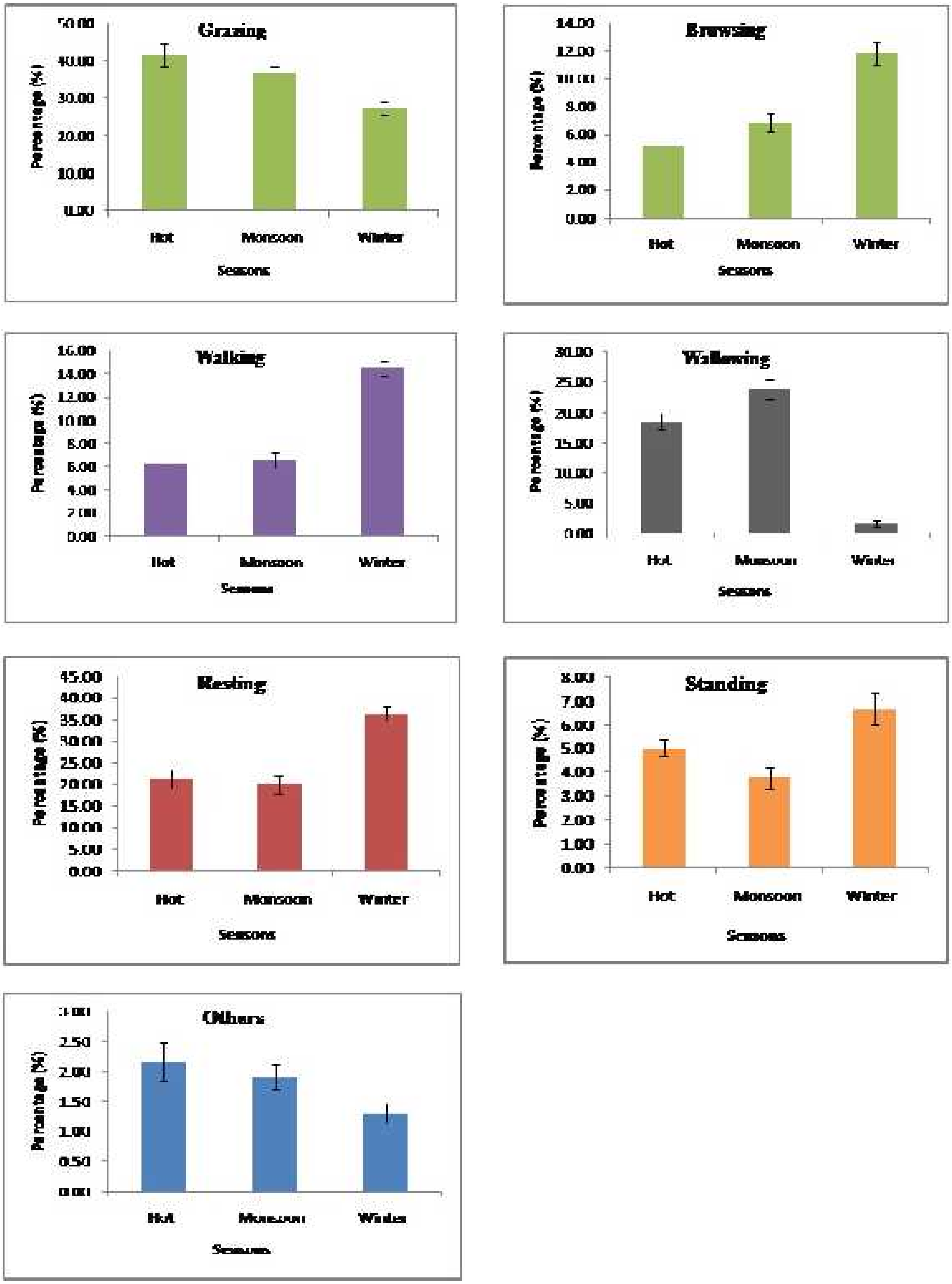


Fig. 4.3: Showing different activities of Rhinoceros (in percentage) separately. Bars represent standard errors.

contrary to the grazing, **browsing** do not show any prominent peak during hot and monsoon seasons. However, increased browsing activity has been observed during early morning which gradually decreases and maintain throughout the day in winter season.

The **walking** activity of rhinoceros did not show much variation in hot and monsoon seasons whereas during winter time between 7 to 9 AM, the activity showed greater enhancement.

The **wallowing** activity during hot and monsoon seasons showed greater prominence over winter season. In hot season, wallowing found to be remarkable higher between 11 AM to 4 PM whereas in monsoon an early shift have been noticed during morning hour 7 to 9 AM. Very little wallowing have been noticed during winter time however, occasional mid-sunny day wallowing have been observed.

The **resting** activity was prominent between 11 AM to 2 PM during hot season whereas its shift to early in the morning have been noticed during winter season. The **standing** and **other activities** did not show any specific patterns in all three seasons.

4.3.3 Food and feeding

For feeding activity, all 10 identified rhinoceros were followed for 518 hours i.e. 223 h in hot season, 159 h in monsoon and 136 h in winter season. The data is presented in Table 4.2 and depicted in the Fig. 4.7. During the process total 16774 bites were

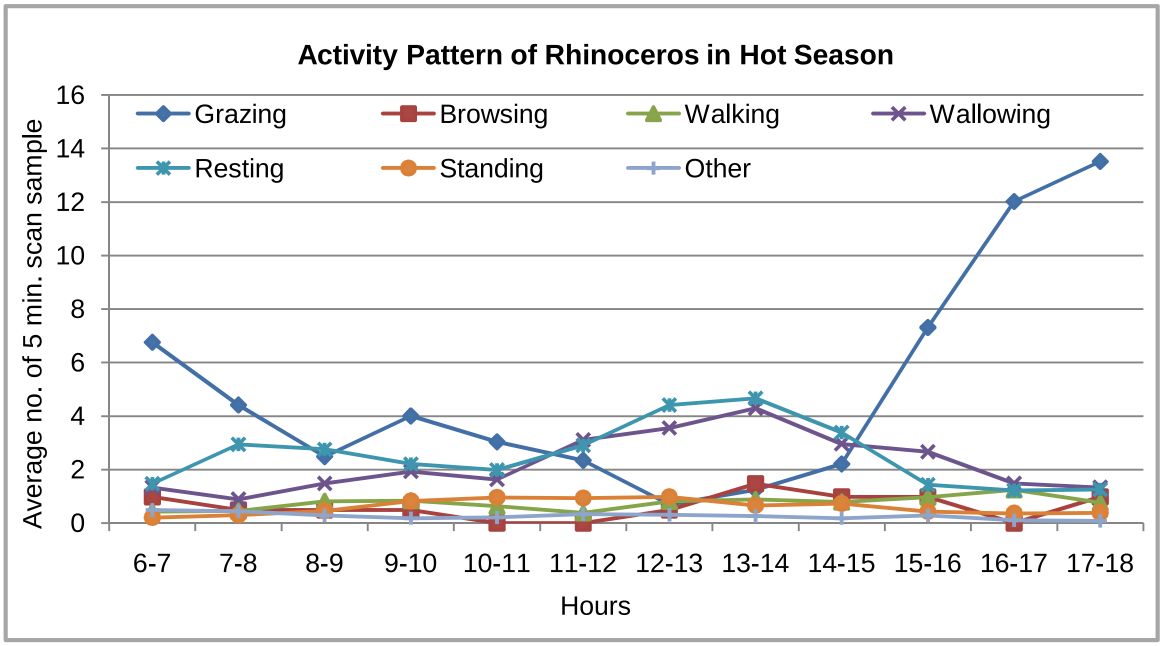


Fig. 4.4: Diurnal activity patterns of rhinoceros in hot season (based on twelve hours activity).

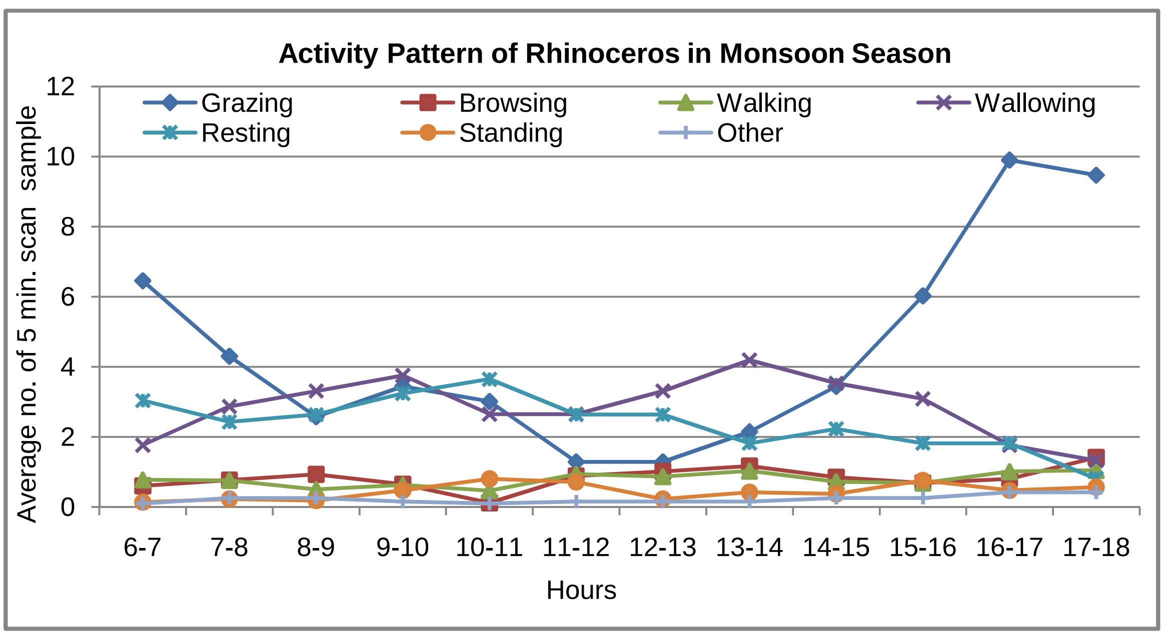


Fig. 4.5: Diurnal activity patterns of rhinoceros in monsoon season (based on twelve hours activity).

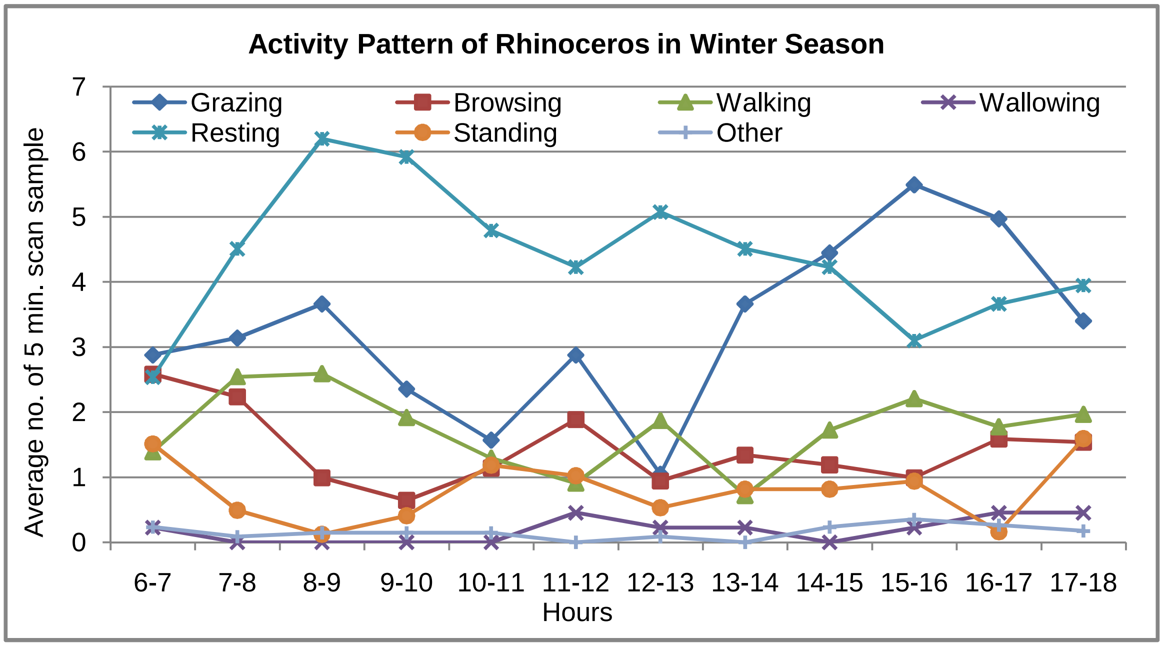


Fig. 4.6: Diurnal activity patterns of rhinoceros in winter season (based on twelve hours activity).

recorded during my two years study period from 2009 to 2011. This total bites recorded were distributed 6951 bites during hot season, 5974 bites in monsoon and 3849 bites in winter season (Table 4.2; Fig. 4.7) . The average bite rate per minute was higher i.e. 10.77 ± 0.31 in hot season followed by monsoon (10.22 ± 0.34) and 9.54 ± 0.27 in winter season. Variations of bite frequency in rhinoceros during different seasons were highly significant in different habitats types as revealed through one way ANOVA tests ($F_{3, 75} = 36.17$, $p < 0.0001$ in hot season; $F_{3, 76} = 54.09$, $p < 0.0001$ in monsoon season and $F_{2, 72} = 51.53$, $p < 0.0001$ in winter season).

Table 4.2: Bites records of rhinoceros in different habitats for different seasons (n = 10; observation hours = 518).

S.N.	Seasons	Obs. Hrs.	Habitat Types				Total
			Tall Grassland	Riverine Forest	Short Grassland	Aquatic Bodies	
1	Hot	223	4979 (71.63%)	1124 (16.17%)	791 (11.38%)	57 (0.82%)	**6951**
2	Monsoon	159	2197 (36.77%)	2455 (41.09%)	1314 (21.99%)	8 (0.14%)	**5974**
3	Winter	136	1743 (45.28%)	1930 (50.14%)	176 (4.57%)	0 (0.00%)	**3849**
Total		**518**	8919	5509	2281	65	**16774**

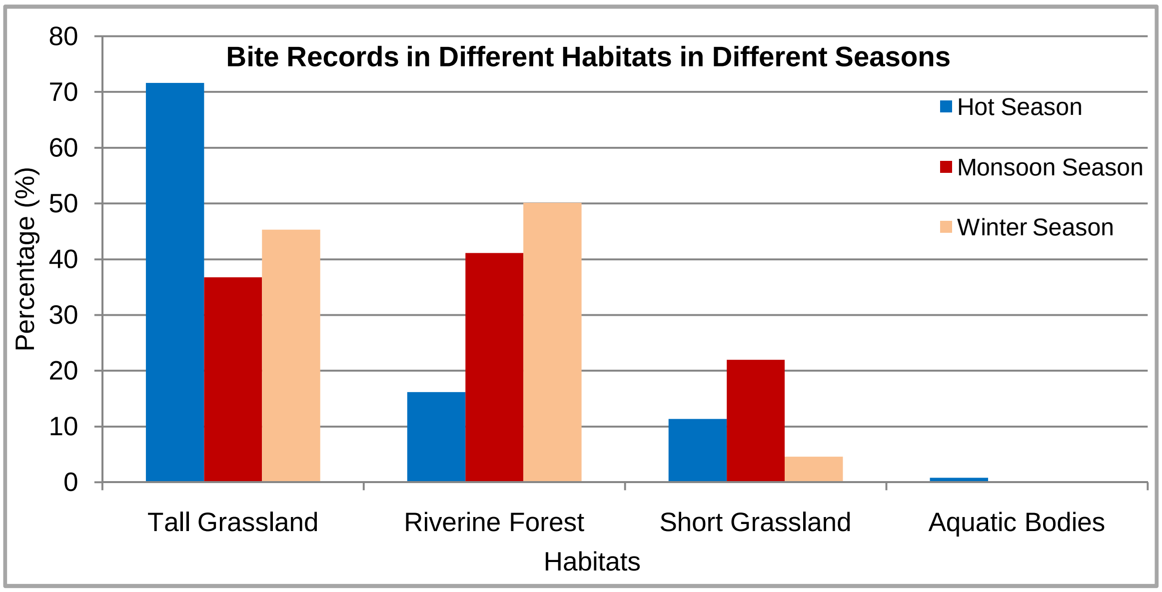


Fig. 4.7: Percentage of bites records in different habitats in different seasons.

The feeding study on plant consumption revealed utilization of 149 plant species belonging 57 families during the study period. Listing of all plant utilized by rhinoceros were compiled and placed in Appendix I. The plant species utilized by rhinoceros above one percent frequency is shown in the Table 4.3. From this Table it can be seen that out of 21 species, 5 were tall grasses, 7 short grasses, 4 shrubs, 2 trees, 2 aquatic plants and 1 herb (Table 4.3). In terms of frequency, most frequently eaten tall grass species were *Saccharam spontaneum* (19.14%) followed by *Narenga porphyrocoma* (4.97%), *Saccharum benghalensis* (4.43%), *Phragmites karka* (3.81%) and *Themeda villosa* (1.14%; Table 4.3).

The preference of short grass species varied from *Cynodon* dactylon (5.39%) followed by *Imperata cylindrica* (4.71%), *Eragrotis tenella* (4.63%), *Hemartheria compressa* (1.84%), *Paspalidium flavidum* (1.40%), *Chrysopogon aciculatus* (1.27%) and *Scleria laevis* (1.04%; Table 4.3). The preferred shrub species in order of the preference were *Callicarpa macrophylla* (4.35%), *Pogostemon benghalensis* (2.25%), *Coffea benghalensis* (2.12%) and *Colebrookea oppositifolia* (1.17%; Table 4.3). The two tree species preferred for their fruits and twigs are respectively *Trewia nudiflora* (1.68%) *and Litsea monopetala* (1.32%). In aquatic habitat, rhinoceros utilized two major plant species namely *Hydrilla verticillata* (1.84%) *and Vallisneria spiralis* (1.50%). The only preferred herb utilized in short grassland habitat was *Cassia tora* (1.01%; Table 4.3).

The distribution of the plant utilized by the rhinoceros according to represented floral families are shown in Table 4.4 and shown through Pie chart in Fig. 4.8. The six major families in order of their utilization preference were Graminae (n=2230; 57.74 %), Verbenaceae (n=249; 6.45%), Euphorbiaceae (n=141; 3.65%), Labiatae (n=139; 3.60%), Hydrocharitiaceae (n=129; 3.34%) and Leguminosae (n=122; 3.16%) constituted total 77.94% (Table 4.4). The remaining 22.06% food items fall in 51 families.

4.3.4 Seasonality of diet

On the basis of the total frequency of feeding species (n=149), rhinoceros utilized 95 species in monsoon season followed by 85 species in winter and 77 in hot season which revealed some dietary overlap in different seasons.

In hot season, total of 1435 feeding records were taken, the five major species constituting 47.17% were *Saccharum spontaneum* (305 i.e. 21.25%), *Narenga porphyrocoma* (146, i.e. 10.17%), *Imperata cylindrica* (97, i.e. 6.76%), *Cynodon dactylon* (84, i.e. 5.85%) and *Eragrotis tenella* (45, i.e. 3.14%).

During monsoon season, total records of feeding taken were 1306 constituted by 95 species. The five major species forming 43.5% were *Saccharum spontaneum* (237 i.e. 18.15%), *Cynodon dactylon* (115, i.e. 8.81%), *Eragrotis tenella* (94, i.e. 7.20%), *Saccharum benghalensis* (63, i.e. 4.82%) and *Hemartheria compressa* (59, i.e. 4.52%).

In winter season, total 1121 feeding records were taken that constituted composition of 88 species. The five major species constituting 48.71% were *Saccharum spontaneum* (197 i.e. 17.57%), *Callicarpa macrophyla* (123, i.e. 10.97%), *Saccharum benghalensis* (90, i.e. 8.03%), *Phragmatis karka* (69, i.e. 6.16%) and *Coffea benghalensis* (67, i.e. 5.98%) (Table 4.3).

The month-wise frequency of feeding records and their percentages is presented in Table 4.5 and depicted in Fig. 4.9. This reveals that active feeding period was in March, April and in the month of July.

Table 4.3: Feeding frequency of Rhinoceros on various plant species in three season (species included only n > 1% frequency level).

S.N.	Scientific Name	Type	H/S/T	Hot Season	Monsoon Season	Winter Season	Total	%
1	*Saccharam spontaneum*	Grazed	Tall Grass	305	237	197	739	19.14
2	*Cynodon dactylon*	Grazed	Short Grass	84	115	9	208	5.39
3	*Narenga porphyrocoma*	Grazed	Tall Grass	146	44	2	192	4.97
4	*Imperata cylindrica*	Grazed	Short Grass	97	36	49	182	4.71
5	*Eragrotis tenella*	Grazed	Short Grass	45	94	40	179	4.63
6	*Saccharum benghalensis*	Grazed	Tall Grass	18	63	90	171	4.43
7	*Callicarpa macrophylla*	Browse	Shrub	8	37	123	168	4.35
8	*Phragmites karka*	Grazed	Tall Grass	33	45	69	147	3.81
9	*Pogostemon benghalensis*	Browse	Shrub	19	17	51	87	2.25
10	*Coffea benghalensis*	Browse	Shrub	5	10	67	82	2.12
11	*Hemartheria compressa*	Grazed	Short Grass	8	59	4	71	1.84
12	*Hydrilla verticillata*	Browse	Aquatic Plant	16	55	0	71	1.84
13	*Trewia nudiflora*	Browse	Tree	2	57	6	65	1.68
14	*Vallisneria spiralis*	Browse	Aquatic Plant	18	40	0	58	1.50
15	*Paspalidium flavidum*	Grazed	Short Grass	12	26	16	54	1.40
16	*Litsea monopetala*	Browse	Tree	4	9	38	51	1.32
17	*Chrysopogon aciculatus*	Grazed	Short Grass	5	27	17	49	1.27
18	*Cassia tora*	Grazed	Herb	11	15	13	39	1.01
19	*Colebrookea oppositifolia*	Browse	Shrub	4	10	31	45	1.17
20	*Themeda villosa*	Grazed	Tall Grass	8	28	8	44	1.14
21	*Scleria laevis*	Grazed	Short Grass	6	9	25	40	1.04
22	Others species			581	273	266	1120	29.00
	Total			**1435**	**1306**	**1121**	**3862**	**100**

Note – H/S/T = Herb/Shrub/Tree

Table 4.4: Records of plant families more than one percent in feeding records of rhinoceros.

S.N.	Family	Feeding Frequency	No. of Species	% of Feeding Frequency
1	Graminae	2230	30	57.74
2	Verbenaceae	249	8	6.45
3	Euphorbiaceae	141	2	3.65
4	Labiatae	139	4	3.60
5	Hydrocharitiaceae	129	11	3.34
6	Leguminosae	122	7	3.16
7	Cyperaceae	89	4	2.30
8	Rubiaceae	84	2	2.18
9	Rutaceae	54	2	1.40
10	Compositae	51	4	1.32
11	Lauraceae	51	4	1.32
12	Solanaceae	47	4	1.22
13	Scrophulariaceae	39	2	1.01
14	Other families	437	65	11.32
Total		**3862**	**149**	**100.00**

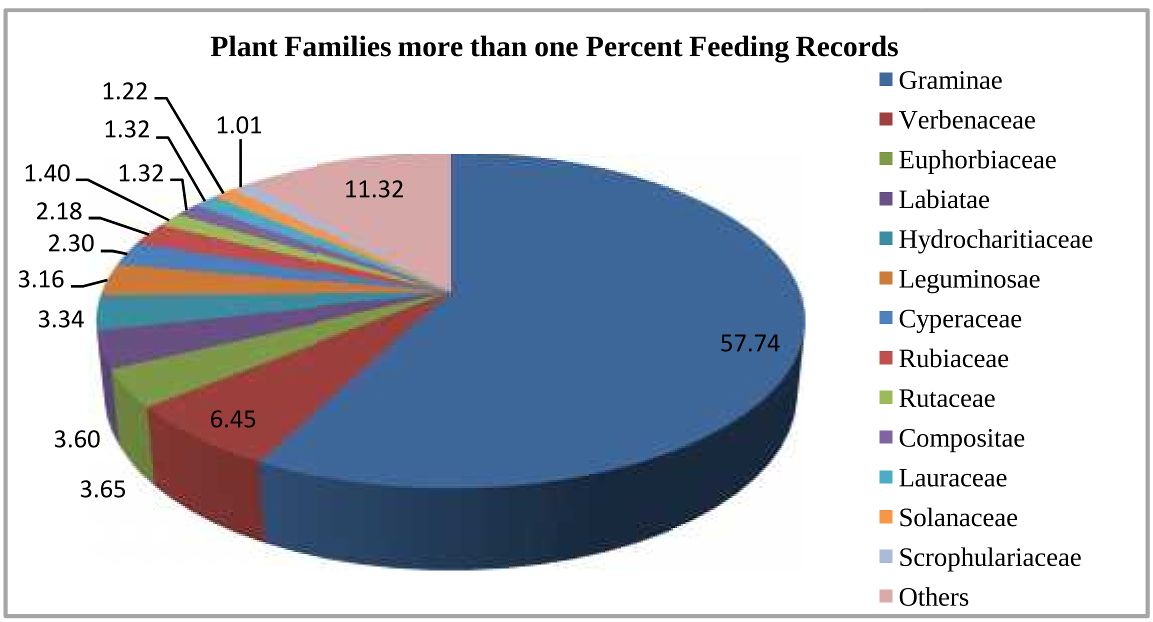


Fig. 4.8: Chart showing records of plant families more than one percent feeding records.

Table 4.5: Month-wise feeding records of rhinoceros in the study period 2009-2011.

S.N.	Months	No. of Feeding Rec.	% of Feeding Rec.
1	January	228	5.90
2	February	312	8.08
3	March	442	11.44
4	April	502	13.00
5	May	275	7.12
6	June	216	5.59
7	July	392	10.15
8	August	277	7.17
9	September	316	8.18
10	October	321	8.31
11	November	334	8.65
12	December	247	6.40
Total		**3862**	**100**

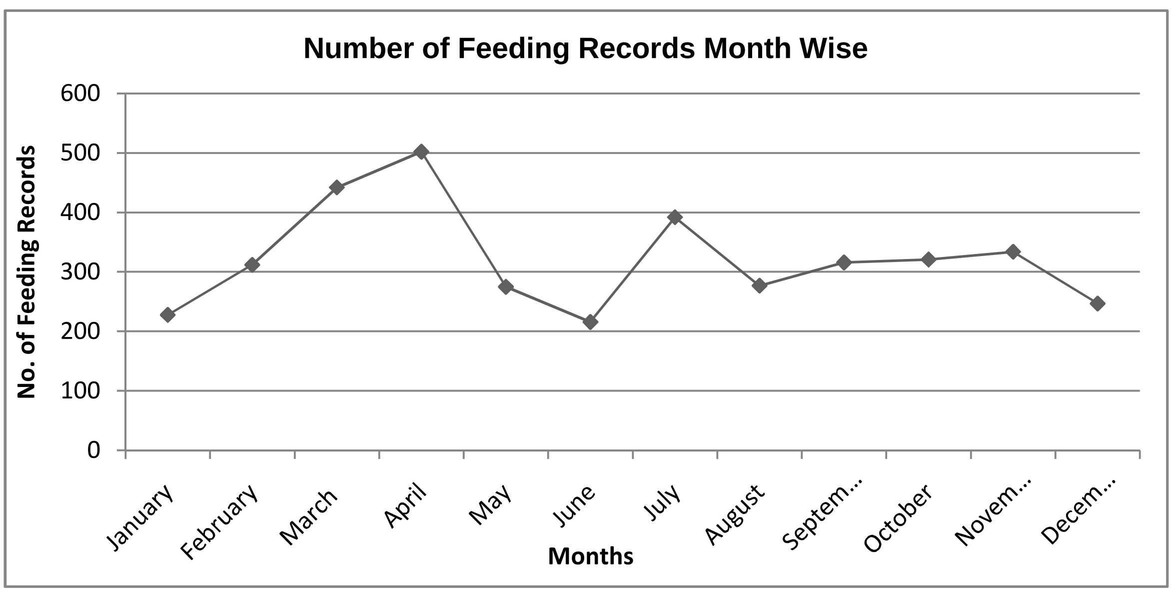


Fig. 4.9: Number of feeding records of Rhinoceros month-wise.

4.4 Discussion

The activity budgeting of rhinoceros is mainly dependent on factors like diet quality, distribution and abundance of food resources (Laurie, 1978; 1982). Spending of higher time (nearly 45%) on feeding activity by rhinoceros in the present study is in consonance with the study carried out by Hazarika and Saikia (2010) in Orang National Park, Assam, India where they have reported 46.2% time on feeding activity. The year-round observation carried out on 28 females in Chitwan National Park (CNP) revealed lower time spent (36%) on study carried out by Dinerstein (2003) whereas time spent by male on this activity was 28%. The lower time spent on feeding activity reported by Dinerstein (2003) might be due to taking diurnal and nocturnal time budgeting of rhinoceros in CNP whereas in present study this was limited to the day hours only.

Foraging in rhinoceros in the present study recorded spent of average time on grazing 35.39 ± 2.12% and browsing 7.96 ± 0.65%. Higher frequencies of grazing were noticed during hot and monsoon season while browsing was higher in winter season. The reporting of sharp bimodal time spent on grazing during hot/dry and monsoon season reported by Dinerstein (2003) is in agreement with the present study where morning and evening hour showed bimodal peaks with intervening resting period. The reporting of lower resting period (comfort) 8.01% compare to the present study average 25.95 ± 1.88% might be reflecting lower availability of food resources in Orang National Park Hazarika and Saikia (2010) compare to the Sauraha sector, CNP. This has bearing for higher movement of rhinoceros in Orang National Park in terms of activities such as vigilance (15.1%)

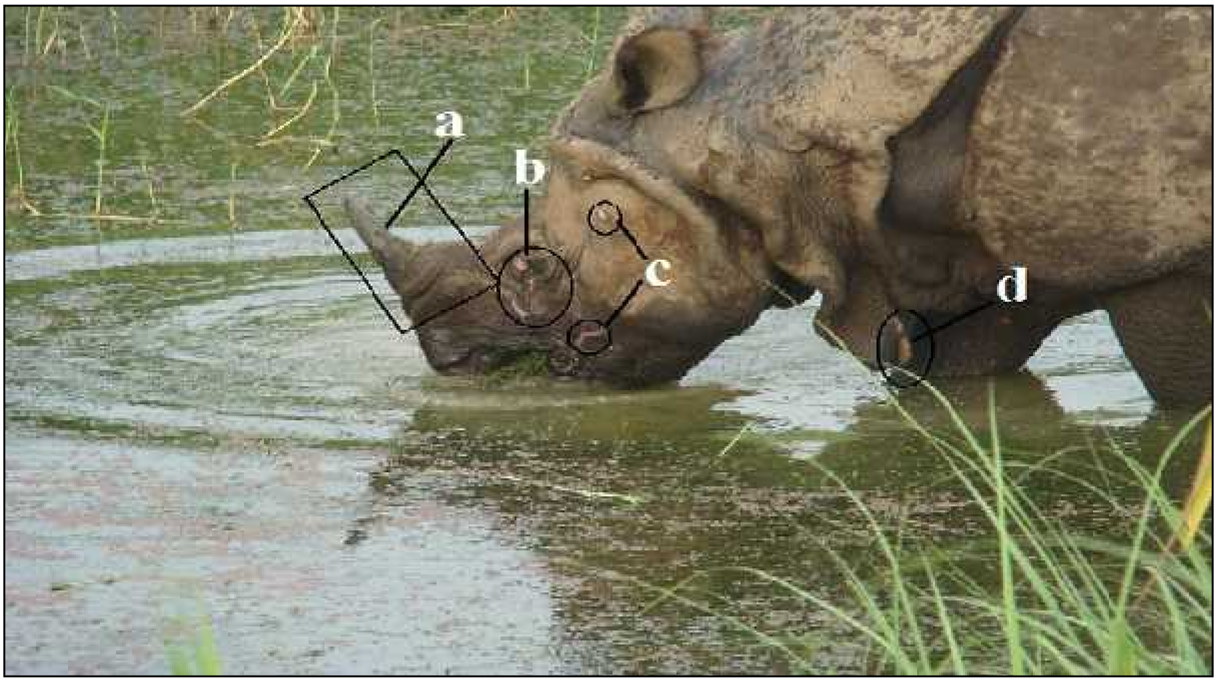
and locomotion (9.1%) totaling 24.2% in comparison to Sauraha sector where this is only 14.28% including walking and standing.

Wallowing with immersing body in water and rolling in mud is an important behavioral need of rhinoceros to dissipate heat stress and maintaining body temperature (Owen-Smith, 1988). Finding of this activity to an average frequency of 14.62 ± 1.23% is slightly lower than what has been reported by Hazarika and Saikia (2010) i.e. 18.41%. Location of Sauraha sector being more northern to the Orang National Park, Assam, India probably require more wallowing to dissipate heat stress of rhinoceros there. This is further evident through this study that wallowing frequency reduces in winter time substantially due to lowering of temperature. While doing the study on rhinoceros, Dinerstein (2003) recorded longest wallowing time during very humid monsoon period. The higher frequency wallowing in the present study also took place during monsoon season when greater humidity prevails. The other reasons for finding higher frequency of wallowing might be attributed to higher insect activity during the periods which force them to roll more in mud to avoid insect bites. The finding of Ghosh (1991) in Jaldapara Sanctuary, West Bengal, India supports this fact of wallowing to avoid ecto-parasites and flies. Hazarika and Saikia (2010) also reported that wallowing activity increases more than two folds during monsoon as compare to other seasons. They further reported that the wallowing activity in monsoon season in Orang National Park helps in avoiding exo-parasites like flies and ticks.

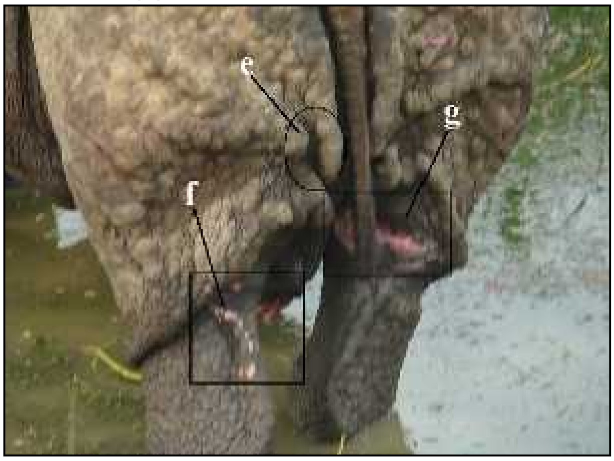
Owen-Smith (1988) distinguished two types of feeding activity in rhinoceros consisting of grazing on grass blades and browsing on twigs and pieces of leaves. He further reported that feeding time of megaherbivores are different for each sex, female generally feed for longer period. In my study in Sauraha sector listed record of feeding on 149 plant species which were higher than the records of 44 plants species listed by Jnawali (1995) was in Chitwan National Park. The present study which collected the feeding records through bite count also indicated higher records in tall grassland (8919 bites; 53.17%) followed by riverine forest (5509 bites; 32.84%) and short grassland (2281 bites; 13.6%) (Table 4.2). However, in seasonal context, in winter season riverine forest recorded higher bite records followed by tall grassland and short grassland. Laurie (1978) recorded utilization of 183 plant species belonging 57 botanical families in CNP. He further recorded presence of 50 species of grasses in the diet of rhinoceros constituting 70-89% in three different seasons. The utilization of 149 plant species in Sauraha sector though was lower than what has been reported by Laurie (1978) but on botanical families to which plant species belong was similar.

In Chitwan four grasses *(Saccharum spontaneum, Saccharum benghalensis, Cynodon dactylon,* and *Narenga porphyracoma*) and three browse plant species *(Coffea benghalensis, Murraya paniculata,* and *Litsea monopetala)* contributed more than 85% of the annual diet (Dinerstein, 2003). In comparison to this, Jnawali (1995) recorded five grass species (*Saccharum spontaneum, Arundo donax, Cynodon dactylon, Saccharum benghalensis* and *Erianthus ravennae)* and four browse species (*Mallotus phillippinensis*, *Dalbergia sissoo, Callicarpa macrophylla* and *Calamus tenuis*) accounted for nearly 75% of the annual diet in Bardia. The present study also on feeding frequency recorded *Saccharum spontaneum* as one of the most preferred plant species constituting highest percentage of utilization during all three seasons (hot, 21.25%; monsoon, 18.15% and winter, 17.57%). However, in Sauraha sector five major grass species *Saccharum spontaneum*, *Narenga porphyrocoma*, *Imperata cylindrica*, *Cynodon dactylon* and *Eragrotis tenella* utilized were during hot season; five major grass species *Saccharum spontaneum*, *Cynodon dactylon*, *Eragrotis tenella*, *Saccharum benghalensis* and *Hemartheria compressa* were used during monsoon and in winter five grass and shrub species utilized were *Saccharum spontaneum*, *Callicarpa macrophyla*, *Saccharum benghalensis*, *Phragmatis karka* and *Coffea benghalensis.* The most preferred 10 ranking food plants in the study of Hazarika and Saikia (2011) were very different and are composed through *Hemartheria compressa* (11.63%), *Hymenachne pseudointerrupta* (10.64%), *Leersia hexandra* (8.80%), *Arundo donax* (6.38%), *Chrysopogon aciculatus* (4.60%), *Phragmites karka* (4.42%), *Brachiaria ramose* (3.83%), *Cynodon dactylon* (2.11%), *Saccharum spontaneum* (2.05%) and *Imperata cylindrica* (1.98%). Though dietary spectrum of rhinoceros had different composition of food plant species but they prefer utilizing of habitats composed with tall, short and riverine habitats. Knowing the ranging of rhinoceros and its activities for moving, feeding and wallowing are useful to understand for the managers to plan and institute necessary protection strategies wherever poaching threats on them are eminent.

Reference ID: M2



a. Long and slender horn; Pink colors marking around left eye (b), on left chin (c) and on bib (d).



e. Vertical cut mark on the inner side of LLCF
f. Vertical pink color mark below LLCF
g. Presence of deep wound on LRCF

h. Pink color mark between two front legs

Plate 4.1: Identified adult male in Jay Mangala block showing identification features.

Identifying features

First date of sighting - 3.23.2009
First sighting location – Jay Mangala block; UTM 547523 / 3049789
Sex - Male
Age - Adult (20-24 yrs)
Calf position - No
Tail - Normal
Remarks – Presence of numerous pink color markings

Reference ID: M3

a. Long and slender horn
b. Cut mark on the tip of left ear

c, d, e and f. Cut marks on left and right LCF
g. Cut marks and wound on URCF

h, i and J. Cut marks on RRXF, flank and FRXF

k. Cut marks on LRXF

Plate 4.2: Identified adult male in Icharni Island block showing identification features.

Identifying features

First date of sighting - 3.29.2009

First sighting location – Icharni Island block; UTM 550018 / 3050317

Sex - Male

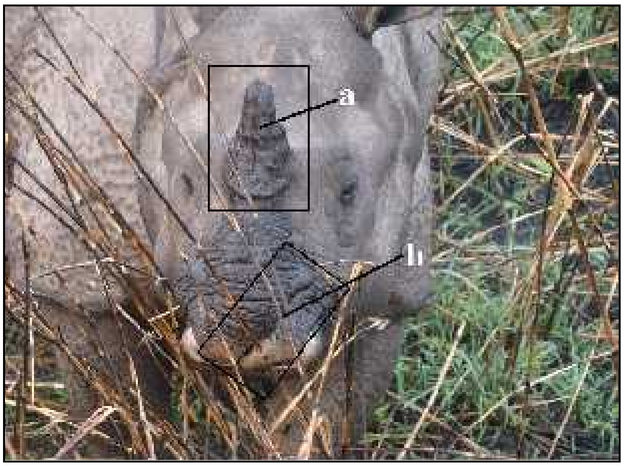
Age - Adult (25-30 yrs)

Calf position - No

Tail - Normal

Remarks – Long and slender horn; cut mark on the tip of left ear; numerous cut marks and wounds

Reference ID: F3



a. Vertical and circular ridges on horn
b. Obliquely bifurcated upper lip

c. Wound and cut marks on RLCF and ULCF
d. Clip mark on ULCF e. Hairs on both ears

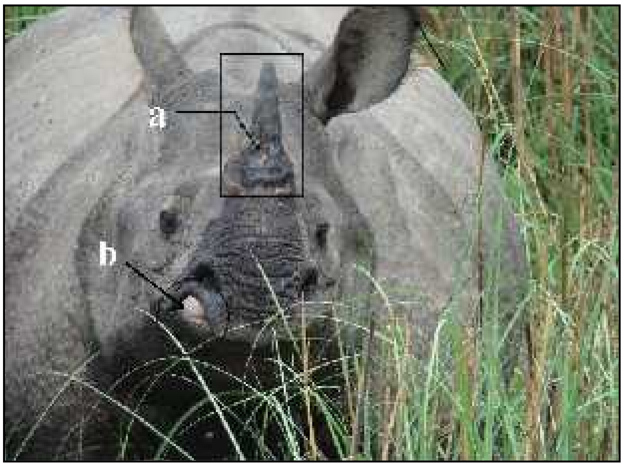
f. Moderate size horn g. Fleshy protruded mass on RRXF

Plate 4.3 Identified adult female in Icharni Island block showing identification features.

Identifying features

First date of sighting - 3.21.2009
First sighting location – Icharni Island block; UTM 549652 / 3049016
Sex - Female
Age - Adult (13- 15 yrs)
Calf position - Having < 6 months' female calf.
Tail - Normal
Remarks - Obliquely bifurcated upper lip.

Reference ID: F4



a. Vertical ridge on horn
b. Protruded white mass on lower right lip fold

c. Upper right corner fold is thicker
d. Presence of wound on lower left corner

e. Long hairy tip on both ears

f. Presence of wound on right flank

Plate 4.4: Identified adult female in Jay Mangala block showing identification features.

Identifying features

First date of sighting - 3.18.2009

First sighting location - Jay Mangala block; UTM 548207 / 3049928

Sex - Female

Age - Adult (16-19 yrs)

Calf position - Having male calf < 3.5 yrs.

Tail - Normal

Remarks - Protruded white mass on lower right lip.

CHAPTER 5

HOME RANGE, RANGING PATTERN AND HABITAT UTILIZATION OF RHINOCEROS IN SAURAHA SECTOR, CHITWAN NATIONAL PARK

Chapter 5

Home Range, Ranging Pattern and Habitat Utilization of Rhinoceros in Sauraha Sector, Chitwan National Park

5.1 Introduction

Habitat is the place where animal can persist suitably by utilizing resources such as food, water, shelter and environment (Goddard, 1967; Mukinya, 1973; Smith, 1974; Frame, 1980; Conway and Goodman, 1989; Berger and Cunningham, 1995) that can ensure avoidance of potential competition for maintaining population through reproduction (Caughley and Sinclair, 1994). The environmental conditions influences distribution of different vegetation types and maintain heterogeneousness among them in resource quantity and quality (Brahmachary *et al.*, 1971). Resource quantity and quality are not uniform in all habitats and variations appear within a season between habitats and within a habitat between seasons (Bell, 1971; Lahan and Sonowal, 1973; Debroy, 1986; Roy, 2009).

The spacing behavior and home ranges varies among different megaherbivores (Owen-Smith, 1988). The sizes of the home ranges are directly related to animal body size (Owen-Smith, 1988); in addition the social structures and behavioral pattern (Laurie, 1982; Schenkel and Hulliger, 1969) of the animal species also have some bearings on the home range sizes (Schoener, 1968; Turner *et al.*, 1969; Gittleman and Harvey, 1982; Lindstedt *et al.*, 1986; Kenward *et al.*, 2001; Jhala *et al.*, 2009). Besides this availability of food, forest quality, sex differences and metabolic requirements also influence the home range size in various species (Jennrich and Turner, 1969; Laurie, 1978; Harris *et al.*, 1990; Fjellstad and Steinheim, 1996; Hazarika, 2007). Habitats with abundant food, water and least disturbance for wildlife usually have small home range sizes (Williams, 2002). Natural barriers such as rivers, hills and unfavorable habitats often impose restrictions along with several other artificial barriers such as dams, canals, walls, fencing and agriculture settlements (Johnsingh *et al.,* 1990; Joshua and Johnsingh, 1995).

Analysis of habitat utilization pattern is an important aspect of wildlife conservation management ecology to draw a comprehensive conservation strategy relevant to any protected area (Dinerstein and Price, 1991; Jnawali and Wegge, 1991; Jethva, 2002). Roy *et al.* (1995) states that conservation of wildlife needs an entire knowledge of their spatial requirements commonly referred to as habitat. Habitat evaluation, an assessment of the suitability of land or water, for a particular species requires information on constraints pertaining to the biotic and abiotic components of the habitat, in particular the food, water and shelter (Kushwasha *et al.*, 2000). Increasing anthropogenic pressures on the habitat has an alarming impact and threatening to the majority of wildlife habitat around the world (Panwar, 1991). Rhinoceros are in critical demographic crisis; primarily by over-exploitation through poaching for its valuable horn and other products and secondarily by loss of habitat due to expanding and developing human settlements (Foose & Strien, 1997; Dinerstein, 2003). Preferred habitat is defined as that area of land or water where wild animals can satisfy their nutritional requirements well and found proportionately more often than other areas (Neu *et al.,* 1974; Dixon and Chapman, 1980; Byers *et al.*, 1984; Aebischer *et al.,* 1993). The conservation manager needs to know which habitat is most preferred by the rhinoceros when a decision has to be taken to enhance the habitat management.

The greater one horned rhinoceros prefer to inhabit in the alluvial floodplain vegetation of sub-tropical climate where water and green grasses are available all year round (Laurie, 1978). Annual monsoon floods altered the spatial distribution of these successional grasslands but maintained prime grazing habitat and high rhinoceros densities (Lehmkuhl, 1989; Jnawali, 1995; Dinerstein, 2003). For greater one horned rhinoceros, major threats are habitat loss, alteration and fragmentation (Sukumar, 1989; Amato *et al.*, 1995; Dierenfeld *et al.*, 2006). Increasing human population around the protected areas and their associated activities are disturbing factors to the preferred rhinoceros habitats in Sauraha and other parts of the CNP.

Habitat use and habitat utilization pattern of the greater one horned rhinoceros have been conducted by Laurie (1978), Dinerstein and Price (1991), Jnawali (1995) and Subedi (2012) in the *Terai* grasslands of Chitwan and Bardia National Park of Nepal. A number of studies in CNP were carried out by several researchers on the aspects of space and habitat use (Jnawali & Wegge, 1993), dry season habitat use (Fjellstad and Steinheim ,1996), habitat preferences, diet analysis and ranging behavior of reintroduced rhinoceros in Bardia National Park and Suklaphanta Wildlife Reserve, Nepal in comparison to the source population of CNP (Jnawali, 1995). The present study carried out from 2009 to 2011 aims at finding out home ranges, movement pattern and habitat utilization of rhinoceros in Sauraha sector of Chitwan National Park, Nepal for drawing comparison how these parameters have changed with time by increasing human population and pressures around the area ?

5.2 Methods

5.2.1 Data collection

The intensive study area of Sauraha sector, CNP was surveyed for collecting information on home ranges, movement patterns and habitat utilization of rhinoceros from April, 2009 to March, 2011. Ten identified individual rhinoceros mostly adult males and females with calf or without calf in various blocks of Sauraha sector were searched and on location their GPS coordinates were taken to overlay on classified map. Out of ten rhinoceros, five (M1, M2, M3, M4 and M5) were males and five other (F1, F2, F3, F4 and F5) were females. Among males, two (M1 and M2) were dominant, one old male (M3), two sub-dominant males (M4 and M5). Among females, F1, F3, F4 and F5 were adult females having calves attached and F2 was adult female without calf.

Systematic survey was conducted covering all 11 blocks of the study area of Sauraha sector, CNP. During the field visit whenever these 10 individuals were sighted, their GPS locations were registered and other additional information were recorded for two annual seasons. I used Garmin Etrex, GPS instrument for the purpose. The park staffs, field assistants and game scouts also helped me in collecting various information on rhinoceros location and recording other related information. All these data were entered in excel (XL) sheets for computing and further analysis. The details of the methods used for the estimation of home ranges, core areas utilization, overlapping areas, habitat utilization, habitat preference and movement pattern are as given below.

5.2.2 Habitat map generation

The study site was surveyed to classify the vegetation types and land-use pattern. Several GPS points were collected from different landscape elements (LSEs). For each GPS location, types of landscape element and degree of biotic pressure were also recorded.

For this study, geo-database of different layers of information has been generated from topomaps scaling 1:25000 taken by aerial photography in 1992 and field verification in 1994 (Survey Department of Government of Nepal, 1994). I used mainly two toposheets (Sheet no. 2784 06D, 07C) which almost covered the study area (Sauraha sector). Scan data of toposheets were geo-referenced and projected on Modified Universal Transverse Mercator (MUTM) format based on WGS 84 datum in one scene covering the study area and used as reference. I have selected the intensive study area of 77.1 km^2 covering the grassland patches of the Sal forest in the south and 500 m outlying area from the Khageri Khola in the north-west. This is the place of Sauraha sector where most of the rhinoceros populations inhabit.

I used the USGS Landsat Satellite image from the Earth Explorer (www.earthexplorer.com). The spatial resolution of these images (Row, 41 and Path, 141 & 142) were 30m×30m which is suitable for vegetation monitoring in such type of landscape. Mainly 142 path image was used which covers the whole intensive study area. Both the scenes were relatively cloud free and recent imagery. Acquisition date of the image is 23 November, 2015. I used the false color composite (FCC) corresponding to red (R), green (G) and blue (B) with band combination of 5, 4 and 3.

ERDAS IMAGINE 9.2 (Leica Geosystems) was used for image processing and ArcGIS 9.3 (Environmental Systems Research Institute, ESRI) for final map preparation. Using the shape-file for both core area and buffer zone boundary prepared by DNPWC was clipped to extract the study area.

The image was registered geometrically in ERDAS Imagine 9.2 using Ground Truthing Points (GTPs) collected from field visits. I used 125 random Ground Truthing Points which were taken at the time of data collection from various parts of the study area. From each Ground Truthing Point (GTP) location, major species of vegetation was recorded. Signature for different category of habitat was prepared with the help of Ground Truthing Points and final supervised classified map was prepared for the analysis of home range, habitat utilization and habitat preferences. Before doing classification, cultivated lands and built up areas were omitted out from the image to avoid misclassification. Habitat mapping and land cover classification were mainly based on previous literatures

(Stainton, 1972; Lehmkuhl, 1994: Champion and Seth, 1968). For the convenience of the data analysis, habitat of intensive study area was classified in to seven categories; riverine forest, Sal forest, tall grassland, short grassland, wooded grassland/scrub, water body and river bed. The vegetation habitat types with plant composition are illustrated greater details in Chapter 2.

I prepared the supervised classified image in ERDAS IMAGIME 9.2 and for the accuracy assessment of the image; I have generated 300 random location points and checked with reference points. They were verified after field visit during December, 2014. I checked all the points and compared with Kappa Coefficient value and 78.29 % accuracy was found.

5.2.3 Estimation of home ranges

Locations of individually identified rhinoceros were collected using Global Positioning System (GPS) along with date, time and related habitat information (Laurie, 1978; Bhattacharya, 1991; Dinerstein, 2003; Hazarika, 2007; Hazarika and Saikia, 2011). I used at least 1 to 5 locations per day for home range computation based on more than 250 m displacement. These locations were plotted on a prepared classified map of the study area and finally each individual rhinoceros was assessed for home ranges.

In this study, the two most common estimators were used, the Minimum Convex Polygon (MCP) (Mohr, 1947) and the Fixed Kernel Density Estimator (FKDE) (Worton, 1989; Silverman 1986). I used the Home Range Tools (HRT) software version 1.1 of the Home Range Extension (HRE) for ArcView GIS, 9.3 to calculate Minimum Convex Polygons (MCPs) and Fixed Kernel Density Estimations (FKDEs) (Rodgers *et al.,* 2007). I calculated using a fixed bivariate normal smoothing parameter that minimized the least squares cross validation score (Worton 1989, Kie *et al.*, 2010). The fixed kernel method gave area estimates with very little bias when least squares cross validation was used to select the smoothing parameter (Kernohan *et al.*, 2001). The cross-validated fixed kernel also gives surface estimates with the lowest error (Seaman & Powell, 1996).

The HRT tools automatically compute smoothing parameters (bandwidth) based on standardized or non-standardized data and directly estimated by least squares cross validation (LSCV) (Rodgers *et al.*, 2007). I used 95% and 50% isopleths for computing fixed kernel density estimations. I used one-way ANOVA to check for variation in seasonal home ranges of rhinoceros (Zar, 2010).

I have computed the **spatial overlapping** of each rhinoceros to the other in ArcGIS 9.3 using Clip Analysis Tools.

5.2.4 Estimation of core areas

The core areas were estimated as 50% cluster polygons using Fixed Kernel Density Estimator with 50 percent volume contours in previous studies (Dinerstein, 2003). I used the point of inflection to determine the core area with area probability curve by plotting percentage of the fixed kernel density at different contour levels against the kernel area. I calculated fixed kernel home ranges in each five percent interval contour from 95% to 40% for each individual rhinoceros. This inflection point determines the core area of the home ranges (Powell, 2000).

5.2.5 Analysis of habitat utilization pattern

To analyze the habitat utilization pattern of rhinoceros in the study area, ten focal rhinoceros were searched in all habitats in different seasons during the study period. All the sightings were recorded by handheld GPS (GARMIN, Etrex) in UTM from the possible place where rhinoceros were observed. In addition to this, activities of rhinoceros and the habitat types used were also recorded (Laurie, 1978; Jnawali, 1995; Hazarika, 2007; Hazarika and Saikia, 2011). Seasonal habitat use pattern was studied for individual rhinoceros to know how they use different habitat types in various seasons. The direct sighting locations data collected for each target animal was superimposed on the vegetation and the land use map. The use of a particular landscape element by each individual rhinoceros was analyzed by calculating the percentage of number of sightings in each landscape element used per different season and overall number of direct sighting locations. All analysis was carried out using computer software Arc GIS 9.3 using Spatial Analysis tool (extract values to points). Habitat selectivity of rhinoceros in the particular habitat was calculated by using the following formula-

$$\text{Habitat Selectivity} = \frac{\text{Total no. of rhino sighted in a particular habitat}}{\text{Total no. of sighting record of rhino in all habitats}} \times 100$$

5.2.6 Analysis of habitat preference

To estimate the habitat preference, the MCP home ranges were superimposed on the supervised classified vegetation and land use map of the intensive study area. The availability of habitat types within the home range was calculated by using Spatial Analysis Tool (extract by mask) in Arc GIS 9.3 from classified map. The used location points of particular rhinoceros for each season were extracted (using Spatial Analysis Tool; extract values to points) and the percentages of both habitat use and habitat availability were calculated.

Habitat preference in relation to seasonal and overall study period was estimated by Compositional Analysis in Resource Selection Program (Aebischer *et al.*, 1993). This program automatically ranked the habitat preference order in hierarchy from most preferred to less preferred or avoided. A consequence of the constraint is that an animal's avoidance of one habitat type will almost invariably lead to an apparent preference for other types, so the interpretation of absolute preference or avoidance of habitat types is not appropriate (Neu *et al.,* 1974, Byers *et al.,* 1984). A chi-square value obtained from the compositional analysis provided the significance of the result. Ivlev Electivity Index (Ivlev, 1961) was also used to ensure the habitat preference order.

5.2.7 Estimation of diurnal movement rate

GPS points were collected at every half hour interval by handheld GPS instruments during continuous observation periods of activity patterns simultaneously. These locations were generated in Arc GIS 9.3 and average distance travelled per day and hourly displacements were calculated therefrom.

5.3 Result

5.3.1 Home ranges

In total, 1774 GPS locations were recorded, out of which 998 for males and 776 for males. Annual and seasonal home range (Minimum Convex Polygon, MCP) and Fixed Kernel Density, FKD (95% & 50%) for individual rhinoceros were calculated and presented in Table 5.1.

Average annual home range, MCP of five adult male rhinoceros was 10.67 ± 0.92 km^2 and 5.46 ± 0.65 km^2 for five female rhinos. The average male home range during hot season was 9.91 ± 0.96 km^2, monsoon season 7.94 ± 0.74 km^2 and 6.45 ± 0.65 km^2 in winter season. Likewise, average female home range for hot season was 5.01 ± 0.64 km^2, 4.36 ± 0.46 km^2 for monsoon season and 3.69 ± 0.45 km^2 for winter season (Table 5.1).

Annual and seasonal Fixed Kernel Density, FKD (95% & 50%) for each rhinoceros was also calculated. Annual average 95% & 50% of FKD were 11.38 ± 1.20 / 3.09 ± 0.45 km^2 for male and 6.29 ± 0.68 / 1.66 ± 0.18 km^2 for female. FKD (95% & 50%) for males were 14.2 ± 1.78 / 4.05 ± 0.62 km^2 in hot season, 12.79 ± 0.99 / 3.61 ± 0.44 km^2 for monsoon season and 10.09 ± 1.33 / 2.71 ± 0.43 km^2 in winter season. Likewise, females FKD (95% & 50%) were 6.97 ±

0.93 / 1.80 ± 0.24 km^2 in hot season, 7.01 ± 0.98 / 1.91 ± 0.24 km^2 in monsoon season and 7.13 ± 1.48 / 1.80 ± 0.41 km^2 in winter season (Table 5.1).

The variations between male and female home range as well as seasonal variations were calculated from the estimated home ranges. The data result (in one way ANOVA test) showed that there was significant variation between home range of male and female ($F_{1, 38} = 18.99$; $p < 0.0001$). I calculated the significance of variation in seasonal home range for male and female but there was no significant seasonal variation ($F_{2, 27} = 1.315$; $p = 0.2849$). The following Figures (5.1 to 5.13) depicted the annual and seasonal home ranges, locations of ten rhinoceros and 95% and 50% fixed kernel density for individual rhinoceros in the study area.

Table 5.1: Annual and seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density,FKD (95% & 50%) of five males and five females Rhinoceros.

S.N.	ID	Annual				Hot Season				Monsoon Season				Winter Season			
		Location Points	MCP (Km²)	Kernel (Km²) 95%	Kernel (Km²) 50%	Location Points	MCP (Km²)	Kernel (Km²) 95%	Kernel (Km²) 50%	Location Points	MCP (Km²)	Kernel (Km²) 95%	Kernel (Km²) 50%	Location Points	MCP (Km²)	Kernel (Km²) 95%	Kernel (Km²) 50%
1	M1	248	17.80	17.57	4.29	96	15.89	20.43	5.83	80	14.11	21.65	5.63	72	11.58	15.64	4.01
2	M2	206	11.44	13.68	4.36	82	11.35	19.03	5.91	73	7.70	12.17	3.93	51	6.98	12.76	3.69
3	M3	188	9.92	10.73	3.00	81	8.95	12.01	3.40	59	7.71	13.02	4.23	48	5.88	10.17	2.90
4	M4	192	8.31	8.42	1.91	75	7.99	11.43	2.87	62	6.48	9.79	2.18	55	4.73	6.80	1.46
5	M5	164	5.87	6.52	1.88	70	5.38	8.08	2.24	55	3.68	7.32	2.09	39	3.08	5.06	1.48
Mean (Male)			10.67	11.38	3.09		9.91	14.20	4.05		7.94	12.79	3.61		6.45	10.09	2.71
S.D			2.06	2.67	1.01		2.14	3.98	1.39		1.64	2.22	0.98		1.44	2.98	0.95
S.E.			0.92	1.20	0.45		0.96	1.78	0.62		0.74	0.99	0.44		0.65	1.33	0.43
1	F1	133	4.68	4.75	1.15	52	3.92	4.28	0.88	47	4.06	7.07	1.92	34	3.04	6.77	1.53
2	F2	156	7.50	8.69	2.30	62	7.11	9.95	2.26	54	6.12	10.98	2.86	40	4.84	11.92	3.14
3	F3	173	6.90	7.38	1.84	75	6.38	8.74	2.34	57	4.83	7.08	1.91	41	4.94	9.48	2.54
4	F4	155	4.15	5.76	1.69	73	3.95	6.22	1.96	47	3.41	5.02	1.47	35	3.10	4.92	1.21
5	F5	159	4.08	4.85	1.32	62	3.68	5.67	1.56	53	3.40	4.92	1.37	44	2.51	2.55	0.59
Mean (Female)			5.46	6.29	1.66		5.01	6.97	1.80		4.36	7.01	1.91		3.69	7.13	1.80
S.D.			1.45	1.53	0.40		1.44	2.07	0.54		1.02	2.20	0.53		1.00	3.30	0.92
S.E.			0.65	0.68	0.18		0.64	0.93	0.24		0.46	0.98	0.24		0.45	1.48	0.41

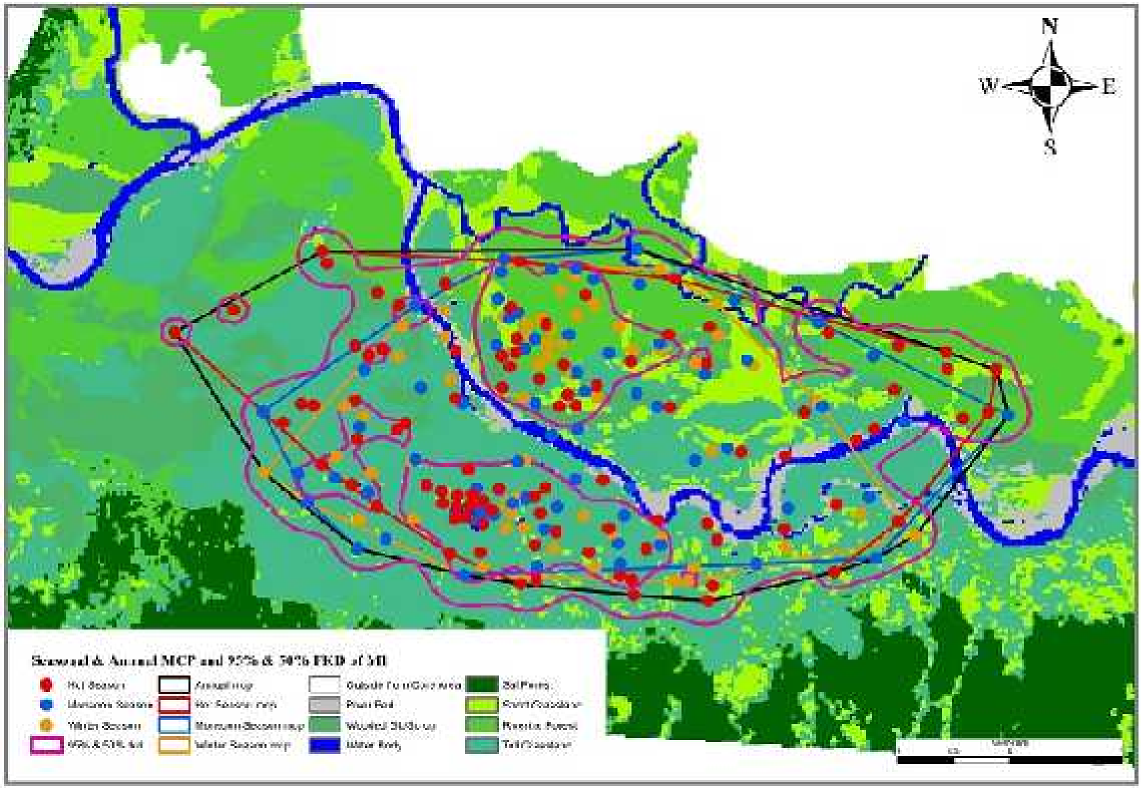


Fig.5.1: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M1.

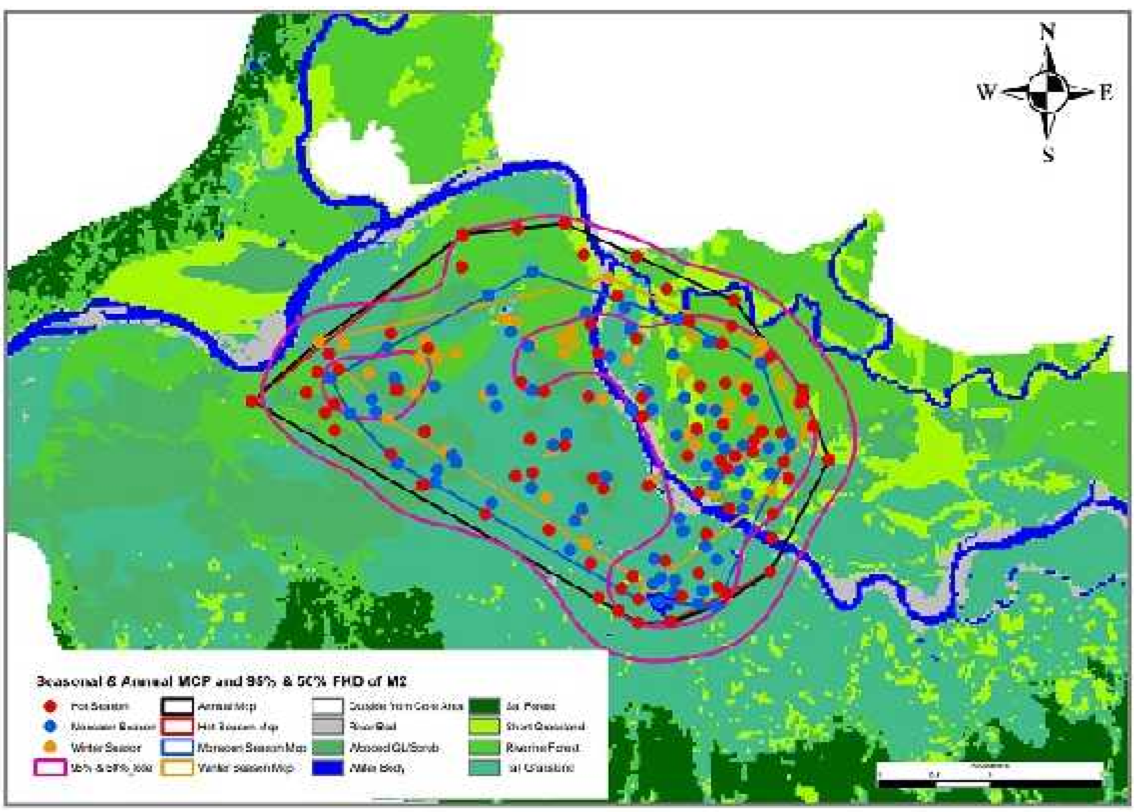


Fig.5.2: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M2.

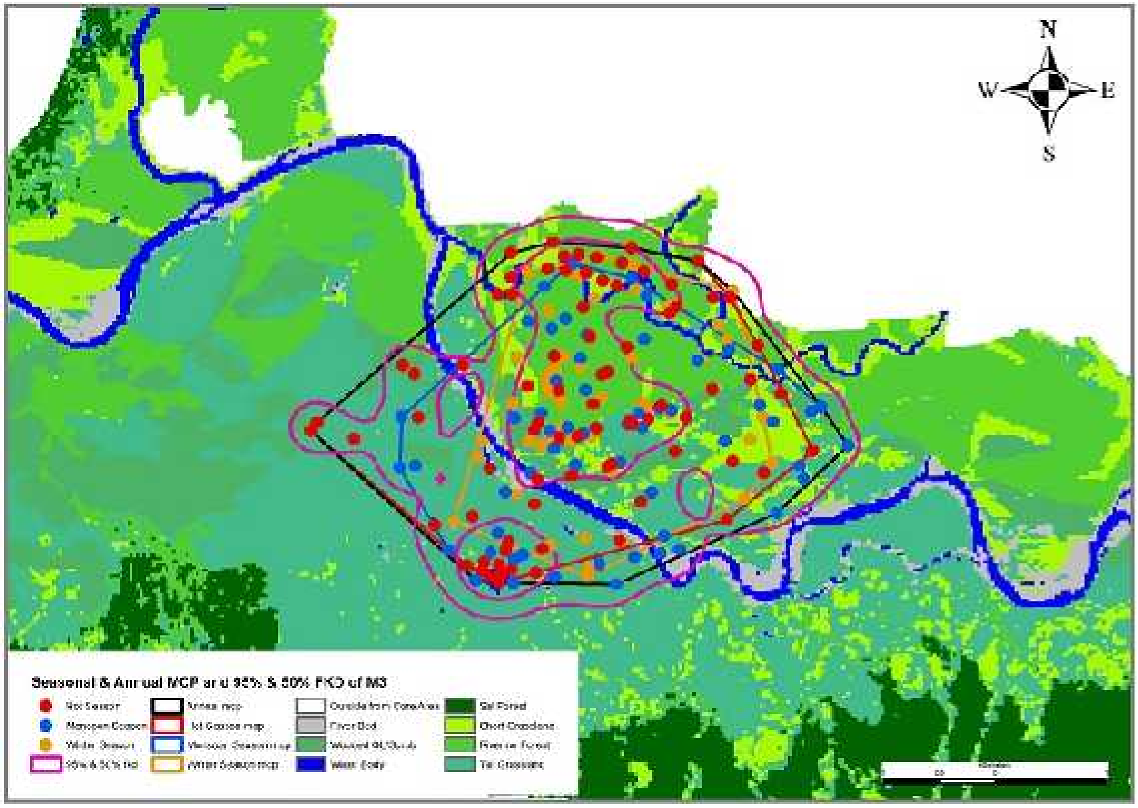


Fig.5.3: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M3.

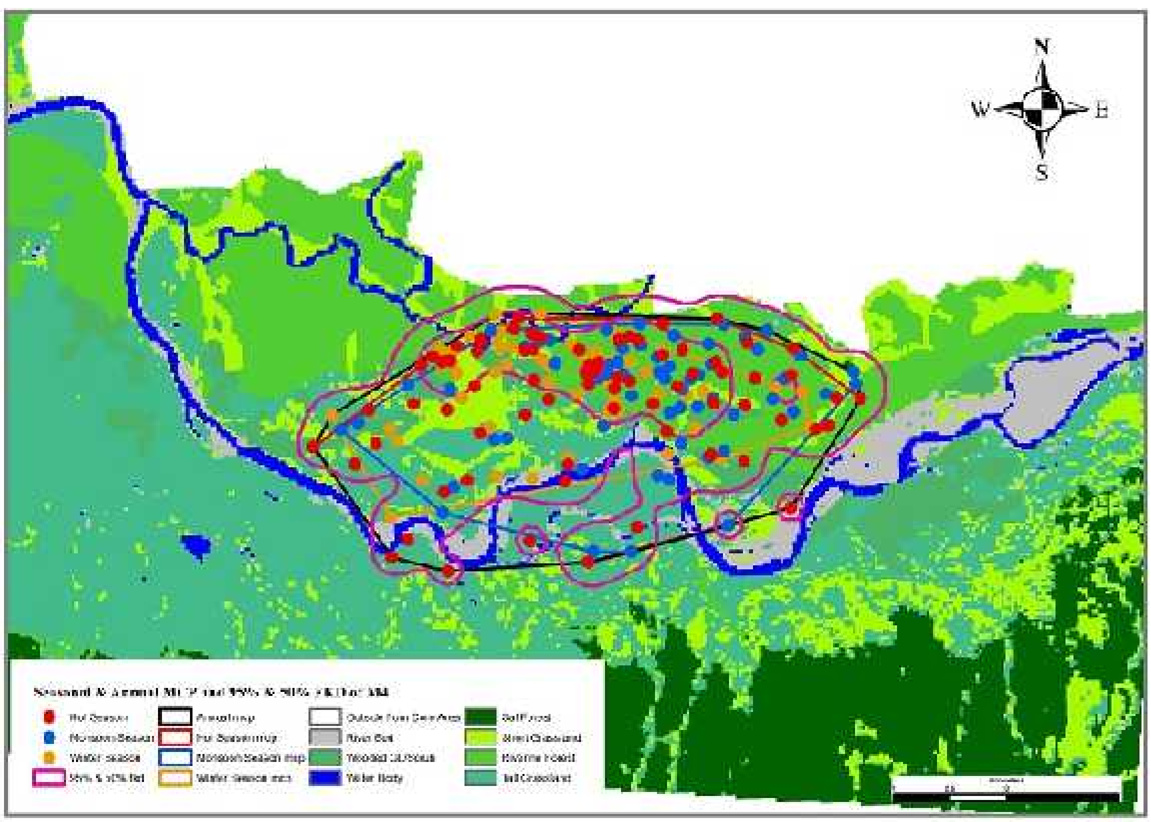


Fig.5.4: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M4.

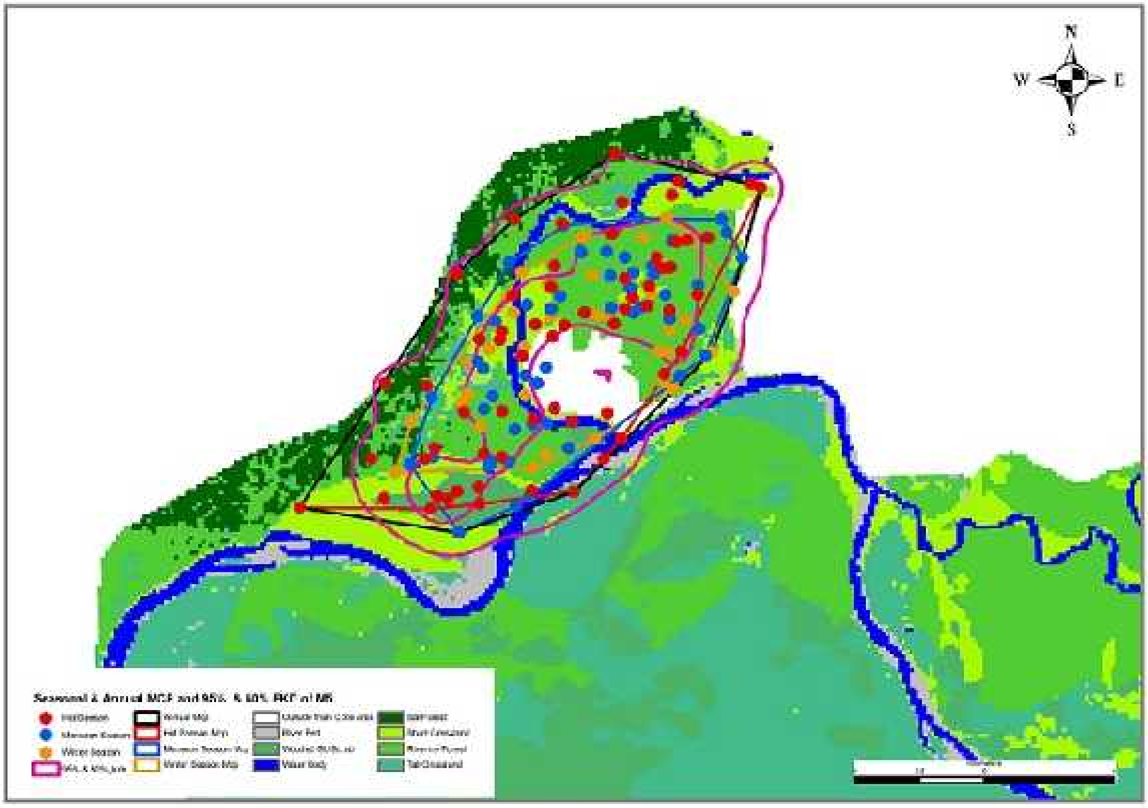


Fig.5.5: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M5.

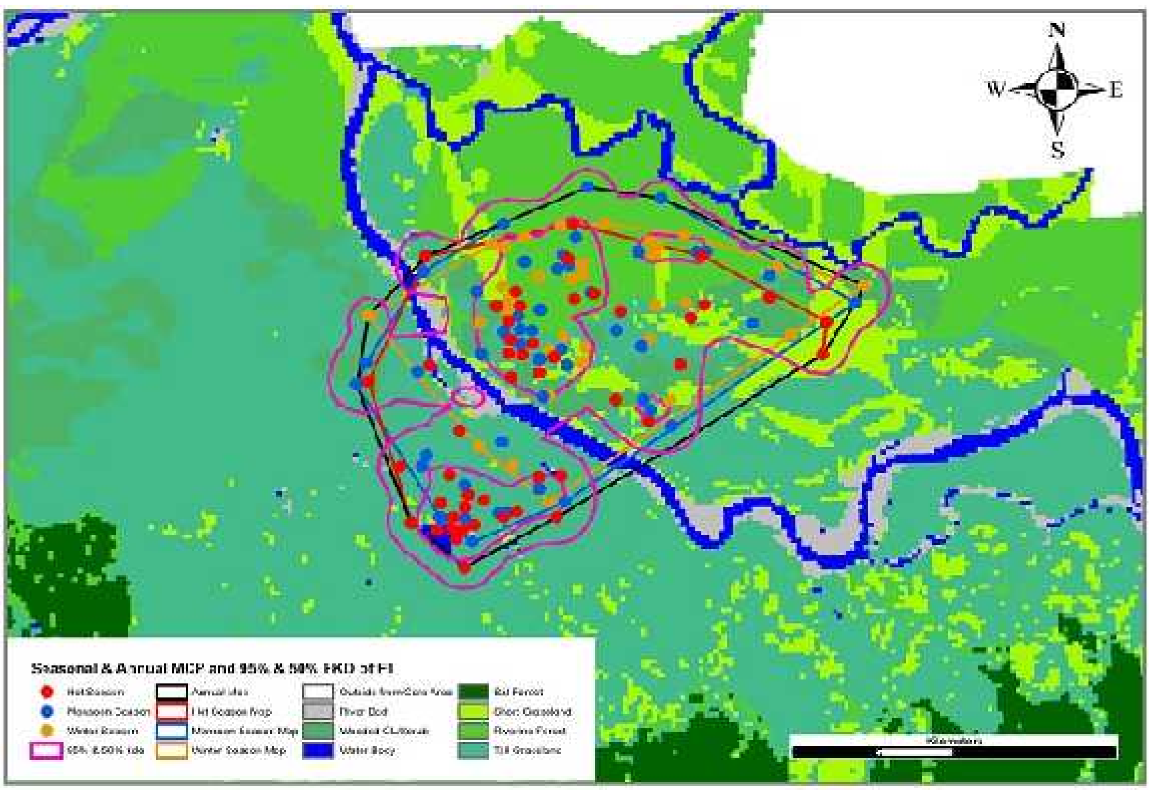


Fig.5.6: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F1.

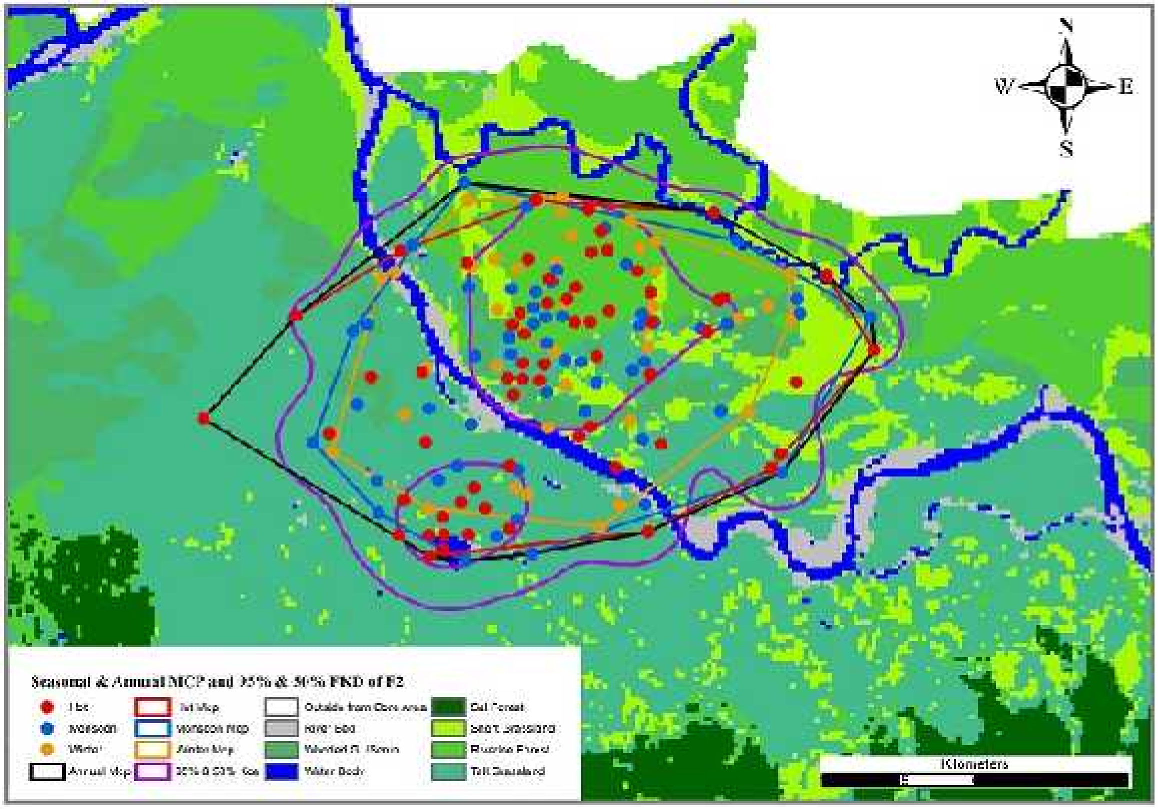


Fig.5.7: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F2.

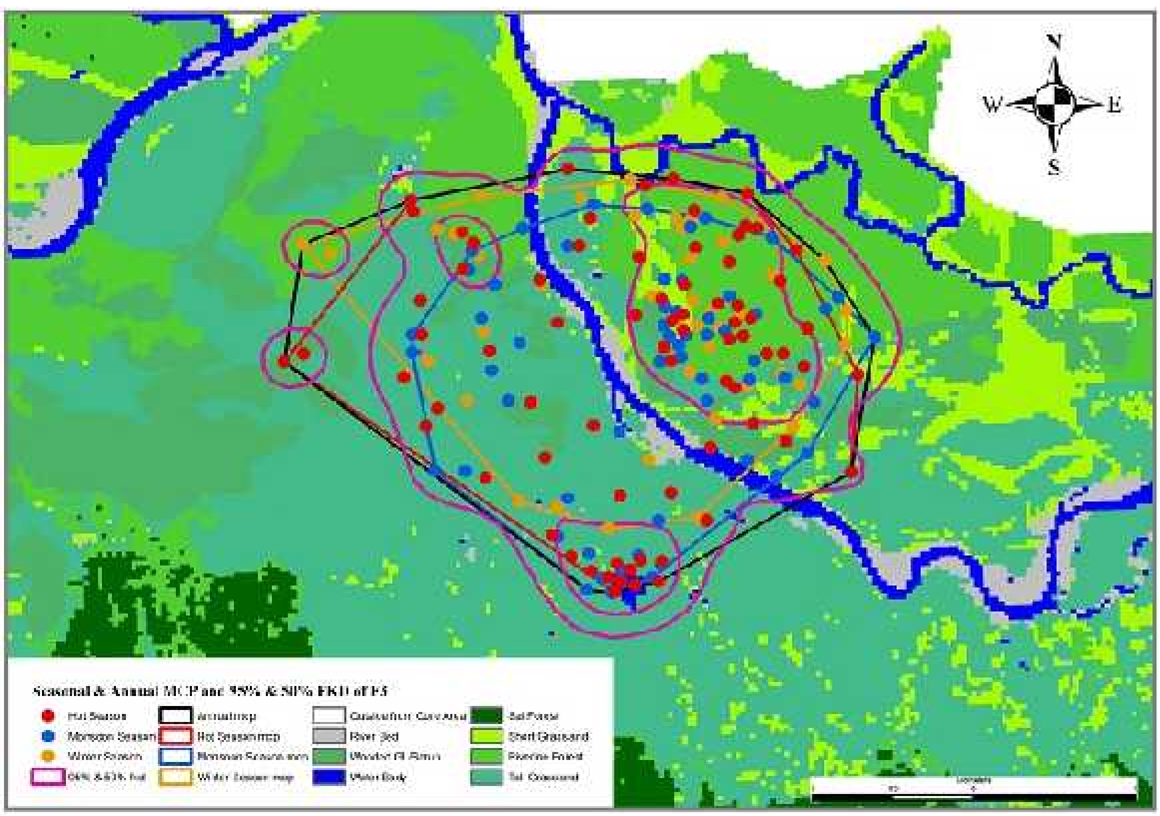


Fig.5.8: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F3.

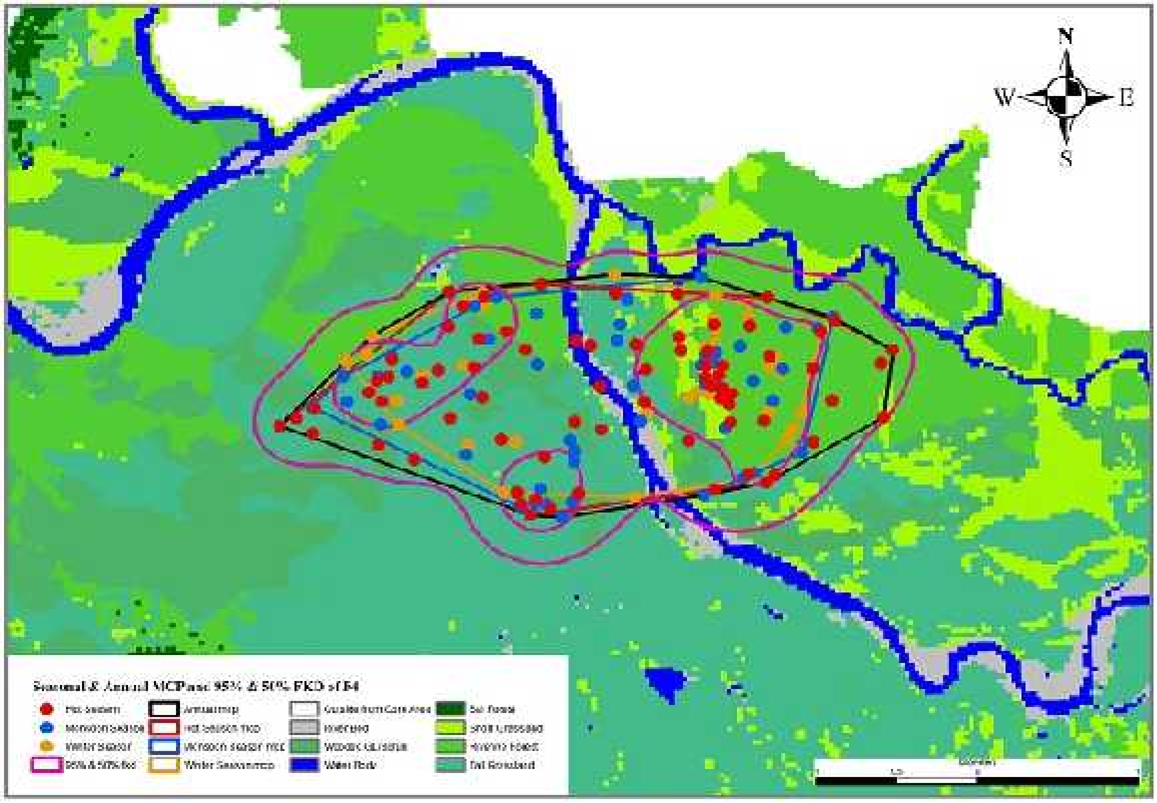


Fig.5.9: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F4.

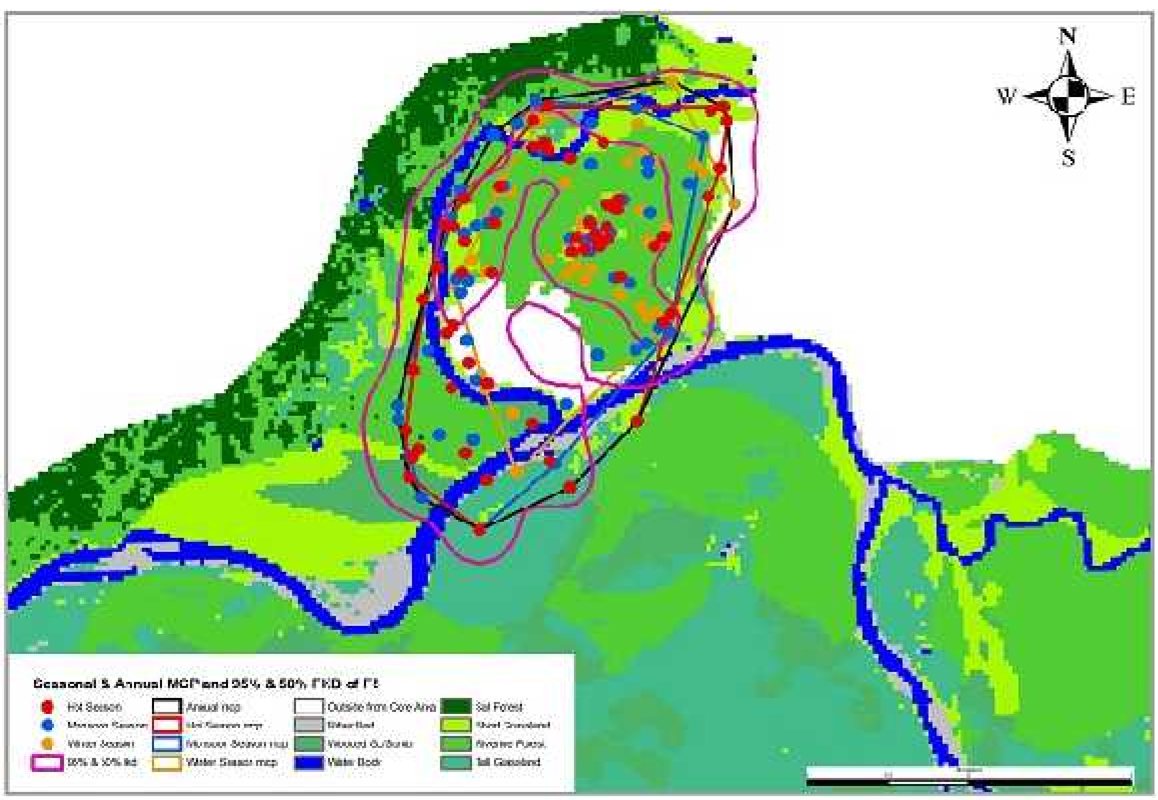


Fig.5.10: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F5.

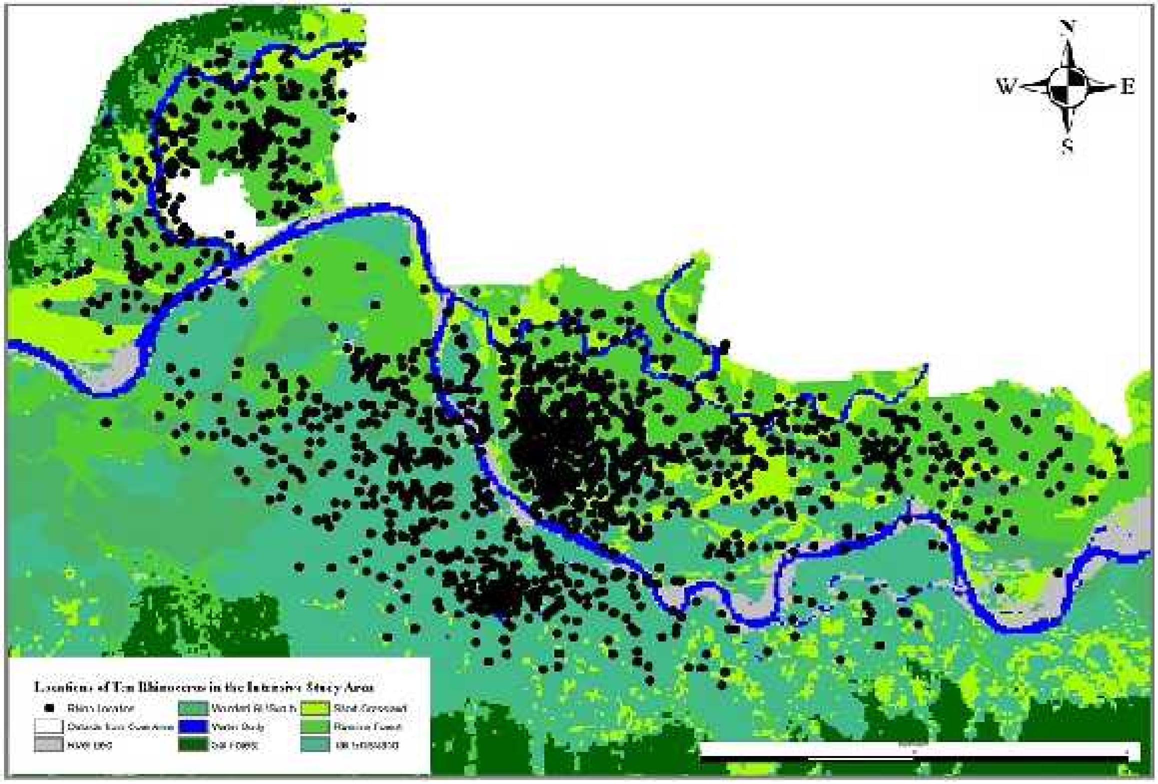


Fig.5.11: Locations of all ten rhinoceros in the intensive study area of Sauraha sector.

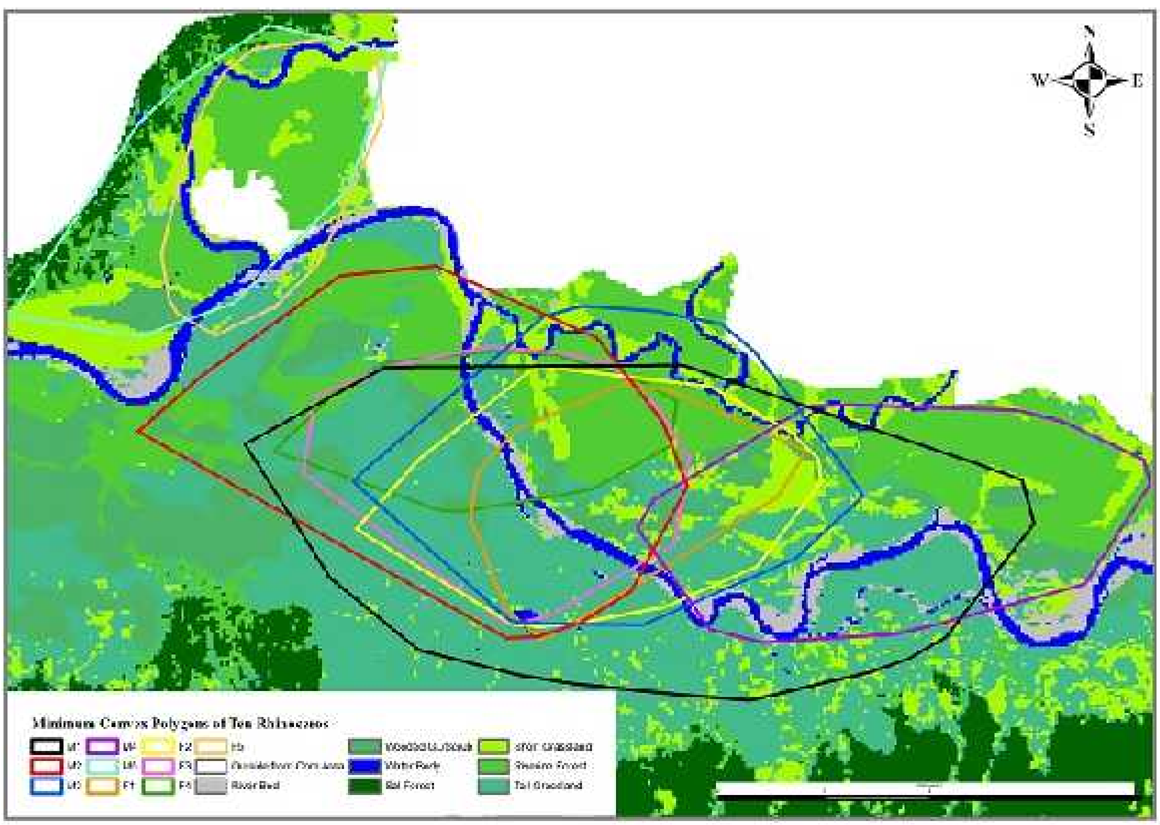


Fig.5.12: Annual Minimum Convex Polygons (MCP) of ten rhinoceros in the intensive study area of Sauraha sector.

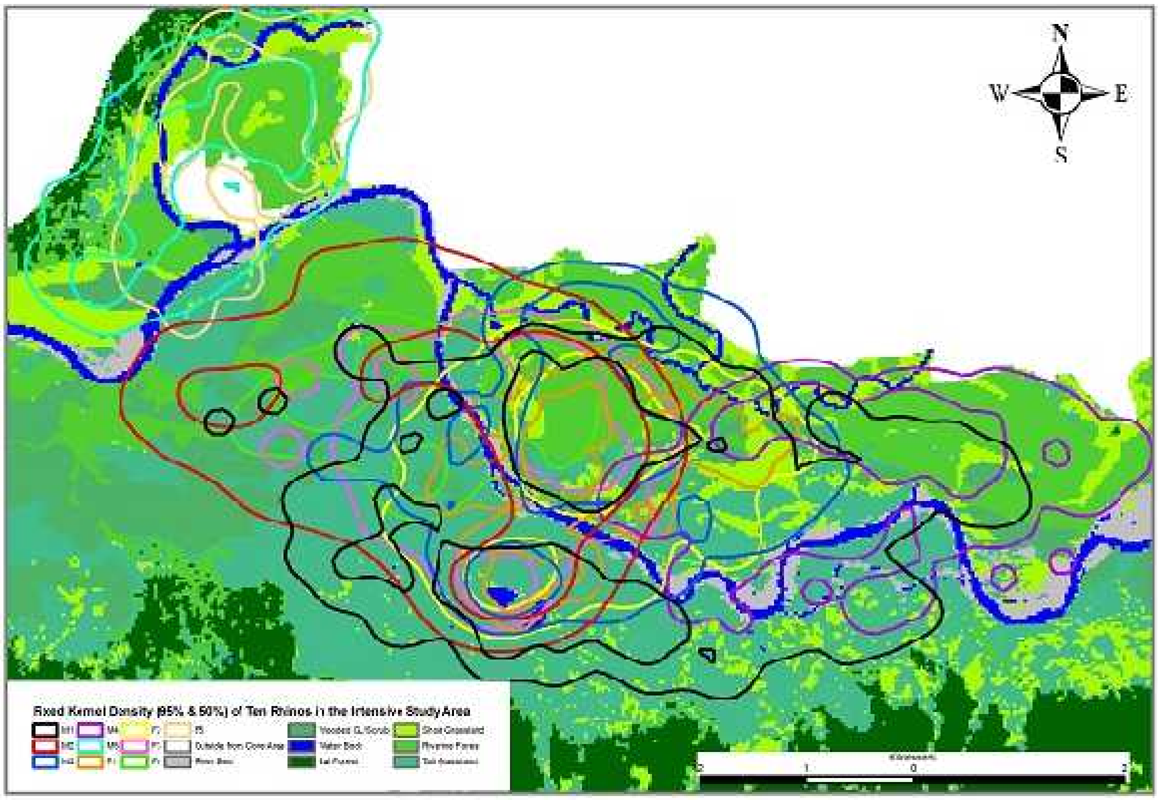


Fig.5.13: Fixed Kernel Densities, FKD (95% & 50%) of ten rhinoceros in the intensive study area of Sauraha sector.

5.3.2 Spatial overlapping of rhinoceros

It was recorded that the most dominant male, M1 of the study area recorded the largest areas (17.8 km^2) and griped four females of that area within its own territory. One male (M5) and one female (F5) had home ranges without any overlap with others except themselves. Data showed that three males (M1, M2 and M3) had also spatial overlapping (5.40 km^2) with each other (Fig. 5.14). The four females (F1, F2, F3 and F4) were found having overlapping areas (1.31 km^2) along east west axis of the study area (Fig. 5.15; Table 5.2). These three males and four females overlapped by an area of 1.28 km^2.

Table 5.2: Spatial overlaps (km²) in MCPs of ten rhinoceros in the study area of Sauraha sector.

Rhino ID	M1	M2	M3	M4	M5	F1	F2	F3	F4	F5
M1		7.84	8.68	5.93	0.00	4.68	7.50	6.63	3.94	0.00
M2	7.74		5.76	0.13	0.00	3.35	5.11	6.79	4.06	0.00
M3	8.68	5.76		2.15	0.00	4.64	7.20	5.43	3.00	0.00
M4	5.93	0.13	2.15		0.00	0.94	1.62	0.17	0.00	0.00
M5	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	3.54
F1	4.68	3.35	4.64	0.95	0.00		4.65	3.26	1.37	0.00
F2	7.50	5.11	7.20	1.62	0.00	4.65		4.93	2.37	0.00
F3	6.63	6.79	5.43	0.17	0.00	3.26	4.93		3.99	0.00
F4	3.94	4.06	3.00	0.00	0.00	1.37	2.37	3.99		0.00
F5	0.00	0.00	0.00	0.00	3.54	0.00	0.00	0.00	0.00	

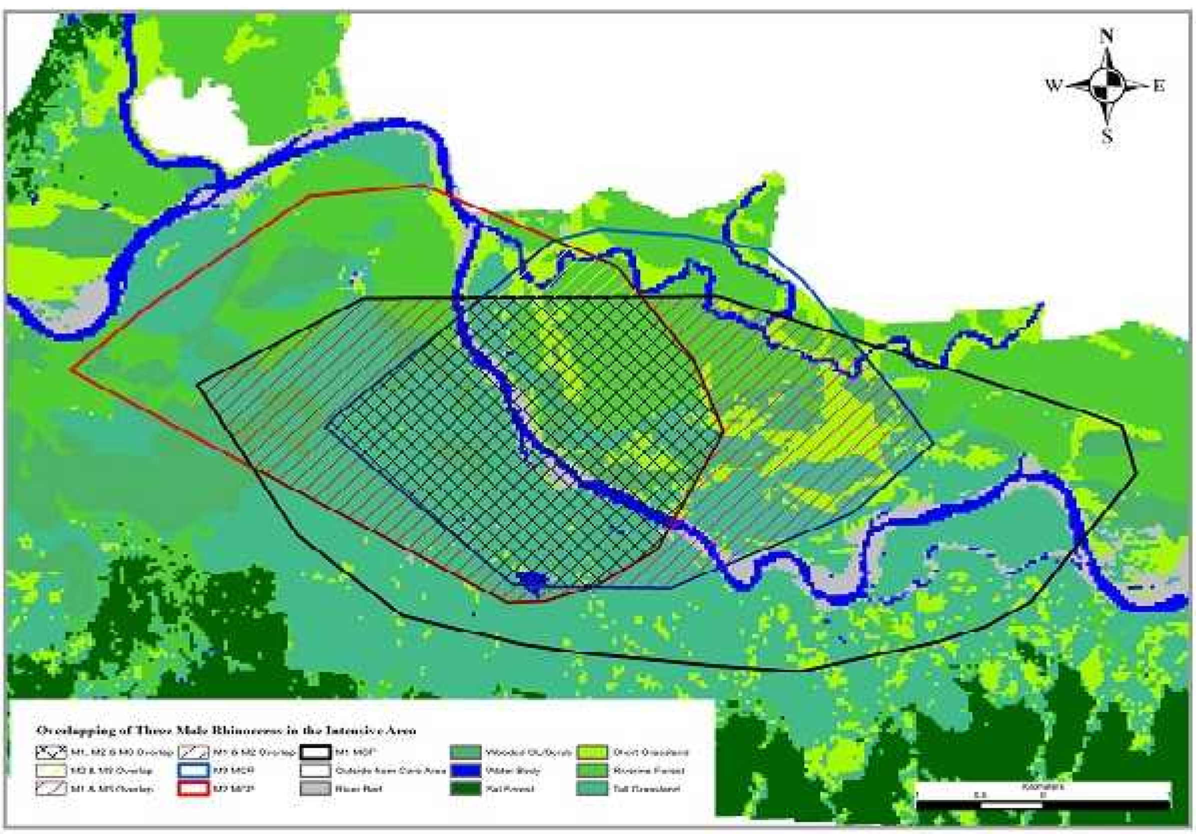


Fig.5.14: Spatial overlaps in MCPs of three male Rhinoceros in the study area.

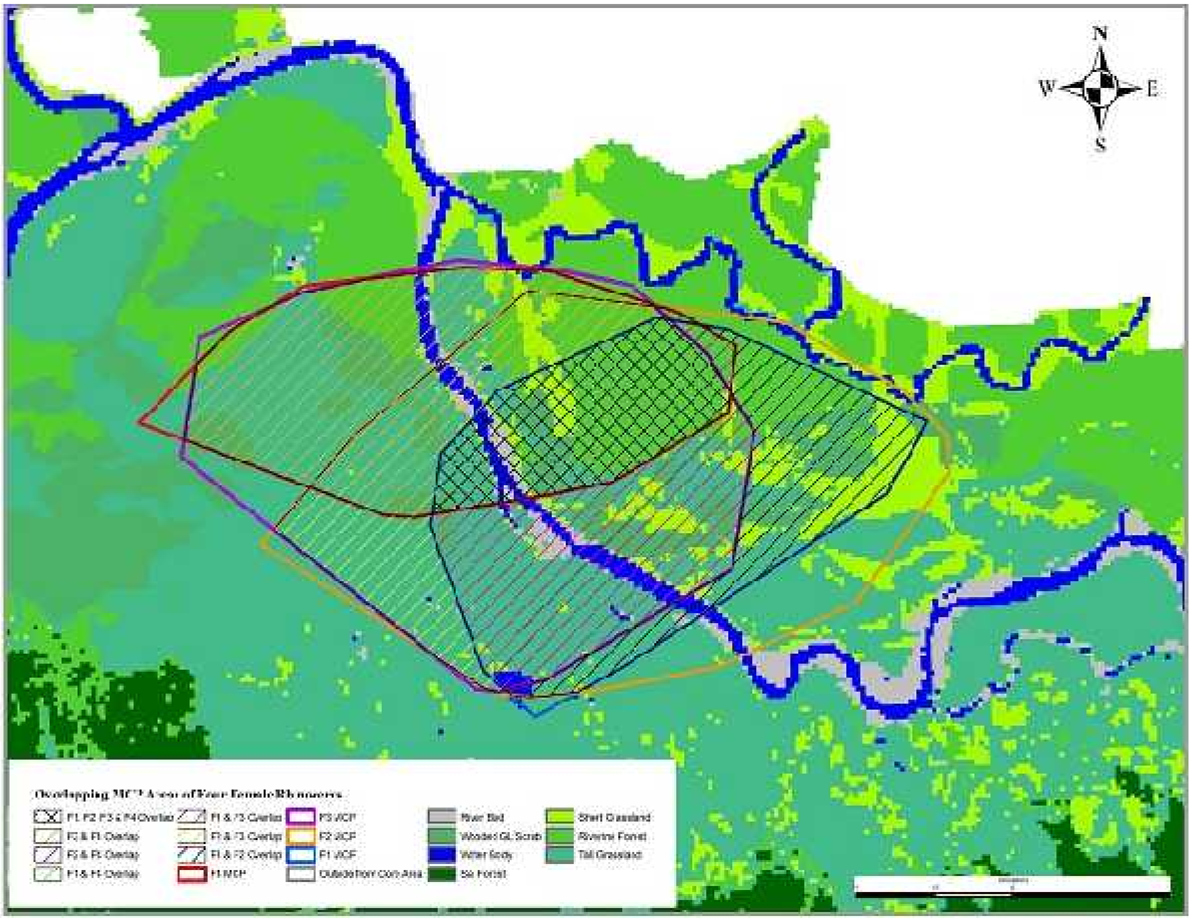


Fig.5.15: Showing overlapping areas of four female Rhinoceros in the study area of Sauraha sector.

5.3.3 Core areas

The point of inflection at 65% contour level (Fig. 5.16) and represented the core area of individual rhinoceros in Table 5.3. I have calculated the variation of annual core areas between male and female. There was no significant difference in core areas between males and females (in one way ANOVA, $F_{1, 8} = 5.07$, $p = 0.0544$).

Table 5.3: Fixed Kernel Density, FKD (km^2) in different percentage contour volumes (95% - 40%) of ten rhinoceros.

Rhino / Isopleth	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%
M1	17.57	14.34	12.39	10.72	9.46	8.48	6.92	5.97	5.19	4.29	3.65	3.03
M2	13.68	11.63	10.26	9.21	8.23	7.80	6.58	5.82	5.08	4.36	3.76	3.14
M3	10.73	9.05	7.93	6.84	6.06	5.30	4.68	4.04	3.51	3.00	2.59	2.09
M4	8.42	6.80	5.66	4.88	4.20	3.56	3.11	2.66	2.27	1.91	1.56	1.34
M5	6.52	5.35	4.59	3.95	3.49	3.12	2.74	2.44	2.09	1.88	1.59	1.39
F1	4.75	3.89	3.36	2.93	2.55	2.19	1.82	1.60	1.38	1.15	1.00	0.83
F2	8.69	7.27	6.28	5.40	4.78	4.09	3.59	3.11	2.64	2.30	1.96	1.58
F3	7.38	6.56	5.24	4.52	3.99	3.42	3.02	2.54	2.19	1.84	1.57	1.28
F4	5.76	4.84	4.24	3.77	3.34	3.00	2.54	2.27	2.02	1.69	1.44	1.23
F5	4.85	4.06	3.48	3.09	2.65	2.29	2.03	1.78	1.52	1.32	1.12	0.93

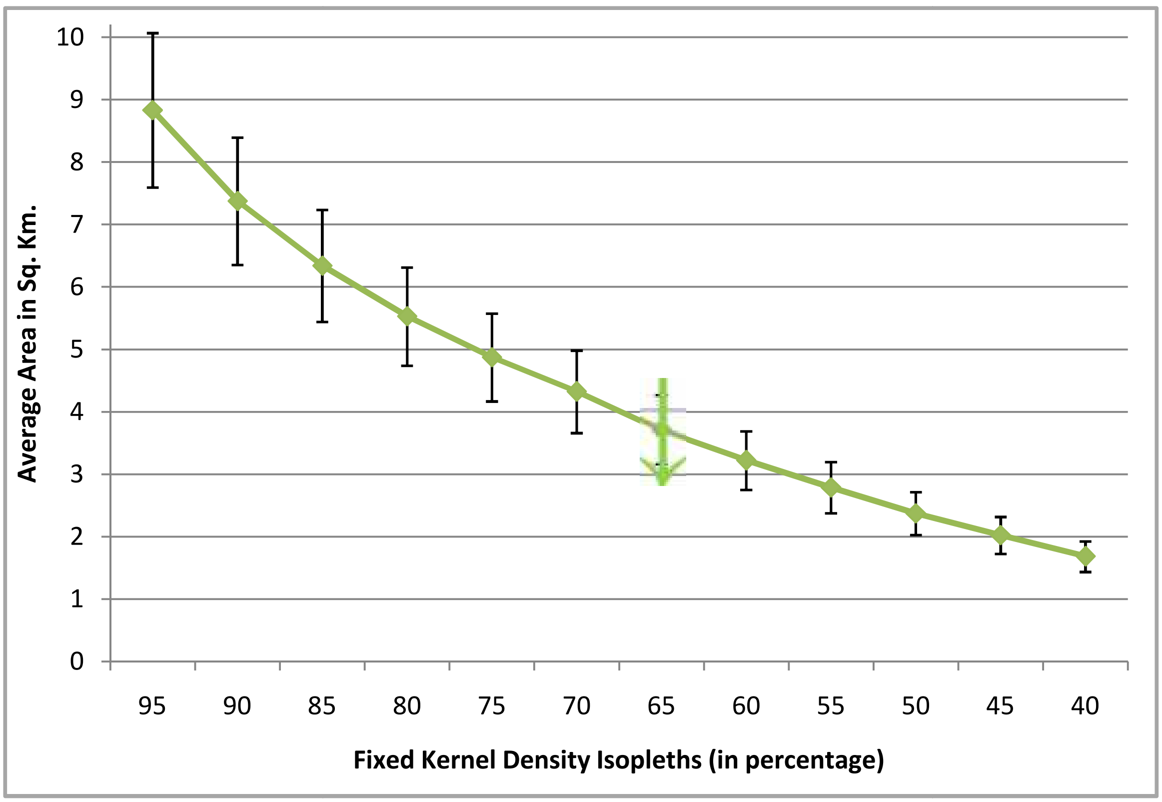


Fig.5.16: Average Fixed Kernel Density Isopleths area of ten rhinoceros showing point of inflection (arrow) in different percentage (95%-40%) contour level.

5.3.4 Habitat utilization pattern

In order to test whether the identified rhinoceros were using habitat types in proportion to their availability, I used a Chi-square test following Neu *et al.,* (1974). It was found that the various habitat types used by rhinoceros differed significantly from the available habitat types.

In **hot season**, rhinoceros used tall grassland habitat, short grassland and water body more extensively in comparison to the other habitat. They avoided or less preferred wooded grassland/scrub, river bed and Sal forest (χ^2 = 76.32, d.f. = 6, $p < 0.0001$). During **monsoon season**, rhinoceros most utilized tall grassland, riverine forest, short grassland and water body than the availability, and less utilized wooded grassland/scrub, river bed and Sal forest (χ^2 = 20.70, d.f. = 6, $p < 0.01$). Likewise, in **winter season**, they mostly utilized riverine forest, short grassland and tall grassland and less utilized wooded grassland/scrub, water body, Sal forest and river bed (χ^2 = 71.39, d.f. = 6, $p < 0.0001$).

On cumulative terms, rhinoceros mostly utilized riverine forest, tall grassland and short grassland in comparison to other habitats and less utilized water body, wooded grassland/scrub, Sal forest and river bed (χ^2 = 54.42, d.f. = 6, $p < 0.0001$).

5.3.5 Habitat preference

The classified habitat map of intensive study area of Sauraha sector covering an area of 77.1 Km^2 was categorized in seven different habitat types which were utilized by 10 identified rhinoceros. Out of which tall grassland covers the largest area (30.47%) followed by Sal forest (20.10%), riverine forest (19.76%), short grassland (12.39%), wooded grassland/scrub (9.61%), water body (3.85%) and river bed (3.82%) (Table 5.4).

Table 5.4: Area (km^2) and percentage of habitat types in the study area of Sauraha sector in CNP.

S.N.	Habitat Type	Square Kilometer	Percent (%)
1	River Bed	2.94	3.82
2	Wooded GL/Scrub	7.41	9.61
3	Water Body	2.97	3.85
4	Sal Forest	15.50	20.10
5	Short Grassland	9.56	12.39
6	Riverine Forest	15.24	19.76
7	Tall Grassland	23.49	30.47
Total		77.10	100.00

Result of compositional analysis showed that the rhinoceros exhibited preferences for certain habitats (χ^2 = 36.58, d.f. = 6, P < 0.0001). The order of annual habitat preference in the intensive study area being riverine forest > short grassland > tall grassland > water body > wooded grassland/scrub > Sal forest > river bed.

During the hot season rhinoceros were found to have a preference for tall grassland (χ^2 = 19.43, d.f. = 6, P < 0.05). The order of habitat preference being tall grassland > short grassland > riverine forest > water body > wooded grassland/scrub > river bed > Sal forest.

The order of habitat preference by rhinoceros during monsoon season in the study area (χ^2 = 32.41, d.f. = 6, P < 0.0001) was tall grassland > riverine forest > short grassland > water body > wooded grassland/scrub > river bed > Sal forest.

Habitat preference order for rhinoceros for winter season (χ^2 = 22.68, d.f. = 6, P < 0.001) was riverine forest > short grassland > tall grassland > wooded grassland/scrub > water body > river bed > Sal forest.

The Ivlev's Electivity Index analysis presented in Fig. 5.17 conferred identical results of habitat preferences as determined by compositional analysis for the intensive study area.

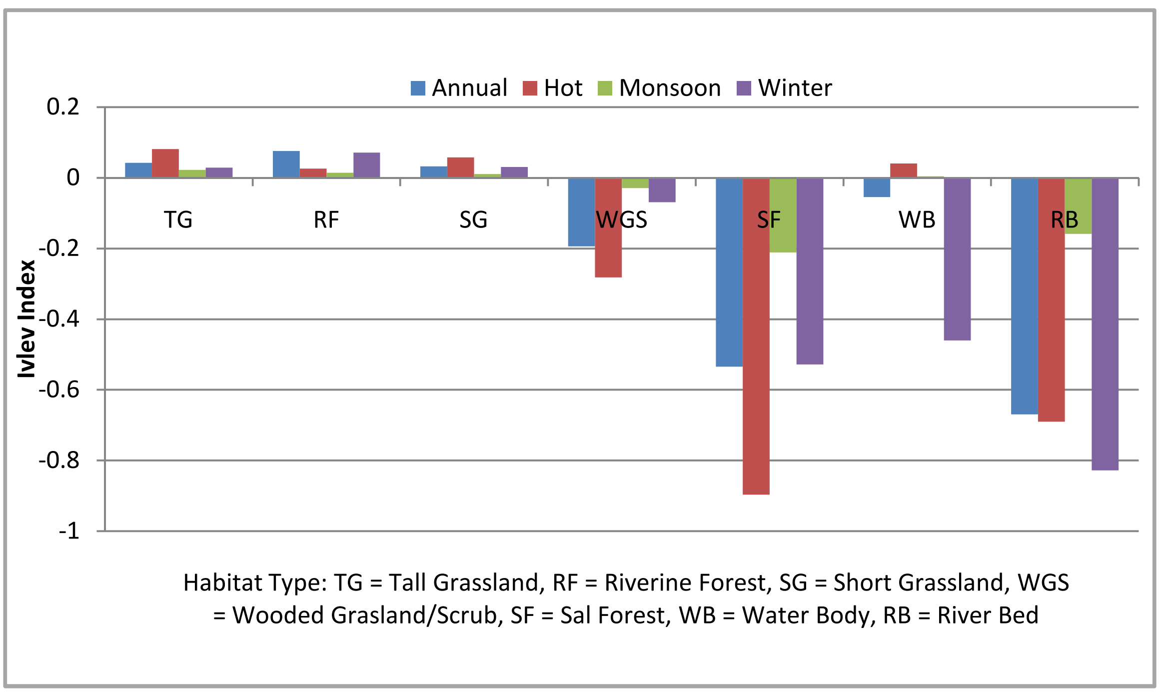


Fig.5.17: Ivlev Electivity Index for annual and seasonal habitat preference and avoidance in different habitat types.

5.3.6 Movement pattern

Average male rhinoceros moved 3.55 ± 0.48 km/day (in 12 hours day time) in hot season, 3.74 ± 0.57 km/day in monsoon season and 3.97 ± 0.51 km/day in winter season. Female rhinoceros moved 2.16 ± 0.25 km/day in hot season, 2.47 ± 0.39 km/day in monsoon season and 2.88 ± 0.43 km/day in winter season. Male rhinoceros covered larger distance than females. Both males and females walked longer distance in winter season in comparison to other two seasons.

The annual average hourly displacements of male and female rhinoceros were 212.70 ± 9.90 m and 152.22 ± 6.36 m respectively. The average hourly displacements of male rhinoceros were 193.67 ± 9.35 m in hot season, 203.61 ± 10.68 m in monsoon season and 240.83 ± 9.67 m in winter season. The average hourly displacements of female rhinoceros were 137.83 ± 5.11 m in hot season, 149.33 ± 6.98 m in monsoon season and 169.50 ± 7.01 m in winter season. Hourly displacements of male rhinoceros were longer than females. Both males and females' hourly displacement were longer in winter season than in other seasons (Fig. 5.18 and Fig. 5.19). Diurnal displacement of male rhinoceros was higher than female (in two way ANOVA test; $F_{1, 70} = 38.19$, $p < 0.0001$) but there was no seasonal variations for both males and females (in two way ANOVA test; $F_{2, 69} = 2.05$, $p = 0.1365$).

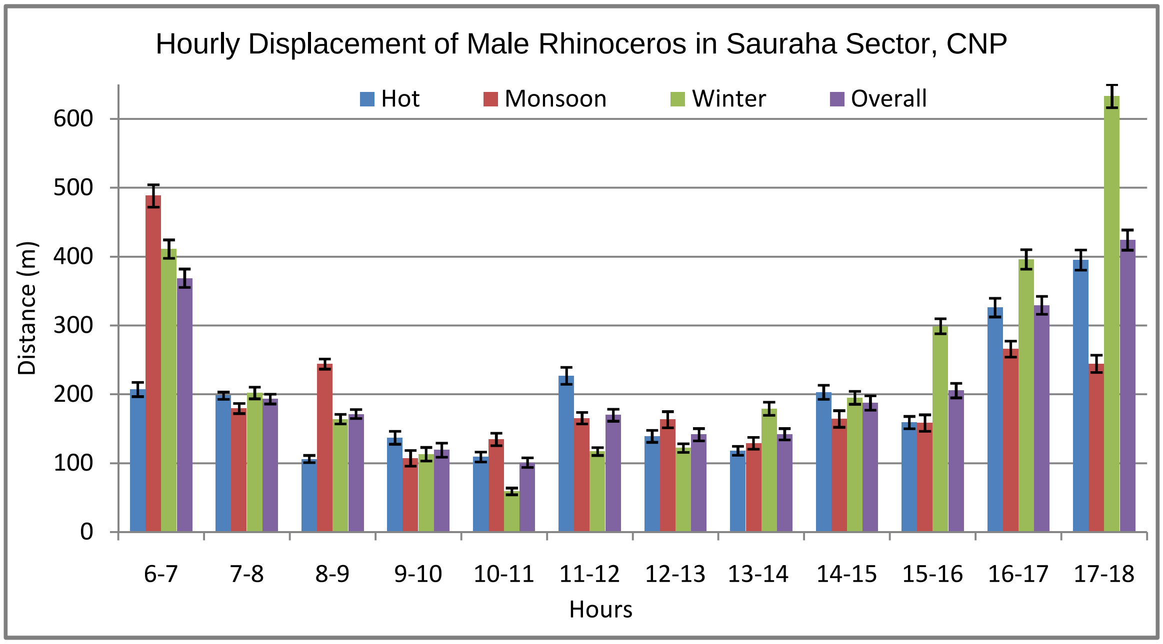


Fig. 5.18 Annual and seasonal hourly displacement of male rhinoceros in Sauraha sector, CNP. Error bars are standard errors.

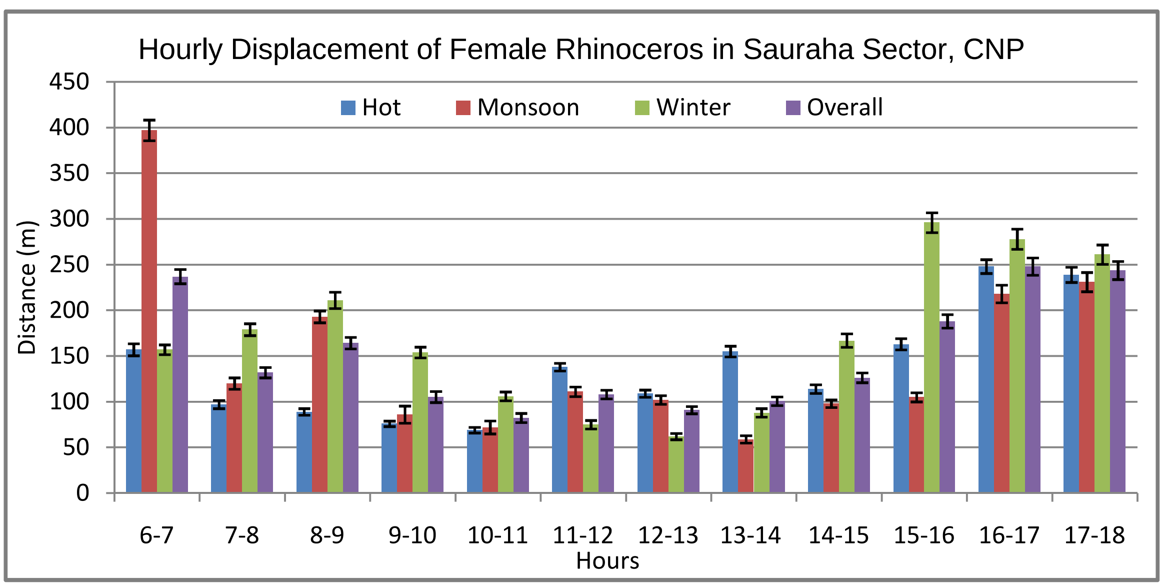


Fig. 5.19 Annual and seasonal hourly displacement of female rhinoceros in Sauraha sector, CNP. Error bars are standard errors.

5.4 Discussion

Our finding of home range sizes is consistent with the previous studies (Laurie, 1978; Jnawali, 1995; Dinerstein, 2003; Subedi, 2012) where males have been reported to occupy larger home ranges than the females. While working on rhino population in Chitwan National Park, Jnawali (1995) and Dinerstein (2003) reported near equal annual home range sizes of male (3.30 km^2) and 2.90 km^2 for females. The annual home ranges estimated for males (10.67 km^2) and females (5.46 km^2) found in the present study were much larger than what had been reported by Jnawali (1995) and Dinerstein (2003). The home range sizes studied by Subedi (2012) through radio-collared data also revealed larger in sizes for males (19.27 km^2) and females (10.20 km^2) in comparison to the present study. The finding of larger home ranges both for males and females though compared close with the studies of Subedi (2012) but appeared much larger than what has been reported by earlier worker in the park. When I looked into the occupancies of rhinoceros in terms of densities in Sauraha sector, it was found that earlier densities reported by Dinerstein (2003) 13 rhinos/km^2 was much higher than the present density i.e. 0.83 rhino/km^2. As Jnawali (1995) and Dinerstein (2003) studies were between 1984 to 1995 and the reintroduction program started concurrently from 1986 to 2003 wherein 91 rhinoceros were translocated from Sauraha sector. Reduction in rhinoceros densities in Sauraha sector as a result of transloctions might have influence over occupying larger ranges both by males and females. Other important aspects of high density of rhinoceros during Jnawali (1995) and Dinerstein (2003) study period were due to availability of smaller grassland in Sauraha sector that became large by adding additional areas through village relocation in this sector. It is presumed that as the population of rhinoceros will grow in Sauraha sector, home range sizes will be squeezed further to accommodate more population of rhinoceros with decreasing home range sizes both for males and females.

The size of the annual home ranges varied for both males (10.67 km^2) and females (5.46 km^2) in the present study however, on seasonal context the variations within individual males and females were not significant ($F_{2, 27} = 1.315$; $p = 0.2849$). The home range size recorded maximum during hot season in both males and females, moderate during rainy season and least in winter (Table 4.1). The finding of Dinerstein (2003) for home range size was larger in hot season though have a similar agreement with the present study but differ for the monsoon season when he reported to be contracted with availability of abundant forage. The core area utilization estimated by Dinerstein (2003) at 50% of all locations ranged from 22 - 28 ha which was much lower than the present study i.e. 1.82 – 6.92 km^2 at 65% of all locations. The core area utilization within males and females did not show any significant differences ($F_{1, 8} = 5.07$, $p = 0.0544$) in the present study.

In the present study female ranges overlapped some male territories with an area overlap of (1.28 km^2). The one dominating male, M1 occupied spatially distinctively larger home range. However, considerable spatial overlaps among three male territories (5.40 km2) were recognized in the Sauraha sector. Occupancy of distinctive home ranges by dominant males either temporally or spatially have also been reported by Dinerstein (2003) and is in concurrence with the finding of the present study. He further reported that two males overlapped in their home ranges but maintained dominance at different time.

The habitat utilization and habitat preference by rhinoceros showed a similar pattern in the present study in Sauraha sector as pointed out by Subedi (2012) in their findings while working on the same area. The preference of order was riverine forest followed by tall grassland and short grassland (Fig. 5.17). Presence of large number of natural and artificial water holes in riverine forest and tall grassland habitat also facilitate the animal to access these water bodies for thermoregulation through wallowing and dissipating heat stresses. The preference of tall grassland in hot and monsoon season might be due to availability of newly sprouted grasses following annual burning and rains. On contrary, during winter season preference shifts to riverine forest as more browse are available than other habitats. During this period, the riverine forest also acts as a better place to avoid cool winters and frost bites. Hazarika *et al.* (2011) reported that the rhinoceros in Orang National Park preferred wet grassland and water bodies throughout the year which was not the case in the present study.

The present study recorded the highest movement rate 3.97 km/day for male and 2.88 km/day for female in 12 hours diurnal period in winter season. The same pattern of finding was recorded by Dinerstein (2003) in 24 hours period. He further reported the highest movement in cool season 7.17 km/day for male and 3.58 km/day for female.

CHAPTER 6

SUMMARY AND MANAGEMENT RECOMMENDATIONS

Chapter 6

Summary and Management Recommendations

6.1 Summary

The greater one horned rhinoceros, *Rhinoceros unicornis* is an unique dweller of *Terai* grassland habitat, where their activities through grazing succession benefits several other sympatric herbivores to co-exist, and maintain productivity and diversity in the ecosystem. In spite of low predation through natural predators, they could not survive in their former ranges due to large scale hunting for their horns and destruction and conversion of habitat for human uses. Historical records revealed that they were once widespread throughout the northern floodplains and nearby foothills extending from Indo-Myanmar boarder in the east and the Sindh River basin, Pakistan to the west. The present free ranging populations are now restricted to few pockets of protected areas including north-east state of Assam, West Bengal and Nepal where such remnant *Terai* grassland constitute the last strongholds for rhinoceros. The current estimate of wild one horned rhinoceros in Nepal and India are between 3250 to 3300; of which Chitwan National Park, Nepal (503) become the second largest population after Kaziranga National Park (2329), Assam, India. Besides these, several zoos around the world hold a population of 50 to 75 greater one horned rhinoceros in the captivity. On the ground of the existing threats, IUCN Red Data Book has listed the greater one horned rhinoceros in the category of

“Vulnerable” species; whereas it is further listed in the Appendix I of CITES due to existing trade on them.

With the availability of small grant, I have selected Sauraha sector (77.1 km^2) as my study area that was one among the four other sectors found in Chitwan National Park (CNP), the last major stronghold of rhinoceros in Nepal. This grassland sector though have been studied by several researcher between the years 1978 to 1995 but thereafter no ecological studies ever undertaken on rhinoceros until recently. Furthermore from this grassland sector 91 rhinoceros were moved away/translocated for building populations in other protected areas of Nepal i.e. Bardia National Park and Suklaphanta Wildlife Reserve; and India i. e. Dudhwa National Park. Over the gap of 14 years, this sector further have seen several habitat changes due to village relocation and increasing human pressures in and around. This study therefore fulfils the needs for undertaking a renewed research on population status, demography, food and feeding ecology, habitat utilization and preference, home range and movement of rhinoceros. It is hoped that outcome of the research in comparison to the earlier studies will provide several useful information which will strengthen conservation and management of rhinoceros in CNP.

The Chapter 1 reviews the evolutionary and historical account of rhinoceros and its ecological significance within the ecosystem. The population status of rhinoceros in CNP since 1950 to present have been reviewed to highlight how this population have seen the severe decline and again revived back to the self sustaining level with increased conservation efforts. The review highlighted poaching and political instability as major threats for rhinoceros survival in CNP including several other threats such as encroachment, flood, fire, grass cutting, tourism and invasion of exotic plants. A detail account of past research studies undertaken on one horned rhinoceros were also reviewed for understanding how these research findings gone along with the conservation to develop national and international commitments for saving the rhinoceros.

The Chapter 2 provided a detail account of the study area including physical, biological and climatic feature of CNP. This protected area is established in 1973 as a Nepal's first National Park in the southern central *Terai* covering an area of 932 km^2. The substantial addition of the area 750 km^2 as buffer zone in 1996 further enhanced its ecological integrity to absorb adverse human pressures around. In 1984, entire area was identified as a priority landscape for the conservation of mega-fauna including tiger and designated as "World Heritage Site". The park has three basic types of terrestrial vegetation consisting of Sal forest (72.9%), grassland (11.54%) and riverine forest (7.54%). The riverine forest and grassland habitats as important habitats for rhinoceros are formed with the activities of major rivers like Narayani, Rapti and Reu. The sub-tropical climate is characterized by three distinctive seasons of hot, monsoon and winter. In hot season, temperature ranges from 11.1 to 35.1°C. The annual rainfall ranges from 1183 to 2399 mm; of which nearly 70% occurs in the monsoon season. Annual fire and grass harvesting by local communities are common management practices for maintaining the grassland and also meeting resource need of the local people. The park is annually visited over 150 thousands visitors that include national and foreign tourists. Nearly 30-50% revenue earned through tourism ploughed back for community development and eliciting public support for conservation.

For conducting the research in two annual periods between 2009 to 2011, rhinoceros in Sauraha sector were identified by physical landmarks captured through photographs and photo files maintained on them (Plates 4.1 to 4.4; Chapter 4). All sighted individuals were recorded for their age-sex categorization (calves, < 4 years; sub-adults, 4-6 years and adults, >6 years) and taking their specific locations through Global Positioning System (GPS). The habitat map of the study area covering 77.1 km^2 was prepared by integrating USGS Landsat image (acquisition date 23 November, 2015; resolution 30m×30m) with other theme layers from topographic map in ERDAS IMAGINE 9.2 and Arc GIS 9.3. The randomly selected 125 Ground Truthing Points were used for signature verification. The image was classified in seven habitat types such as tall grassland (30.47%), Sal forest (20.10%), riverine forest (19.76%), short grassland (12.39%), wooded grassland/scrub (9.61%), water body (3.85%) and river bed (3.82%). The GPS locations of rhinoceros were overlaid on classified image to query and measure relevant information related to habitat occupancy, home ranges and habitat utilization etc.

The Chapter 3 provided an analysis of rhinoceros population and its demographic features in 11 blocks of Sauraha sector. For doing this, individuals were identified and categorized in various age and sex classes. The density, birth and death during the periods of two years were recorded. The result indicated occupancy of 74 rhinoceros constituted through 20 adult males, 26 adult females, 5 sub-adult males, 7 sub-adult females, 5 male calves, 7 female calves and 4 unsexed calves. The sex ratio male to female in the adult segment tend to be 1:1.3 while in calf segment it remained 1:1.4 showing virtually no mortality due to predation factors. The rhino population in Sauraha sector was found to be growing at a rate of 5.76% per annum whereas this growth rate was offset by mortalities recorded at a rate of 6.75%. The mean density of rhinoceros in all blocks ranged from 0.11 – 5.43 rhinos/km^2 with a mean of 0.83 rhinos/km^2. There was no relationship between the area and occupancy of rhinoceros in different blocks ($r_s = 0.637$, d.f. = 9, $p = 0.03$). The occupancy of rhinoceros showed greater use of tall grassland (35.14%) followed by riverine forest (32.43%), short grassland (12.16%), wooded grassland/scrub (10.81%), water body (6.76%) and Sal forest (2.70%). The distribution of rhinoceros in different habitats were significantly different ($\chi^2 = 60.89$, d.f. = 6, $p < 0.0001$).

The Chapter 4 presented an account of activity pattern, food and feeding habits of rhinoceros in Sauraha sector, CNP. To study this, the study site was systematically surveyed on 10 identified focal animals. *Scan Animal Sampling* and *Ad. Libitum Sampling* methods were used for recording activities of rhinoceros. Feeding records were collected through direct observations and feeding trails observations. The inventory of food plants consumed by rhinoceros were also recorded and analyzed. The analysis of activity pattern indicated that rhinoceros spent nearly 45% of time for grazing (35.39 ± 2.12%) and browsing

(7.96 ± 0.65%). The other activities for which rhinoceros spent more time were resting (25.95 ± 1.88%) followed by wallowing (14.62 ± 1.23%) respectively. The activities in three seasons – hot ($F_{6, 63} = 80.58$; $p < 0.0001$), monsoon ($F_{6, 63} = 103.24$; $p < 0.0001$) and winter ($F_{6, 63} = 144.08$; $p < 0.0001$) showed significantly different patterns. The grazing activity showed bimodal peaks between 6 AM to 9 AM and 2 PM to 6 PM during hot and monsoon seasons while browsing did not show any prominent peak in these two seasons except in winter time when it continued gradually throughout the day. The wallowing activities were more prominent during hot and monsoon during 11 AM to 4 PM but urges for it was minimal during winter season. The bite frequencies during different seasons were significant in different habitat types (hot, $F_{3, 75} = 36.17$, $p < 0.0001$; monsoon, $F_{3, 76} = 54.09$, $p < 0.0001$ and winter season, $F_{2, 72} = 51.53$, $p < 0.0001$).

Though 149 plant species belonging to 57 families were recorded as a food plants of rhinoceros in Sauraha sector yet > 1% utilization were recorded only for 21 plant species. The number of plant species utilized were higher in monsoon (95) followed by winter (85) and 77 in hot season having some dietary overlap. *Saccharum spontaneum* constituted the most staple food by rhinoceros in all three seasons. In tall grassland the five plant species in order of preference were *Saccharum spontaneum* (19.14%), *Narenga porphyrocoma* (4.97%), *Saccharum benghalensis* (4.43%), *Phragmites karka* (3.81%) and *Themeda villosa* (1.14%). The most preferred five short grasses were *Cynodon dactylon* (5.39%), *Imperata cylindrica* (4.71%), *Eragrotis tenella* (4.63%), *Hemartheria compressa* (1.84%) and *Paspalidium flavidum* (1.40%). The preferred shrub species were *Callicarpa* *macrophylla* (4.35%), *Pogostemon benghalensis* (2.25%), *Coffea benghalensis* (2.12%) and *Colebrookea oppositifolia* (1.17%). The most preferred tree species were *Trewia nudiflora* (1.68%) and *Litsea monopetala* (1.32%). Most utilized aquatic species were *Hydrilla verticillata* (1.84%) and *Vallisneria spiralis* (1.50%). The six major families constituted 77.94% of total feeding frequencies were Graminae (57.74 %), Verbenaceae (6.45%), Euphorbiaceae (3.65%), Labiatae (3.60%), Hydrocharitiaceae (3.34%) and Leguminosae (3.16%).

The Chapter 5 analyzed home range, ranging pattern and habitat utilization of rhinoceros in Sauraha sector. For estimating home ranges, Minimum Convex Polygon (MCP) and Fixed Kernel Density Estimator (FKDE) were used based on the locations of ten identified rhinoceros in GIS domain. Spatial overlaps on home ranges were estimated through the Clip Analysis Tool in Arc GIS. The core area utilizations were determined through area probability curve in different counter isopleths varying from 95% - 40%. The point of inflection indicated the highly utilized core areas.

The annual home range of males (n=5) was higher (10.67 ± 0.92 km^2) compared to the females (n =5; 5.46 ± 0.65 km^2). In seasonal terms, males occupied larger home ranges in hot season (9.91 ± 0.96 km^2) followed by monsoon (7.94 ± 0.74 km^2) and winter (6.45 ± 0.65 km^2). The females also showed a similar pattern by occupying larger home ranges in hot (5.01 ± 0.64 km^2), monsoon (4.36 ± 0.46 km^2) and winter season (3.69 ± 0.45 km^2). The annual home ranges of male and female were found significantly different ($F_{1, 38}$ = 18.99; $p < 0.0001$) however, these variations in seasonal context were not significant ($F_{2, 27}$ = 1.315; p = 0.2849). The males home ranges showed an overlap of 5.4 km^2 where this overlap among females remained 1.31 km^2. The overlap between males and females ranges was 1.28 km^2. The core area utilization between males and females did not show any significant differences ($F_{1, 8}$ = 5.07, p = 0.0544).

The habitat utilization and preference of rhinoceros in Sauraha sector varied in order of riverine forest > short grassland > tall grassland > water body > wooded grassland/scrub > Sal forest > river bed (χ^2 = 36.58, d.f. = 6, P < 0.0001). During the hot season, the order of habitat preference was tall grassland > short grassland > riverine forest > water body > wooded grassland/scrub > river bed > Sal forest (χ^2 = 19.43, df = 6, P < 0.05). The order of habitat preference during monsoon season was tall grassland > riverine forest > short grassland > water body > wooded grassland/scrub > river bed > Sal forest (χ^2 = 32.41, df = 6, P < 0.0001). Habitat preference order for winter season was riverine forest > short grassland > tall grassland > wooded grassland/scrub > water body > river bed > Sal forest (χ^2 = 22.68, d.f. = 6, P < 0.001). In the diurnal 12 hours cycle, male rhinoceros moved 3.75 ± 0.52 km/day compared to the female 2.50 ± 0.36 km/day. Both sexes moved longer during winter season compared to other seasons to get enough browse species from the riverine forest situated away from the grassland.

6.2 Management recommendations

From the above study, it emerged out that Sauraha sector is an important zone for rhinoceros conservation in Chitwan National Park. The current population of at least 74 rhinoceros in this sector only provides a density of 0.83 rhinos/km^2 which is much lesser than its holding capacity 13 rhinos/km^2 as was earlier recorded by Dinerstein and Price (1991). The current less population of rhinoceros in Sauraha sector is a reflection of earlier translocation program in which 91 rhinoceros were taken away from this sector. This sector has a greater potential for rhino recovery with better protection and management of habitat for them. The current estimated population growth rate 5.76% per annum seems to be adequate for early recovery of rhinoceros in this sector. However, for improvement and augmenting the *In-situ* conservation of rhinoceros some general management recommendations suggested are as below;

1. The vulnerability of rhinoceros in Sauraha sector on the west at Bhimpur, Dudhoura, Bhawanipur and Kachwani area need to be strengthen through intensive anti-poaching, so that, better protection to individual rhinoceros can be ensured. During my study period, four rhinoceros mortalities by poaching were recorded from these areas adjoining to Patihani and Gitanagar villages.
2. Effective intelligence network for apprehending rhino poaching offenders to be strengthened by involvement of local people and getting their support for the conservation activities. No village level committees to provide support on this aspect are yet constituted.

3. ID based individual rhinoceros profile need to be maintained and monitored by field staffs during their regular patrolling. Such records need to be mapped to maintain vigilance on the animal movement and taking necessary steps for their protection.
4. The livelihood issues of fringe villages need to be looked into by several NGOs, INGOs and Buffer Zone Management Committees (BZMCs). The User Groups and Youth Groups should try to implement such programs that can enhance park-people partnership for promoting necessary support of the local people in all management activities of rhinoceros.
5. The annual burning of tall grassland as prescribed in management plan is between December to January but due to some administrative reasons, they sometimes follow late burning which impede new flush of grass due to low moisture contents. More studies on grass burning and grassland species to be undertaken for improving decision on this matter.
6. Habitat management activities such as invasive species removal and removal of woodland invasion in the grassland habitat to be undertaken or monitored systematically. So that, grass composition over the years should not change much. More studies on this aspect need to be planned in the grassland habitat of Sauraha sector.
7. The capacity requirement for the rhinoceros management is poor for the security and park staffs which need to be strengthened through several training programs designed for all aspects of rhinoceros management.

8. The illegal activities such as grazing livestock, thatch grass collection and firewood collection are quite rampant in western and eastern part of Sauraha sector which need to be managed through proper involvement of local people.
9. The entire Sauraha sector of CNP is open for tourism which needs to be regulated so that disturbance to rhinoceros and their habitat can be reduced for proper population growth of rhinoceros.

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Appendix I

Appendix I: List of plant species (with local name and family) eaten by Rhinoceros in Sauraha secotr, CNP in different seasons.

S.N.	Family	Scientific Name	Local Name	Type	Herb/Shrub/Tree	Frequency	Percentage
1	Acanthaceae	*Barleria cristata (L.)*	Lhari Phool	Browse	Shrub	2	0.05
2	Amaranthaceae	*Amaranthus spinosus (L.)*	Lude Kanda	Graze	Herb	3	0.08
3		*Achyranthus aspera (L.)*	Datiwan	Graze	Herb	4	0.10
4	Anacardiaceae	*Magnifera indica (L.)*	Aam	Browse	Tree	2	0.05
5		*Buchanania latifolia (Roxb.)*	Piyari	Browse	Tree	3	0.08
6	Annonaceae	*Miliusa velutina (Dunal)*	Kalikath	Browse	Tree	11	0.28
7	Apocynaceae	*Holarrhena antidysentrica (Wall.)*	Dudh Khirra	Browse	Tree	3	0.08
8	Aspidaceae	*Tectaria macrodonta (Fee.)*	Kali Nigro	Graze	Fern	4	0.10
9		*Dryopteris cochleata (D. Don)*	Pani Niuro	Graze	Fern	8	0.21
10		*Diplazium esculantum(Retz.)*	Pani Niguro	Graze	Fern	17	0.44
11	Asteraceae	*Mikania micrantha*	Banmasa	Browse	Climber	21	0.54
12	Bombacaceae	*Bombyx ceiba (L.)*	Simal	Browse	Tree	12	0.31
13	Boraginaceae	*Cynoglossum zeylanicum (Vahl.)*	Kanike Kuro	Graze	Short Grass	4	0.10
14	Cannabaceae	*Cannabis sativa (L.)*	Bhang	Browse	Herb	3	0.08
15	Chenopodiaceae	*Chenopodium album (L.)*	Bethe	Graze	Short Grass	20	0.52
16	Combretaceae	*Terminalia bellirica (Gaertn.)*	Barro	Browse	Tree	2	0.05
17	Commelinaceae	*Commelina benghalensis (L.)*	Kane jhar	Graze	Short Grass	5	0.13
18	Compositae	*Crassocephalum crepidioides (Benth.)*	Anikale Jhar	Graze	Short Grass	3	0.08
19		*Cirsium wallichi (DC.)*	Gaida kada	Graze	Short Grass	28	0.73
20		*Eupatorium odoratum (L.)*	Aule Banmara	Graze	Herb (Weed)	7	0.18
21		*Ageratum conyzoides (L.)*	Gandhe	Graze	Herb (Weed)	13	0.34
22	Convolvulaceae	*Ipomoea quamoclit (L.)*	Jayanti Lahara	Browse	Climber	5	0.13
23	Cordiaceae	*Cordia grandis (Roxb.)*	Bohori	Browse	Tree	3	0.08
24		*Ehretia laevis (Roxb.)*	Datrung	Browse	Tree	16	0.41
25	Cruciferae	*Raphinus sativa (L.)*	Mula	Graze	Herb	2	0.05
26	Cucurbitaceae	*Cucumis sativus (L.)*	Khira	Graze	Creeper	2	0.05
27		*Trichosanthes wallichiana (Seringe)*	Indreni	Browse	Climber	3	0.08
28		*Trichosanthes dioica (Roxb.)*	Parval	Graze	Creeper	5	0.13
29		*Mukia scrabella (L.)*	Gol Kankri	Graze	Creeper	9	0.23

Continued……

S.N.	Family	Scientific Name	Local Name	Type	Herb/Shrub/Tree	Frequency	Percentage
30	Cyperaceae	*Cyperus niveus (Retz.)*	Sano Mothe	Graze	Short Grass	14	0.36
31		*Cyperus digitatus (Roxb.)*	Mothe	Graze	Short Grass	16	0.41
32		*Cyperus rotundus (L.)*	Mothe	Graze	Short Grass	19	0.49
33		*Scleria laevis (Retz.)*	Karaute Jhar	Graze	Short Grass	40	1.04
34	Dillenaceae	*Dillenia indica (L.)*	Thulo Tatari	Browse	Tree	3	0.08
35	Equisetaceae	*Equisetum dubile (Roxb.)*	Aakhle Jhar	Graze	Short Grass	15	0.39
36	Euphorbiaceae	*Euphorbia thymifolia (L.)*	Dudhilahara	Graze	Short Grass	2	0.05
37		*Phyllanthus emblica (L.)*	Amala	Browse	Tree	2	0.05
38		*Bridelia retusa (L.)*	Gayo	Browse	Tree	7	0.18
39		*Mallotus philippinensis (Lam.)*	Sindure	Browse	Tree	10	0.26
40		*Phyllanthus amarus (Schum. & Thonn.)*	Bhui Amala	Graze	Short Grass	23	0.60
41		*Euphorbia hirta (L.)*	Dudhe Jhar	Graze	Short Grass	32	0.83
42		*Trewia nudiflora (L.)*	Vellar	Browse	Tree	65	1.68
43	Graminae	*Eragrostis atrovirens (Desf.)*	Banso	Graze	Herb	2	0.05
44		*Coix lachryma-jobi (L.)*	Bhirkaunla	Browse	Tree	3	0.08
45		*Cymbopogon oliveri (Boiss.) Bor*	Kagati gans	Graze	Short Grass	3	0.08
46		*Eleusine indica (L.) Gaertn.*	Kode Jhar	Graze	Short Grass	3	0.08
47		*Panicum maximum (Jacq.)*	Gini gans	Graze	Short Grass	3	0.08
48		*Thysanolaena maxima (Roxb.)*	Amliso	Browse	Herb	3	0.08
49		*Paspalum distichum (L.)*	Janai Gans	Graze	Short Grass	4	0.10
50		*Echinochola colona (L.)*	Sama Ghas	Graze	Short Grass	5	0.13
51		*Paspalum scrobiculatum (L.)*	Kodi	Graze	Herb	6	0.16
52		*Erianthus ravennae (L.)*	Lahare Banso	Graze	Grass	7	0.18
53		*Digitaria ciliaris (Retz.)*	Kalo Banso	Graze	Short Grass	8	0.21
54		*Eragrotis tenella (L.)*	Banso	Graze	Short Grass	179	4.63
55		*Arundo donax(L.)*	Narkat	Graze	Tall Grass	10	0.26
56		*Themeda arundinacea (Roxb.)*	Ooreli Ghans	Graze	Tall Grass	11	0.28
57		*Saccharum munja (Roxb.)*	Ukhudhatti	Graze	Tall Grass	38	0.98
58		*Digitaria setigera (Roth.)*	Banso	Graze	Short Grass	13	0.34
59		*Apluda mutica (L.)*	Sali Banso	Graze	Herb	14	0.36
60		*Cymbopogon flexuosus (Nees ex Steudel)*	Kagati Ghas	Graze	Short Grass	14	0.36

Continued…..

S.N.	Family	Scientific Name	Local Name	Type	Herb/Shrub/Tree	Frequency	Percentage
61	Graminae	*Vetiveria zizanoides (L.)*	Khuskhus	Graze	Grass	16	0.41
62		*Seteria pallide-fusca (Schu.)*	Kagune Jhar	Graze	Herb	31	0.80
63		*Themeda villosa (Poir)*	Ooreli	Graze	Tall Grass	44	1.14
64		*Paspalidium flavidum (Retz.)*	Mane Banso	Graze	Short Grass	54	1.40
65		*Phragmites karka (Retz.)*	Narkat	Graze	Tall Grass	147	3.81
66		*Chrysopogon aciculatus (Retz.)*	Kuro Ghans	Graze	Short Grass	49	1.27
67		*Hemartheria compressa (L.f.)*	Ghodedubo	Graze	Short Grass	71	1.84
68		*Imperata cylindrica (L.)*	Siru	Graze	Short Grass	182	4.71
69		*Narenga porphyrocoma (Hance ex Trin)*	Phank	Graze	Tall Grass	192	4.97
70		*Saccharum benghalensis (Retz.)*	Baruwa	Graze	Tall Grass	171	4.43
71		*Cynodon dactylon (L.) Pers.*	Dubo	Graze	Short Grass	208	5.39
72		*Saccharam spontaneum (L.)*	Kans	Graze	Tall Grass	739	19.14
73	Hydrocharitiaceae	*Vallisneria spiralis (L.)*	Water hycianth	Browse	Aquatic Plant	58	1.50
74		*Hydrilla verticillata (L. f. ?)*	Pani Unyu	Graze	Aquatic Plant	71	1.84
75	Labiatae	*Elsholtzia blanda (Benth.)*	Ban Silam	Graze	Short Grass	2	0.05
76		*Mentha arvensis (L)*	Pudina	Graze	Short Grass	4	0.10
77		*Colebrookea oppositifolia (Sm.)*	Dhursil	Browse	Shrub	46	1.19
78		*Pogostemon benghalensis (Burm. F.)*	Rudhilo	Browse	Shrub	87	2.25
79	Lamiaceae	*Anisomeles indica (L.)*	Rato Charpate	Graze	Herb	3	0.08
80	Lauraceae	*Litsea monopetala (Roxb.)*	Kutmiro	Browse	Tree	51	1.32
81	Leeaceae	*Leea macrophylla (Roxb. ex Horn.)*	Galeni	Browse	Shrub	2	0.05
82	Leguminosae	*Albizia julibrissin (Var.)*	Patke Siris	Browse	Tree	2	0.05
83		*Bauhinia purpurea (L.)*	Rato Koiralo	Browse	Tree	2	0.05
84		*Desmodium gangeticum (L.) DC.*	Ban Gahate	Graze	Herb	2	0.05
85		*Flemingia strobilifera (L.)*	Bhatmaspate	Browse	Shrub	2	0.05
86		*Albizia lucida (Steud.)*	Padke	Browse	Tree	3	0.08
87		*Acasia cathechu (L.f.)*	Khayar	Browse	Tree	6	0.16
88		*Dalbergia sissoo (Roxb.)*	Sissoo	Browse	Tree	11	0.28
89		*Bauhinia malabarica (Roxb.)*	Amil Tanki	Browse	Tree	11	0.28
90	Leguminosae	*Cassia occidentalis (L.)*	Thulo tapre	Browse	Shrub	12	0.31
91		*Mimosa pudica (L.)*	Buhari Jhar	Graze	Short Grass	24	0.62

Continued…..

S.N.	Family	Scientific Name	Local Name	Type	Herb/Shrub/Tree	Frequency	Percentage
92	Leguminosae	*Cassia tora(L.)*	Saano tapre	Graze	Herb	47	1.22
93	Lemnaceae	*Wolffia globosa (Roxb.)*	Pani jhar	Browse	Aquatic Plant	3	0.08
94	Lentibulariaceae	*Urticularia aurea (Lour.)*	Sim Gans	Graze	Herb	6	0.16
95		*Urticularia bifida (L.)*	Sim Ghans	Graze	Short Grass	7	0.18
96	Liliaceae	*Smilax ovalifolia (Roxb.)*	Kukurdaino	Browse	Climber	2	0.05
97		*Asparagus racemosus (Willd.)*	Kurilo	Graze	Short Grass	3	0.08
98	Lythraceae	*Woodfordia fruticosa (L.)*	Dhaiyaro	Browse	Shrub	2	0.05
99		*Rotala rotundifolia (Roxb.)*	Sim Jhar	Graze	Herb	7	0.18
100	Malvaceae	*Sida rhombifolia (L.)*	Balu or Khareti	Browse	Shrub	5	0.13
101		*Urena lobata (L.)*	Bhede Kuro	Graze	Short grass	5	0.13
102		*Sida acuta (Burm. f.)*	Balu Jhar	Graze	Short Grass	14	0.36
103	Meliaceae	*Toona ciliata (M. Roem.)*	Tooni	Browse	Tree	2	0.05
104		*Dysoxylum binectariferum (Roxb.)*	Dhamina	Browse	Tree	11	0.28
105	Menispermaceae	*Tinospora sinensis (Lour.)*	Charchare Lahara	Browse	Climber	7	0.18
106	Moraceae	*Ficus auriculata (Lour.)*	Timilo or Bhemala	Browse	Tree	2	0.05
107		*Ficus semicordata (Buch.- Ham.)*	Khanyu	Browse	Tree	7	0.18
108	Myrsinaceae	*Ardisia solanacea (Roxb.)*	Damai Phool	Browse	Shrub	2	0.05
109		*Maesa chisia (Buch.-Ham.)*	Belouni	Browse	Tree	13	0.34
110	Myrtaceae	*Psidium guajava (L.)*	Amba	Browse	Tree	2	0.05
111		*Syzygium cumini (L.)*	Jamun	Browse	Tree	10	0.26
112	Onagraceae	*Ludwiga hyssopifolia (G. Don.)*	Khursani Jhar	Graze	Grass	3	0.08
113	Oxalidaceae	*Oxalis corymbosa (DC.)*	Thulo Chariamilo	Graze	Short Grass	6	0.16
114		*Oxalis corniculata (L.)*	Sano Chariamilo	Graze	Short Grass	9	0.23
115	Palmae	*Calamus tenuis (Roxb.)*	Bet	Browse	Shrub	3	0.08
116	Piperaceae	*Piper longum (L.)*	Pipla	Graze	Short Grass	7	0.18
117	Polygonaceae	*Polygonum plebezium (R. Br.)*	Sukul Jhar	Graze	Short Grass	16	0.41
118	Pteridaceae	*Pteris vittata(L.)*	Bish Unyou	Graze	Fern	2	0.05
119		*Pteris cretica(L.)*	Unyou	Graze	Fern	7	0.18
120	Rhamnaceae	*Zizyphus mauritiana (Lam.)*	Bayar	Browse	Shrub	7	0.18
121	Rubiaceae	*Adina cordifolia (Willd. ex.Roxb.)*	Kadam	Browse	Tree	2	0.05
122		*Coffea benghalensis (Heyne ex. Roem.)*	Baramasi	Browse	Shrub	82	2.12

Continued…..

S.N.	Family	Scientific Name	Local Name	Type	Herb/Shrub/Tree	Frequency	Percentage
123	Rutaceae	*Aegle marmelos (L.)*	Bel	Browse	Tree	3	0.08
124		*Boenninghausenia albiflora (Hook.)*	Dampate	Graze	Herb	8	0.21
125		*Muraya paniculata (L.)*	Laathikat	Browse	Tree	11	0.28
126		*Murraya koenigii (L.)*	Kadipatta	Browse	Tree	32	0.83
127	Santalaceae	*Osyris wightiana(Wall.)*	Nundhiki	Graze	Short Grass	4	0.10
128	Scrophulariaceae	*Linderbergia indica (L.)*	Ukuchi	Graze	Short Grass	18	0.47
129		*Scoparia dulcis (L.)*	Chini Jhar	Graze	Short Grass	21	0.54
130	Solanaceae	*Solanum indicum (L.)*	Bihi	Browse	Shrub	8	0.21
131		*Solanum torvum (Swartz.)*	Thulo Bihi	Browse	Shrub	11	0.28
132		*Solanum surattense (Burm. f.)*	Kantakari	Graze	Herb	12	0.31
133		*Solanum nigrum (L.)*	Kaligedi	Graze	Herb	16	0.41
134	Tiliaceae	*Grewia subinaequalis (DC)*	Falsa	Browse	Shrub	9	0.23
135		*Grewia sclerophylla (Roxb.)*	Pharsa	Browse	Shrub	12	0.31
136	Typhaceae	*Typha elephantina (L.)*	Pater	Graze	Tall Grass	6	0.16
137	Umbelliferae	*Centella asiatica (L.)*	Ghodtapre	Graze	Short Grass	31	0.80
138	Urticaceae	*Urtica dioica (L.)*	Sisnu	Graze	Herb	2	0.05
139		*Boehmeria platyphylla (D. Don)*	Gargalo or Kamle	Graze	Short Grass	4	0.10
140		*Gonostegia hirta (Blume)*	Chiple Ghans	Graze	Short Grass	6	0.16
141	Verbenaceae	*Lantana camara (L.)*	Banmara	Browse	Shrub	4	0.10
142		*Premna obtusifolia (R. Br.)*	Bakuchi	Browse	Shrub	4	0.10
143		*Caryopteris odorata (D. Don)*	Nilo Dhusure	Browse	Shrub	7	0.18
144		*Lippa nodiflora (L.)*	Kurkure Jhar	Graze	Herb	9	0.23
145		*Clerodendrum viscosum (Vent.)*	Bhati	Browse	Shrub	16	0.41
146		*Premna barbata (Wall. ex.Schauer)*	Ginari	Browse	Tree	20	0.52
147		*Callicarpa arborea (Roxb.)*	Thulo Daikamala	Browse	Tree	21	0.54
148		*Callicarpa macrophylla (Vahl.)*	Daikamala	Browse	Shrub	168	4.35
149	Vitaceae	*Vitis latifolia (Roxb.)*	Pani Lahara	Graze	Climber	1	0.03
Sps.	**57 families**	**Total**	**149 sps.**			**3862**	**100**

Plates

Plate 5 and 6: Showing different activities as illustrated below.

(i) Tourism in Bagmara community forest

(ii) People pressure for grass collection in Badreni

(iii) Grassland after burning

(iv) *Mikania* invasion in Icharni Island

(iv) *Bombyx* invasion in grassland of Jay Mangala

(g) Ecological separation of riverine and sal forest

(vii) Male rhinoceros drinking water in Rapti River

(viii) Adult female with calf wallowing in mud hole

(ix) Female rhinoceros browsing on *Dalbergia sissoo*

(x) Small calf with no scars and small sign of horn

(xi) Feeding trail investigation by author

(xii) Electric fencing to restrict rhinoceros movement along Rapti River bank.