A STUDY ON
BEHAVIOUR AND HABITAT PREFERENCES OF TRANSLOCATED RHINOS (*Rhinoceros unicornis*)

At

MANAS NATIONAL PARK, ASSAM INDIA

A THESIS

SUBMITTED TO GAUHATI UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ZOOLOGY IN THE FACULTY OF SCIENCE

SUBMITTED BY
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2015

Dedication

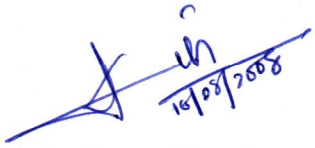
This thesis is dedicated to my loving parents

late Nirmal Kumar Dutta and Smt Joyamai Dutta.

DECLARATION

I, hereby declare that this thesis is the result of my own research work which has been carried out under the guidance of Dr. Rita Mahanta of Cotton College, Gauhati University. I further declare that this thesis as a whole or any part thereof has not been submitted to any university (or institute) for the award of any degree or diploma.

This thesis contains less than 90,000(ninety thousand) words excluding bibliography and captions.



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CERTIFICATE

This is to certify that the thesis titled "A Study on Behaviour and Habitat Preferences of Translocated Rhinos (*Rhinoceros unicornis*) at Manas National Park, Assam, India" is the result of the research work by Mr Deba Kumar Dutta, carried under my supervision, submitted to Gauhati University, Guwahati for the award of Doctor of Philosophy in Zoology.

This thesis conforms to the standard of PhD Thesis under Gauhati University, Guwahati including the standard related to plagiarism and has a similarity index not more than 20% (twenty percent), excluding the bibliography.

Place: Cotton College, Guwahati
Date: 16.08.2018

Rmahanta
Dr. Rita Mahanta, Supervisor

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(Deba Kumar Dutta)

Abstract

The Great Indian One Horned Rhino (GoH) *Rhinoceros unicornis*, (Linnaeus, 1758) is one of the threatened mega herbivore in the world. At present (August, 2015), the total wild population of GoH in the world is estimated to be 3554 individuals; out of which, 2909 (81.85%) are found at national parks and wild life sanctuaries in India. Assam shelters two third (73.86%) of the entire GoH of the World. But this population is under continuous threat from poachers and habitat destruction. However, due to continuous conservation efforts, rhino population has increased significantly in entire rhino bearing areas of Assam.

Manas National Park (MNP) is a UNESCO World Heritage Site and located in the foothill zone of Himalayas in the north bank of Brahmaputra Valley along the international boundary between Indo-Bhutan and Assam India. Original rhino population of Manas NP was wiped out because of poaching. Thus, new rhino population was established through the program of Indian Rhino Vision 2020 (IRV2020). Under the rhino range expansion programme, 18 rhinoceros were translocated from two rhino bearing areas Assam- Kaziranga National Park (KNP) and Pobitora Wildlife Sanctuary (PWS) during 2008-2012. For the present study, 10 animals (3 adult males, 4 adult females, 2 male calves and 1 female calf) were selected to this study for six years (2008-2013). It has been more than eight years (2008-2015) since the inception of the rhino reintroduction program in Assam. Today (August, 2015), Manas has 32 numbers of wild populations with 14 new born calves. The success of rhino reintroduction program in Manas NP has opened a new dimension in the history of rhino conservation in Assam. There has been little research in to translocated free release GoH rhino and this study is the innovative effort in Assam. Therefore, the present study on "To Study Behaviour and Habitat Preferences of Translocated Rhino (*Rhinoceros unicornis*) at Manas National Park Assam India" has been proposed and carried out at Manas.

From the study of the different aspects of the behaviour and habitat preferences of the translocated rhinoceros, it was observed that after the translocation from their earlier natural habitats (PWS and KNP) the rhinos in the MNP has exhibited maximum tendency to adapt in the new environment retaining some behaviour characteristics as it was. Though some amount of habitat and food plants differences were observed in the MNP from the PWS and KNP, the translocated rhinoceros became habituated with the new environment within a year. The behavioural changes for adaptation is one of the noticeable finding in the present investigations.

CONTENTS

LIST OF ABBREVIATION

AF	Adult Female
AM	Adult Male
ANOVA	Analysis of Variance
AsRSG	Asian Rhino Specialist Group
AfRSG	African Rhino Specialist Group
BTC	Bodoland Territorial Council
BC	Before Christ
CA	Core Area
CCF	Chief Conservator of Forest
CEO	Chief Executive Officer
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CHD	Council Head of Department
CWRC	Centre for Wildlife Rescue and Rehabilitation and Conservation
CWLW	Chief Wildlife Warden
ESRI	Environmental System Research Institute
FKD	Fixed Kernel Density
GIS	Geographic Information System
GPS	Global Positioning System
GoH	Greater One-Horned Rhinoceros
HOFF	Head of Forest Force
LHNI	Living Himalaya Network Initiatives
IFAW	International Fund and Animal Welfare
INR	Indian Rupees
IRS	Indian Remote Sensing
IRF	International Rhino Foundation
IRV 2020	Indian Rhino Vision 2020
IUCN	International Union for Conservation of Nature
LISS	Low Imaging Sensing Satellite
KNP	Kaziranga National Park
MCP	Minimum Convex Polygon

MHz Mega Hertz

MNP Manas National Park

MSL Mean Sea Level

NP National Park

NTNC National Tiger Conservation Authority

PA Protected Areas

PCCF Principal Chief Conservator of Forest

RMG Rhino Monitoring Guidelines

RGONP Rajiv Gandhi Orang National Park

TCC Translocation Core Committee

UK United Kingdom

UNESCO United National Education Scientific Cultural Organisation

USFWS United States Fish and Wildlife Service

USA United States of America

UHF Ultra High Frequency

VHF Very High Frequency

WAWDT Wild Life Areas Welfare Development Trust

WII Wild Life Institute of India

WHS World Heritage Site

WLS Wild Life Sanctuary

WPA Wild Life Protection Act

WTI Wild Life Trust of India

WWF World Wide Fund for Nature

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Chapter 1
Introduction

The Greater One-Horned Rhinoceros, (*Rhinoceros unicornis)* (Linnaeus, 1758) is one of the most threatened megaherbivores surviving on the earth. It is one of the most enduring emblems of Indian Subcontinent's rich biological heritage and the State animal of the Government of Assam. Rhinoceros is not only important ecologically but this also represents the pride of Assamese people.

This iconic animal is now highly vulnerable as witnessed by recent declines. Once, the rhinos ranged in the entire stretch of the Indo-Gangetic Plain across northern Pakistan, northern India, Nepal, Myanmar, northern Bangladesh and Brahmaputra valley of Assam (Fig.1.1). However, as a result of habitat fragmentation, rapid socio-economic changes, poaching and being a *K*-selected species (long gestation, long calving intervals, slow maturation and single offspring), range and population of this species gradually declined over the last 400 years and by the 19th century, the rhino population became restricted only to the Terai grassland of Northern Uttar Pradesh, Southern Nepal and Northern Bengal in addition to the Brahmaputra valley of Assam(Blanford, 1891; Foose and VanStrien, 1997).

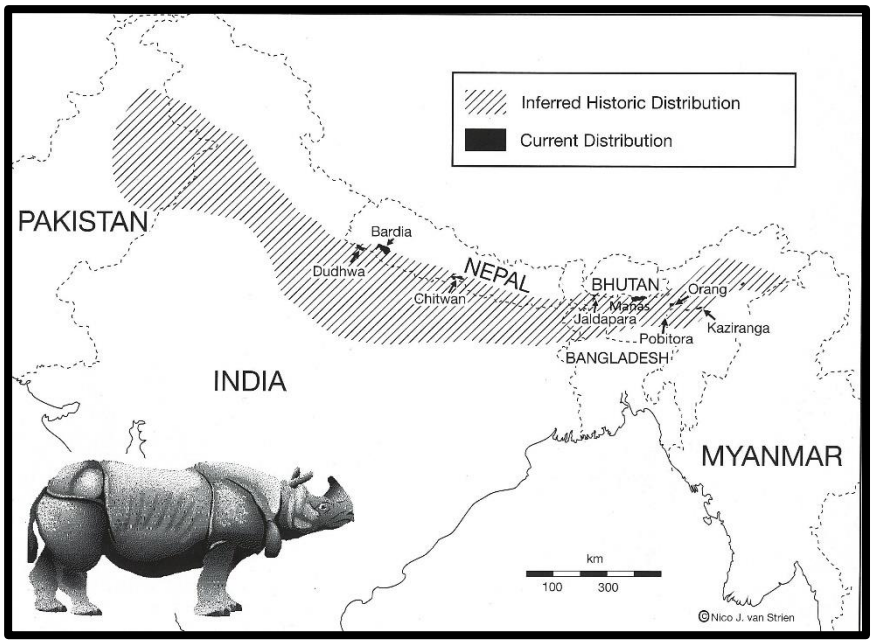


Fig.1.1 Historical and Current Geographical Distribution of GoH (Source: Nico.J.ven Strien)

By the beginning of the 20th century the species close to extinction and was estimated fewer than 200 Greater One Horned Rhinoceros (GoH) remained in wild (Rookmaaker, 1980). In the year 1975, there were only 600 surviving individuals. Due to continuous and intense conservation effort in India and Nepal, GoH population has been increased dramatically since 1975. GoH population is now larger compared to the two other Asian Species (i.e. Javan and Sumatran rhinoceros). In Assam, GoH population grew 57% in between the period of 1999 to 2015 (Fig 1.2). By 2015, the population grew to 3,550 in Terai Arc Landscapes of India and Nepal, the rhino ranging areas of Assam and north Bengal in northeast India. It is the only large mammal in Asia to be downlisted from endangered to vulnerable on the IUCN Red List of Endangered Species (Talukdar *et al*., 2008) (Table 1.1).

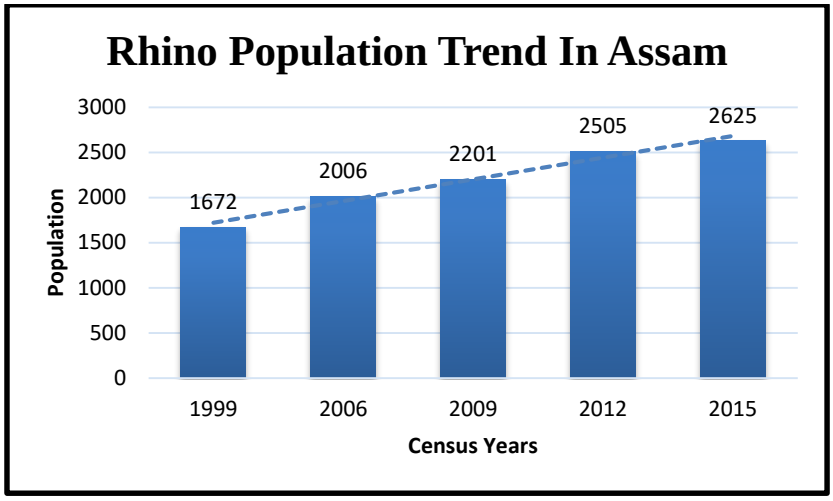


Fig.1.2 GoH Population Growth trend in Assam (Source: The Forest & Environment Department, Govt. of Assam)

As megaherbivores, rhinoceros are globally threatened due to habitat conversion, fragmentation and poaching to fulfill the illegal demand of their horn and body parts. During the period of thirty years (1985-2015), more than 800 rhinoceros in Assam were killed by poachers for horns. Recently, 2013 was the highest rhino poaching year (41 rhinos poached) in last ten years (Fig 1.3).

Like other mega-herbivores (eg Elephant), the rhinoceros populations are mostly confined to small, isolated protected areas (Owen-Smith, 1988; Sukumar, 1989). In Assam, rhino population is distributed in four major protected areas (viz. Kaziranga National Park (KNP), Manas National Park (MNP), Rajiv Gandhi Orang National Park (RGNOP), and Pobitora Wildlife Sanctuary (PWS) (Fig.1.4). KNP in Assam, India holds 67% (n=2401) of world's GoH population and Chitwan National Park (NP), Nepal holds the second largest population of 17% (n=605) (Table 1.2).

Fragmented populations are at risk of local extinction due to demographic, genetic and stochastic environmental events. Habitat fragmentation has been linked to the loss of genetic variation in several carnivores (Gottelli *et al.*, 1994; Haag *et al.*,

2010) and herbivores (Zschokke *et al.*, 2011). Further, the growth of populations in a fixed space increases the competition for space and other biological resources leading to more frequent fights for dominance that result in injuries. This highlights the need to provide more space for long-term conservation of the species (Emslie *et al.*,2009).

Table.1.1 Present IUCN, Red List Status of Greater One-horned Rhinoceros

Common name	**Latin Name**	**IUCN Red List Assessment**	**Existing estimates of range, population size, or abundance**
Greater One-horned Rhinoceros	*Rhinoceros unicornis*	Vulnerable	About 3,550 individuals confined to India and Nepal over 10 Protected Areas

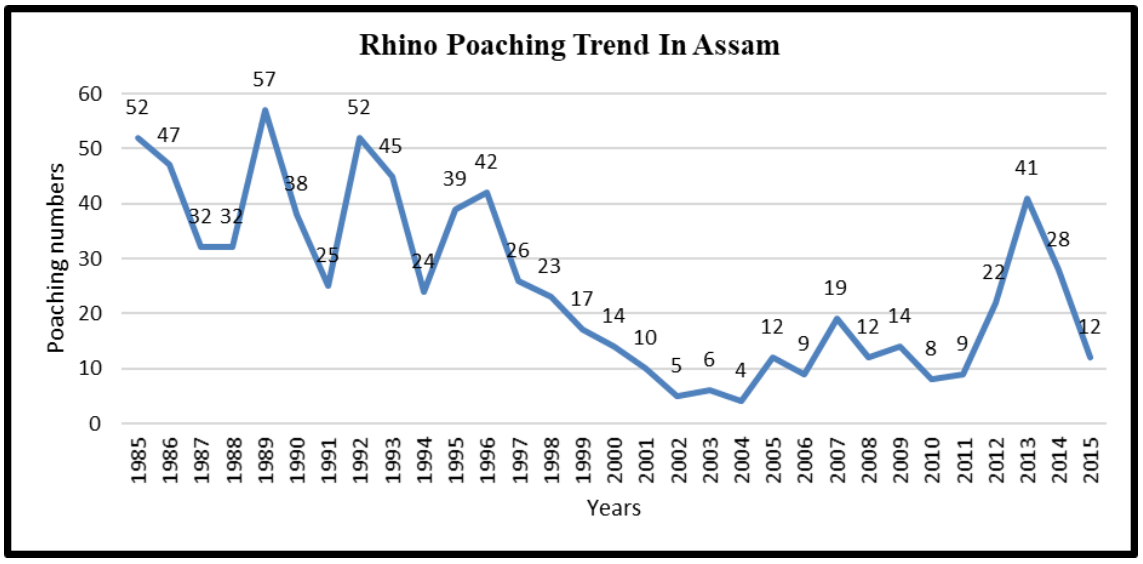


Fig.1.3 GoH Poaching Figure from the year 1985 to 2015 at Assam (Source: The Forest & Environment Department, Govt. of Assam)

Table.1.2 Greater One-horned Rhinoceros Population in India and Nepal

Sl. No	Name of the Rhino bearing Protected Areas	Country	State/District	Area (Km^2)	Population Figure
1.	Kaziranga NP	India	Assam	884.43	2401 (2015)
2	Jaldapara NP	India	West Bengal	216	204 (2014)
3	Rajiv Gandhi Orang NP	India	Assam	78.80	100 (2012)
4	Pobitora WLS	India	Assam	38.81	93 (2012)
5	Gorumara NP	India	West Bengal	79	50 (2014)
6	Dudhwa NP	India	Uttar Pradesh	684	32 (2015)
7	Manas NP	India	Assam	500	28 (2016)
8	Chitwan NP	Nepal	Chitwan	932	605 (2015)
9	Bardia NP	Nepal	Bardia	968	29 (2015)
10	Shuklaphanta WR	Nepal	Kanchanpur	305	8 (2015)

(Sources: Government Census Reports**)**

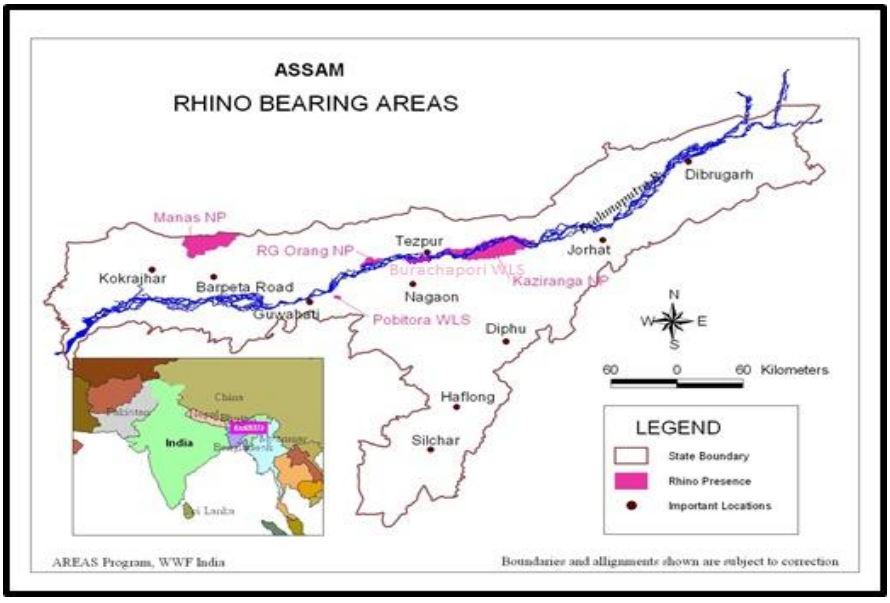


Fig.1.4 Present Rhino Bearing Areas of Assam (Source: WWF-India)

Translocation is the intentional release of the animal to the wild in an attempt to establish, re-establish or augment the population. Translocations have been used to establish the population of non-native species and restore native species extirpated due to poaching or hunting (Griffith *et al.,* 1989). Translocation processes have proved to be valuable conservation both as a component of successful early restoration of animal communities and for assessing the extent of ecosystem dysfunction (Sankar *et al.,* 2010).

Species translocation is a remarkable experiment in evolutionary ecology and increasingly critical to biodiversity conservation. Translocation process involves tiny invertebrate (Morris,2000), fishes (Minckley,1995), amphibian (Germano and Bishop,2009), reptiles (Germano and Bishop,2009), birds(Burger and Both,2011) to larger mammals like elephant (Fernando *et al*., 2012), rhino (Emslie *et al.*,2009), bison (Sankar *et al.*,2013), tiger (Sankar *et al.*,2010), lion (Hunter *et al.*,2007) etc. Several plant species (Sandrine *et al.,* 2011) were also reintroduced under the process of translocation.

The risk in a translocation is multiple, affecting many ways focal species, their associated communities and ecosystem functions in both source and destination areas. Therefore, a proper plan is required to avoid disastrous consequences on any translocation process (IUCN, 2012).Till 1990 the success and effect of translocation program were not well evaluated because there was rarely appreciable post-release monitoring. Since 1995 the post-release monitoring program carefully developed and documented in order to gain knowledge from strategies the succeeded or failed (Grosset and Grandjean 2010). The International Union for Conservation of Nature (IUCN)

established Reintroduction Specialist Group (RSG) in the year 1998. It was established to assist reintroduction practitioners in conducting animal reintroduction project worldwide (IUCN, 1998).

The success of animal population restoration efforts depends in parts on clarification of both the normative and the technical components of translocation goal (Breitenmoser *et al.,* 2001). According to Soorae (2010) assessment, 12% of global translocation program were highly successful, 46% were successful, and 36% were partially successful with only 6% failure. Therefore, translocation should follow a logical process from initial concepts to design, feasibility and risk assessment decision making, implementation, and evaluation.

European bison (*Bison bonesus)* reintroduction program in Europe (Buntjer *et al.,*2002), Peregrine Falcon (*Falco peregrinus)* reintroduction program in North America (Heinzel *et al.,* 1995), Golden lion tamarin (*Leontopithecus rosalia*) in Brazil (Sussman,2000), Arabian Oryx (*Oryx leocoryn*)in Oman in 1980 (Spalton,1999), Red Wolf (*Canis rufus*) recovery program in Eastern North Carolina (USA) (Carrol *et al.*2003, Beeland,2013)were some of the successful animal translocation programs in the world.

Translocation has become a routine in a number of African rhino range states and has played a vital role in increasing both White and Black rhinoceros numbers. The process of translocation has helped Africa's Southern White rhino's population to increase 10 times in recent past. Similarly, translocation has also played a key role in increasing black rhino numbers in major rhino range states in Africa (Hofmeyr *et al.,* 1975; Hitchin, 1984; Adcock *et al.,* 1998; Emslie and Brooks, 1999).

There were several efforts which have been undertaken to translocate the Sumatran Rhinos to Indonesia, England, USA, and Malaysia from 1988-1990 but the program failed due to a combination of poor breeding and very high mortality rate in captivity (Zahari, 1995). No attempt was made to translocate the Javan rhino to establish a second population (Shatiapillae, 1986; Ellis, 2010).

In Nepal, 87(83 to Bardia NP and 4 to Shuklaphanta Wildlife Reserve) rhinos were translocated to Bardia NP and Shuklaphanta WR from Chitwan NP of Nepal during1986 - 2002 (Jnawali, 1995; Dinerstein, 2003; Emslie *et al.,* 2009).

In India, Tiger (*Panthera tigris tigris*) translocation program to Sariska Tiger Reserve from Ranthambore Tiger Reserve during 2008 - 2010 (Sankar *et al.,* 2010), Gaur (*Bos gaurus gaurus*) translocation program to Bhandhabghar Tiger Reserve during 2011 - 2012 (Sankar*et al*.,2013), GoH Translocation program from KNP and PWS to MNP during 2008-2012 (Singh *et al.*,2012), Eastern Swamp Deer (*Reucervus duvacucelii ranjitsinhi*) from KNP to MNP in 2014 (Wild Life Trust of India (WTI, 2014) , Pygmy hog (*Porcula salvania)*reintroduction program in Nameri NP and RGONP in Assam (Narayan, 1990; Narayan *et.al.*,2013) are some successful animal translocation program in India in recent past.

There are lots of planning going on for translocation of threatened as well as critically endangered animals in India. The government of India has also planned to translocate Asiatic Lion (*Panthera leo*) from Gir Forest, Gujarat to Kuno WLS in Madhya Pradesh (Johnsingh, 2006). Asiatic Cheetah reintroduction program in Madhya Pradesh and Rajasthan is another ambitious program of Government of India to reintroduce Cheetah in previous ranging areas (Ranjitsingh & Jhala, 2010).

As per 1979 report of the Species Survival Commission, Asian Rhino Specialist Group (Schenkel & Schenkel, 1979) emphasized the need for continuous effort in the protection and monitoring of the GoH species, adding that steps must be envisaged to establish additional viable population units in suitable areas, preferably in the rhino's former distribution range. Due to intense anthropogenic pressure and poaching, several rhino populations were declared locally extinct as well as the lack of sufficient natural corridors between protected areas prevents animals to move freely. So, translocations have proved to be the valuable tool for the recovery of this species. (Griffith *et al.*, 1989).

In 1949, the first initiative to address the need of translocating rhinos was brought up in the meeting of the Indian Board for Wildlife. The first reintroduction of rhinos happened in Dudhwa NP (Uttar Pradesh) in the year 1984 where four rhinos were translocated from Assam and four from Chitwan NP, Nepal were translocated to the park. Reintroduced population of Dudhwa NP gradually recovered to 32 individuals in 2015 (Sinha *et al.*, 1994).

In 1993, Conservation Breeding Specialist Group at SSC/IUCN had developed a meta-population management strategy by the inclusion of translocation and reintroduction of rhinoceros mainly in India and provided necessary implication for that process (Molur *et al.*1993). In 1993, The Protected Area Management Group of Conservation Breeding Specialist Group IUCN/SSC suggested possible rhino reintroduction in potential areas of Assam Viz. Laokhowa and Burhachapori Wildlife Sanctuary (WLS), Kochmara reserve forest, Kuruwa reserve forest & Disangmukh area of Assam (Molur *et al.*, 1993).The GoH population was again reviewed by the Working

Group on Translocation rhinos in Assam during the Regional Meeting for India and Nepal of the IUCN/SSC Asian Rhino Specialist Group in 1999. The working group listed four suitable areas for rhino translocation viz. Laokhowa Complex (Including Burhachapori, Kochmara), Dibru-Saikhowa WLS (now National Park), Pani-Dehing WLS and Sonai-Rupai WLS. In the same event, thediscussionwas also held on enhancing the security of the existing rhinoceros population Manas National Park and also prioritizing the same as a potential site for translocations (VanStrien and Foose, 1999).

Until the 1980s, six protected areas in Assam had breeding populations of GoH. However, an armed insurgency problem, which led to a breakdown of law and order in Assam, resulted in the extermination of rhinos from Laokhowa WLS &Burhachapori WLS and MNP by the end of the 1990s leaving only three sites with GoH rhinoceros(Choudhury, 1985). Therefore, several efforts have been taken to proper management of rhinoceros population with respect to improve protection, range expansion and habitat.

In 2005, this case for pro-active management got a boost when Umfolozi in Kwazulu-Natal (South Africa) was compared to Kaziranga NP in Assam. Both the sites had started with less than 100 rhinos a century ago, but due to pro-active management, Umfolozi created new populations via translocations, resulting in a southern white rhinoceros population of over 18,000, and over 2,000 rhinoceros in Kaziranga where a strict protection strategy was adopted in addition to general management.

The Department of Environment and Forests, Government of Assam realised that the rhino population needs to be re-introduced to additional potential rhino habitats

of the state to expand populations and initiated the Indian Rhino Vision (IRV) 2020 program in 2005 in partnership with International Rhino Foundation (IRF), World Wide Fund for Nature (WWF) and the United States Fish and Wildlife Service (USFWS). The IRV 2020 program's vision is "to have a rhino population of 3,000 in Assam spread over seven of its protected areas by the year 2020". The program was launched on 12th April 2008 with the translocation of two male rhinos from the PWS to the Rhino release site at Buraburijhar area under Bansbari range at Manas National Park (Bonal *et al.*,2008)(Fig.1.2).

As part of the rhino population range expansion strategy, 18 rhinos were translocated ten (10) rhinoceros from PWS and eight (8) rhinoceros from KNP to MNP during 2008 to 2012 in six batches (Singh *et al.*, 2012). The Government of Assam and Wildlife Trust of India (WTI) translocated 10 rhinos from CWRC (Centre for Wildlife Rescue and Conservation (CWRC), KNP, Assam) to Manas under the rescue and rehabilitated program from the period 2006 to 2013(Barman *et al*.,2014)(Appendix I).

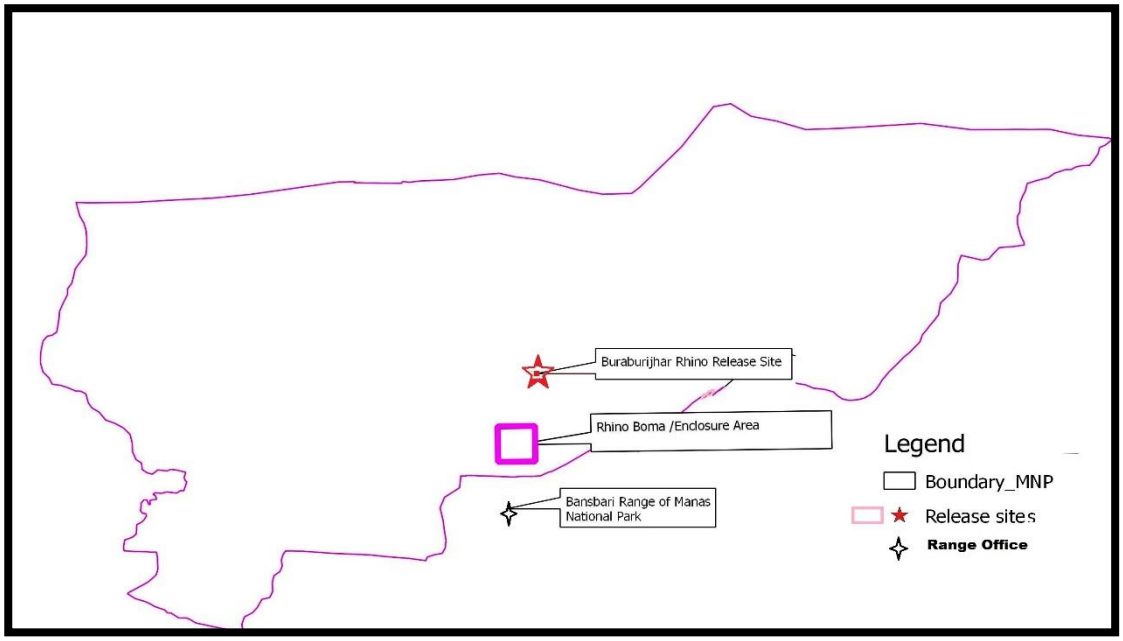


Fig 1.5 Rhino Release Sites of Manas National Park

Reestablishment of new rhino population at Manas NP through the wild-to wild translocation program under IRV 2020 opened up new dimension in conservation efforts for this magnificent pachyderm.

From the period of 1989 and 2003, there was severe social unrest in adjoining areas of MNP due to Bodoland movement (Nath, 2003). The violent struggle devastated MNP infrastructure and relinquished the park protection system. 100 rhinoceros population were left unprotected and poachers killed all the rhinos at MNP (Table.1.3). This put Manas on the World Heritage (UNESCO) Site *in Danger* list (Vigne and Martin, 1994; Menon, 1996; Ghose and Kumar, 2012).

MNP was selected as the first rhino translocation site under IRV 2020. Entire rhino translocation procedure followed a logical method from initial concept design, feasibility and risk assessment, decision making and implementation process, monitoring adjustment and evaluation process. In this extensive and crucial process of

translocation, post-released monitoring and research was treated as priority subject for the success of rhino translocation program (Bonal *et al.*, 2008; Singh *et al.*, 2012).

Table 1.3 Population and Poaching of Native Rhinos at Manas National Park (Upto 2001)

Year	Population	Poaching	Remarks
1962		1	
1963		1	
1965		1	
1966	15	0	Population estimated by Gee and quoted by Spillet (1966)
1971		1	
1976	40	4	Population estimation by Laurie (1978)
1977	75	0	Population estimation by Deb Roy (1991)
1978		1	
1981		2	
1982		1	
1983		3	
1984		4	
1985		1	
1986	75-80	1	Population estimation by Forest department
1987		7	
1988		1	
1989	85	6	Population estimation by Forest department
1990	85-100	2	Population estimation by Forest department
1991		3	
1992	80	11	Population estimation by Forest department
1993	60/30	22	Population estimation by Forest department
1995	30/120		Population estimation by Forest department
2001	-	1	Poaching as reported by Forest Department & this was the last resident rhino of Manas NP

(Source- Ghose and Dutta, 2014)

Demographic performance is the key aspects for the success of any translocation program. Therefore, newly released rhinos under the wild to wild translocation program needs extensive post-release monitoring to determine the extent of their movement, dispersal pattern and use of habitat (water body, feeding pattern and habitat types) at different times since release in respect to different seasons. It is also helpful to identify

any threat to translocated populations which were not expected while designing the translocation process (Emslie *et al.*, 2009; IUCN, 2013). Monitoring of translocated rhinoceros' behaviour can be valuable and it could be treated as an early indicator of translocation progress. In addition to that post-releasemonitoring, conclusions may guide to other GoH translocation process in Assam as well as in the entire country.

Therefore, systematic study of Behaviour and Habitat Preference of Translocated Rhinos (*Rhinoceros unicornis*) at Manas NP was carried out for a scientific understanding of the adaptation of Translocated rhinos in new habitat through the observation of its behavior for better management of the species and its conservation. This present study may be helpful in future efforts of GoH translocation in recipient sites. This study may also help MNP authority to prepare rhino conservation strategy for maintenance of a viable GoH population in near future. Following are my objectives of the studies:

i. To study the behavior of translocated rhinos in Manas National Park.
ii. To investigate the habitat utilization by the translocated rhinos.
iii. To study food plant preferences and seasonal variations.
iv. To study the association among the rhinos and with other wild animals.

Chapter 2
Review of Literature

2.1 Historical Records of Rhinos

Rhinos were mentioned in various folklore, legends, mythology and religious notes. Hindu mythology also placed the greater one-horned rhinoceros on a highly revered pedestal ocPlenty of archaeological evidence shows the significance to earlier civilization in the Indian subcontinent can be found. Some information indicates larger geographical distribution of Indian rhinoceros population than it has been known in more recent times (Rookmaaker, 1980). Rhino's information was found in Indus Valley Civilization which is about 5000 years old during Mohenjo-Daro era. The rhino seals of Mohenjo-Daro and Harappa are well known as they were found in early excavations, but artifacts depicting the animals were found in many other sites too (Choudhury,1985). The representation of the GoH at Mahenjodaro indicates that the species occurred as far south and west as the present Sind Provinces of Pakistan.

In Chandogya Upanishad (900 BC), the occurrence of rhino in India was recorded along with elephant and buffalo, lived in marshes and grazed on the river banks (Rao 1957; Laurie 1978). There are two early stone relics of rhinoceros from

middle age India. At Sanchi, a stone relic showing rhino was found in the Buddhist Stupa No.2 which dates back to 2nd century B.C. Another same period relic from an undocumented locality is on exhibit at the Indian Museum in Kolkata. Madhya Pradesh is also a location for some significant rock engraving with rhinoceros. The first petroglyphs depicting a rhinoceros were found by John Cockburn and Archibald Carleyle near Mirzapur in 1880. The remains of rhino have also been discovered in places like Gujarat too (Choudhury, 1985; Clutton-Brock, 1965; Momin *et al.* 1973).

The Greek physician Ctesias was the first European author who mentioned Indian rhinoceros as the 'Indian Ass' from whose horn a poison detecting cup could be made (Van Strien,1974). Several European authors described rhinos at first hand; their accounts matched strongly with Cetasius. They described rhinoceros rather fanciful ways than realistic views (Laurie, 1978).

There were many records of GoH found in religious literature as well as travelers accounts in the medieval period. The travelers like Al-Biruni (c.1030) and Iban Battuta (c.1334) mentioned rhino in their respective accounts of western and northern India and it was found that Emperor Timur Lane, who invaded India, hunted many rhinos on the frontier of Kashmir in 1398 A.D.(Choudhury,1985). Marco Polo, the famous 13th-century traveler who visited Asia, described rhino in his travel account (Dutta,1991). Records from the time of the Mughal emperors have provided useful evidence of the areas in which rhinoceros were present. The Mughal Emperor Babur (1505-1530) mentioned the existence of rhino in most part of Gangetic U.P. (Uttar Pradesh) in *Babur Nama*. Towards the end of the same century, the Mughal Emperor Akbar in 1590 and Jahangir hunted rhinoceros in western Uttar Pradesh. The Indian

rhinoceros has also been recorded in Sylhet (Bangladesh) and Cachar (Rookmaaker, 1980; Choudhury, 1985).

The first rhino to reach Europe after the fall of Roman Empire was an Indian rhino sent in 1515 by Muzaffar, King of Cambia in Western India, as a gift to King Manual of Portugal (Costa A.Fontourada,1937). A few months after its arrival in Lisbon, King Manuel was described to offer the rhino to Pope Leo X, but the ship carrying it was lost in the Gulf of Genoa, and the animal was drowned. Meanwhile, a drawing of the rhino, possibly by a Portuguese artist and a description by Valentin Ferdinand had reached Nuremberg, where Albrecht Durer made his famous woodcut (Figure 2.1). Parsons (1743) tried to describe the detailed scientific description of the rhinoceros with external drawing. He described the rhinoceros which was brought to London in 1739 that rhino was the second Indian rhinoceros recorded in England and the fourth in Europe (Clarke, 1973).

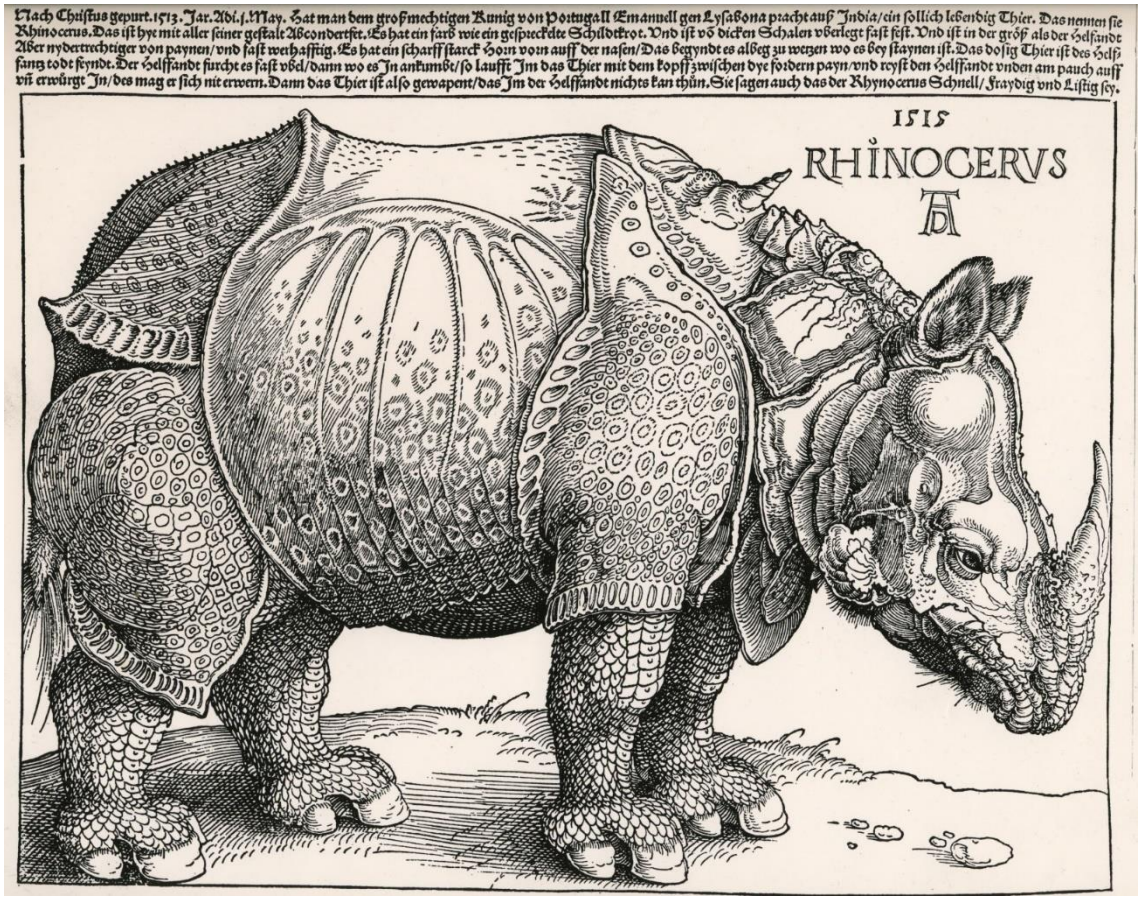


Fig.2.1 The First State Impression of Albrecht Durer's (1471-1572) (Source http://www.rhinoresourcecenter.com)

There were numerous 19th-century literature (created by Surveyors and Military officers, Tea planters, Businessmen and Passionate Hunters etc.) mentioning greater one-horned rhinoceros. Cosh (1837) mentioned the capture process of rhinos in wild condition. He also described the killing of rhino for horn and its market value. McClelland (1839) cataloged birds and mammalian species to study the prospects of tea plantation in Upper Assam and compared the diversity of plants and animals with tea plantation areas of China. He mentioned 324 mammalian species including rhinoceros in Assam. Butler (1847) mentioned the abundance of rhinoceros and its habitat in Assam during the early ninety century. He mentioned capture process of wild

rhinoceros and selling of tamed ones in Calcutta. The first captive rhino birth was recorded in Kathmandu in 1826 (Hodgson, 1834) and second was recorded in Calcutta in 1925 (Gee, 1953a).

Maharaja of Cooch Behar (1908) mentioned remarkable hunting history of Cooch Behar, Western Assam including the Bank of the river Manas. The Maharaja visited Assam with the British associates in the year 1895, 1899 and 1906. Maharaja and British counterpart hunted 454 rhinoceros in the twenty-five years of their hunting history. Ellision and Perry (1925) mentioned detailed account of sports animals in eastern India including rhinoceros.

At the end of 19th century, concern for wildlife conservation and protection was felt by the then British Government of India. Hunting in Assam was regulated in 1889 as per regulation by Dennis Fitzpatrick and prohibited all shooting in reserved forest from November to June without permission of a range officer. Lord Curzon, the appointed Viceroy in 1899, led the effort to create game reserves to secure the future of India's wildlife (Raleigh,1906). Following the Curzon's effort, several wildlife sanctuaries were established laying the foundation of successful system of national parks on which today's conservation efforts depends.

General outlook on rhino conservation being altered gradually since British government promulgation on conservation and protection issues of wildlife. There were studies which mentioned limited distribution and critically threatened population status of rhinoceros. Manners-Smith (1909) gave an account of the distribution and abundance of the Indian rhino in Nepal and Bihar. Gruning (1911) gave a detailed account of flora and fauna of Jalpaiguri district in Eastern Bengal showing concern over protection of rhinoceros, buffalo, and bison. Bhuyan (1931) recorded rhino and elephant killing in the

remote part of Assam and he urged to implement the stringent law to stop the illegal practice in this region. He also suggested better protection in all forest areas including Manas. Milroy (1934) advocated for adequate protection to games in Assam. He emphasized that community participation in protection of games was essential as Forest Department was unable to control indiscriminate shooting of rhino and other bigger games. Stracey (1951) had raised worrisome situation about declining population trend of rhinoceros. He also showed concern for protection and necessary assistance for future conservation of species. Ali (1950) urged on more detailed scientific studies on rhinoceros species for better management of its population. Gee (1964) mentioned increased rhino poaching incidences and wanted better protection in rhino-bearing areas of Assam. Spilleit (1966) mentioned better population status of rhinoceros due to improved protection and management of habitat in rhino-bearing areas of India and Nepal.

The first attempt to conserve the rhinoceros in Assam was through Assam Forest Regulation, 1891 and subsequently the Assam Rhinoceros Prevention Act, 1915. This act was again upgraded in 1954 as Assam Rhinoceros Act, 1954. Kaziranga, Manas, and Laokhowa were declared as rhino-bearing protected areas and accordingly provided legal protection. In Bengal, the initial control for rhino conservation came through Indian Forest Act 1927 followed by Bengal Rhinoceros Prevention Act 1932. Jaldapara and Grumarah were declared as rhino-bearing areas of Bengal and provided legal protection in those habitats since past. The Wildlife (Protection) Act, 1972 which is applicable all over India except Jammu and Kashmir currently provides protection to rhino and its habitat. Wildlife (Protection) Act placed Rhinoceros schedule-I (Part1)

which provides complete protection to the species in India (Molur *et al.*, 1993; VanStrien and Foose, 1999).

Besides enforcement, rhinos being survived due to dedicated efforts of some forest officers such as Shebbeare in Jaldapara West Bengal, Milroy and Miri in Kaziranga, Debroy in MNP and many others. Due to relentless work of some excellent forest officers, field patrolling staff', fringe communities from in an around each rhino-bearing of Assam has contributed immensely to increase the greater one-horned rhinoceros population from verge of extinction in the early 20th century to more than 2621 rhinoceros in the year 2015.

2.2 Presence of Rhinoceros at Manas National Park

Historically entire alluvial plains of Brahmaputra Valley were once populated with GoH population. Due to changes of the river course, increased agricultural activity, expansion of human settlement led shrinkages of habitat for these megaherbivores. Various authors, surveyors, hunters and forest officers mentioned about the presence of rhinos in Manas landscape since the past. Manas was the hunting reserve of rhinoceros and other games for the Royal family of Cooch Behar and King of Gouripur (Swargowari,2012). The Maharaja (1908) documented details of hunting stories of rhinoceros and other games in the dense and thick forest of Bansbari and Bhuyanpara. Lt. Col. Pollok (1879) hunted one rhino for the first time in his life at Bornagar (near Panbari range of MNP).

First two decades of 20th century observed much awareness on security and conservation of rhinoceros in entire Assam including Manas. It was declared as North Kamrup Reserve Forest in the year 1907 and as Manas sanctuary in the year 1928 for the protection of rhinoceros (UNEP, 2012). Milroy (1934) was the forest officer of the

imperial government of Assam and worked extensively on rhino and other game preservation in states. He documented the rhinoceros status in entire provinces of India, Nepal and proclaimed security and habitat improvement of all rhino-bearing areas of Assam including Manas. Starcey (1949) stated that two sanctuaries (Kaziranga and Manas) and two reserves (Pabha and Sonai-Rupai) were with rhinoceros and suggested for improvement security condition. He mentioned about 150 rhinoceros at Kaziranga, more than 100 rhinoceros in Manas and a few rhinoceros at Sonai-Rupai reserve. Gee (1950) mentioned presence of about 45 rhinoceros in Manas. He showed concern over continuous poaching of rhinoceros at Manas. Burnett (1958), mentioned Manas an unspoiled and untouched area in respect to another part of India. He found frequent rhino poaching cases in Manas and suggested to improve the security measures of entire rhinoceros population. He reported existence of about 20 rhinoceros exist at Manas. He noticed rhino stray incident and crop raiding in adjoining areas of Manas park boundary and which might irritated fringe villagers and led to the retaliatory killing of the animal. Wayre (1968) mentioned that rhino was not often seen due to the amount of dense vegetation cover and he observed more aggressive behaviour at Manas rhinos than those of Kaziranga's rhinos. Waller (1972) noted Manas as potential rhino habitat and pointed out improvement in security condition which, however, caused increase in rhino population. Laurie (1978) mentioned approximate 45 rhinoceros in Manas.

Manas Tiger Reserve was declared in the year 1972 with core areas of Manas Wildlife Sanctuary. Debroy (1991) the first Field Director of Manas Tiger Reserve noted 80 rhinoceros population and indicated building of rhinoceros population at a gradual pace. He mentioned that two third of the sanctuary area is ideal habitat for this species. Subsequently, much effort was put forwarded to improve the security of

Manas. Due to the improved security in the 70's, rhino population was increased approximately from 45 to near about 100 in the early eighties (Vigne and Martin,1994).

However, Manas Rhino population underwent major setback in the fifteen years of social unrest due to Bodoland agitation. During this period, rampant poaching completely wiped the rhino population from the Manas and declared locally extinct from that localities. Manas NP was also inscribed as World Heritage Site in danger in the year 1992 (Vigne and Martin ,1994; Menon,1996; UNEP,2012).

With the declaration of Bodoland Accord between Bodoland Liberation Tiger (BLT) and Government of Assam in the year 2003, the entire BTAD region was stabilized (Nath, 2003). Therefore, Manas was selected as first recipient sites of the rhino range expansion program of Government of Assam which is popularly known as Indian Rhino Vision 2020 . IRV2020 was designed by Government of Assam, with the support from International Rhino Foundation (IRF), World Wide Fund for Nature (WWF) and the United States Fish and Wildlife Service (USFWS) in 2005 to help in maintaining existing rhino populations and to reintroduce rhinos into protected areas from which they were exterminated in the recent past (Bonal *et al*.,2008). Another 10 rhinos released at Manas which was rescued at Kaziranga NP and later on rehabilitated and released at Manas (Barman *et al.*,2014).

2.3 Behaviour Studies of Rhinoceros

2.3.1 General Behaviour Studies on Rhinoceros

There were plentiful accounts on the behaviour of Indian rhinoceros since the past. Many British sports person, military officer, hunters, surveyors had described general behavior account of greater one-horned rhinoceros.

McClelland (1839), Butler (1847, 1855), described rhinoceros' general behaviors and mentioned about the preferences of rhinoceros to use dense grassland areas with plenty of water and mud.

Pollok (1879) described three Asian rhinoceros species (Indian, Javan, and Sumatran) with their morphology, behavior and habitat pattern. He reported that Indian rhinos preferred flood plain as well as terai-bhabar areas (foot hills of Bhutan). Javan and Sumatran rhinoceros preferred shrubs and woodland areas. As compared to the Indian rhinoceros, Javan and Sumatran rhinoceros are agile and fast runners. All the three species of rhinoceros are very solitary except females when they have calf.

Scientific studies on rhinoceros ecology and behavior were pioneered by Gee (1950-1964) in Kaziranga NP of Assam. Gee (1953a, 1953b, 1954) documented mating, aggressive and territoriality behavior of rhinoceros in Kaziranga and mentioned that two factors govern between mating of rhinos-the receptivity of the female and the sexual preparedness of male. He observed that during courtship, dominant male rhino always eliminates the other male competent beforehand of mating. Whistling, urination, vigorous running of male rhino behind female are associated with premating period. He observed that female rhinoceros were rarely aggressive unless there is a cow with a young calf.

Ali (1950) and Ripley (1952) surveyed rhinoceros population of Brahmaputra valley of Assam in the year 1949 and documented general behavior (feeding, wallowing, resting) of rhinoceros. They suggested more and more scientific studies should be carried on rhinoceros for better preservation of species.

Ripley (1952) studied the territorial and sexual behavior of rhinoceros. He noted that the rhino maintain loose territory covering average 20-50 acres of areas encompassing *beels and swamps* . He observed that at certain time of year some rhino wander/stray far away from the protected areas. He recorded minimum lactation period of female is about six month and gestation period is about 19 months.

Kakoti and Rajkhowa (1972) documented the reproductive behavior of rhinoceros in captive rhinos in Gauhati zoo, Assam. They recorded female rhino's first mating age to be about 5 years 21 months, gestation period 16 months and inter calving period 28 months.

Ulrich (1972) studied social behavior and social organization of rhinoceros in Kaziranga NP and noted they maintained loose territory as well as social bonding in rhinoceros.

Lahan (1974) studied the aggressive behavior of rhinoceros in respect to territoriality, mating, association and sex in Kaziranga NP. He focussed on single adult male dominant behaviour and pairing with female rhinos during mating seasons.

The most detailed work on greater one-horned rhinoceros was carried out by Laurie (1972-1976) in the Chitwan Valley of Southern Nepal. Laurie (1978) exclusively studied rhinoceros distribution, behavior and habitat patterns. He reported that rhinos are predominately solitary but temporary association was also observed during wallowing, mating and feeding. He found that the rhinoceros spent 36% feeding, during

monsoon, 57% in winter and 65% in spring season. He observed loose territory of breeding adult males and recorded 10 auditory displays among rhinos.

Laurie (1982) studied rhinoceros' territoriality, communication and vocalization, wallowing, defensive, interaction, and reproductive behavior. He recorded females first calved at a mean age of 7.1years and the median inter-calving interval was 2.8 years. He also noticed that young shoots of the tall grasses which made the bulk of the diet in the spring season, short grassland during monsoon and scrub and short grassland during the winter season and frequency of wallowing was lower in colder days during monsoon but rain itself did not result in an immediate reduction in wallowing.

Dinerstein and Wemmer (1988) studied frugivorous habit of *Trewia nudiflora* in Chitwan Valley. They have also studied the role of rhinoceros in seed dispersal of the studied tree species.

Dutta and Bhattacharya (1989) documented daily activity pattern of rhinoceros in Kaziranga NP. They observed the general pattern of grazing during early morning and late evening and reported that in March, rhinos exhibited grazing activity from 5:00 am to 9:25 am after which they enter wallowing pits till evening. They also observed the nocturnal grazing activity of rhinos from 5:00 pm-11:00 pm. They mentioned that rhinos graze whole day in colder and cloudy day irrespective of seasons.

Ghose (1991) did behavior studies of rhinoceros in relation to different ecological aspects at Jaldapara WLS of West Bengal. He mentioned that short grassland with perennial water bodies is most important factor for improvement of productivity of the species.

Dutta (1991) documented a detailed account of rhinoceros behavior in Kaziranga NP and observed the rhinoceros behaviour is restricted to 'eat, sleep and wallow' and very limited period devoted on other behaviour.

Yadav (2000) documented the aggressive behavior of male rhinoceros in Jaldapara NP, West Bengal. He recorded the temporary association between adult male and female during mating season. He observed that during the mating season, dominant bull shows antagonistic behaviour to other male rhinos. Behaviour like squirt urination, digging earth with hind legs, rubbing horn in medium girth size trees, approach to other weaker rhinos with widely opened mouth to overpower are common signs of premating.

Patar (2005) studied feeding, wallowing, resting, territoriality and social behavior of rhinoceros in Kaziranga NP. He observed that due to territorial nature of dominant adults, breeding males have maximum access to available resources like food, water, space, and mates than other weak male rhinos. The territorial bull tries to keep the potentially estrous adult female within its territory for a few weeks. He found rhinos generally graze during the late afternoon, evening and night. Rhino commonly preferred wallowing on 8:00-16:00 hours in the wet season and between 9:00-14:00 hours in dry season.

Hazarika (2007); Hazarika and Saikia (2010, 2012) documented the general behavior of rhinoceros, feeding pattern and seasonal food preferences in RGONP, Assam. They revealed two fundamental and basic types of behaviour, the breeding and non-breeding behaviour. They categorized 14 major behavioural patterns in respect to their daily activity.

Bhatta (2011) documented feeding, territoriality, aggression and stray pattern of rhinoceros at PWS. According to his study, the habitat of rhinoceros at PWS degraded

extensively due to different types natural and anthropogenic pressure. Rhino population also reached up to the carrying capacity level of PWS. Therefore, rhinoceros frequently stray out to distant areas from the park in search of food and shelter.

Hazarika *et al.* (2013) studied activity budgeting of rhinoceros with the support of Scan sampling and Ad Libitum sampling method. As per their study, it was revealed that rhinoceros displayed distinct behavior variations throughout the year.

2.3.2 Behaviour Studies of Translocated Indian Rhinoceros

There were very limited studies on the behaviour of translocated Indian rhinoceros, as translocation practices are limited in this region as compared to Black and White Rhinoceros of African rhino range countries. Dudhwa NP in Uttar Pradesh and Western Nepal Rhinoceros population were established through the translocation process and substantially, limited behavior studies on translocated rhinos were carried out.

From 1986 to 2003, 87 rhinos were translocated from Chitwan to Bardia NP (83) and Suklaphnata WLS (4). Jnawali (1995) studied the behaviour of that small population of rhinoceros at Bardia NP in relation with ecological aspects from 1990-1993. As per the study, he found differences in ranging behaviour between donor and founder population. These attributed to low animal density and suddenly changed animal sex ratio. After translocation, founder population bred at a same high rate as recorded donor (Chitwan NP) population. Study revealed that high breeding rate and low mortality rate of calves and adult indicated adequate quality habitat of Bardia NP.

Dinerstein (2003) documented the behaviour of rhinoceros in Bardia NP. He recorded seasonal behaviour changes in Bardia rhinos in comparison to the Chitwan rhinos. He tried to correlate behaviour (feeding and wallowing) of rhinos to prepare protection strategies of the park.

Sale and Singh (1987) documented the detailed account of rhino translocation to Dudhwa NP and their adaptive nature in a new environment. They reported that initial behaviour patterns (feeding, movement and association) of rhinoceros were monitored daily basis and observed normal.

Sinha and Swarkar (1994) analysed ten years of Dudhwa rhino introduction program and showed concern on the aggressive and intolerant behavior of lone adult bull (Bankey) to other sub- adult and inbreeding threat to reintroduced rhino population.

Sinha *et al.* (2011) studied the social and mating behavior of rhinoceros at Dudhwa NP. They observed that rhino population increased from 5 founder rhinos to 30 rhinos which include 25 new born calves within 25 km rhino enclosure. All these calves born are the progeny of single dominant male-Bankey (the adult male). So, they predict inbreeding depression in that small rhino population which is a threat to genetic viability.

In Manas NP, Bonal *et al.* (2008) documented the process of translocation and dispersal pattern of rhinoceros after the release of two adult males. He reported that immediately after release at Manas, rhinos were moved about 5 km distance from the release sites and later on they settle on two different locations.

Tripathi (2013) documented the social and reproductive behavior and provided some important suggestions to incorporate in management strategy rhinoceros population at Dudhwa NP. He also observed male and female association only in mating

season within 25 km rhino enclosure. The most common association was found in mother and calf and among sub adults. Mating behaviour constitutes whistling, running, chasing, aggressive nature occurs prior 6-10 hour of copulation.

2.4 Studies on Habitat Preferences

2.4.1 Studies on General Habitat Preference

Different researchers studied and reported various accounts on habitat and ecology of Indian rhinoceros since the past. Gee (1953a, 1964) mentioned rhinoceros habitats and ecology in Kaziranga NP and Chitwan NP (Nepal). He described both protected areas had excellent habitat composition for rhinos. He mentioned the aquatic habitat degradation due to rapid propagation of water hyacinth in Kaziranga.

Burnett (1958) mentioned that Manas possesses few perennial waterholes and which directly influenced the rhinoceros low population growth. Therefore, he requested park authority to maintain proper habitat management with perennial water sources.

Avari (1957) studied about habitat situation of Jaldapara in fifties decades of 21st century. He reported suitable rhinoceros habitat at Jaldapara with mixed vegetations including several low lying isolated swamps.He suggested better management of habitat to increase the productivity of rhinoceros populations.

Starcey (1963) indicated the ecological management of rhino habitats and provided implications for better management of grassland habitats in Kaziranga NP. He also mentioned that use of fire to hold the ecological succession of the grass stage is obligatory at Kaziranga.

Lahan and Sonowal (1973) documented habitat preferences of rhinoceros in Kaziranga NP and provide a necessary suggestion for improvement during monsoon and dry period. They found that Kaziranga rhinoceros preferred open and short grassland for most of the time. So, they suggested annual control burning to reduce the density of thick and tall grassland areas. They also mentioned flood is essential for maintaining the habitat of Kaziranga but river erosion has greatly reduced the areas of the park.

Lahan (1974) again studied biotic and edaphic factors influences on rhinoceros population of Kaziranga NP. He observed that annual control grassland burning and annual flood is essential to maintain habitat of Kaziranga. But river erosion, an increase of water hyacinth in water bodies, invasion of weed like Mikania in grassland habitat, disease and poaching are some major threats to the future survival of rhino at Kaziranga NP.

Laurie (1978) documented the habitat preferences of rhinoceros in respect to different seasons in Chitwan NP. He found that rhinoceros in Chitwan reach their highest densities in areas with greatest vegetation densities.

Following Laurie's studies, some good research work were undertaken by several researchers in Chitwan NP. Dinerstein (1979a) has studied ecological aspects of Royal Karnali-Bardia Wildlife Reserve (Present Bardia NP) and habitat interaction. He identified six major vegetational associations in Bardia which includes several subtypes of *Shorea robusta*, open grassland, savannah and riverine forest.

Blanford and Price (1991) and Dinerstein and Price (1991) contemporarily studied demography and habitat used by Rhinoceros in Chitwan Valley. They have

studied from the period of 1984 to 1988 in Chitwan and observed rhino population pattern and influences of habitat on their population growth.

Ghose (1991) studied eco-status of rhinoceros with special reference to altered habitat due to human interference in Jaldapara WLS (now National Park).

Dinerstein (1992) again studied the effect of rhinoceros on riverine forest structure in Lowland Nepal. Purpose of his study was to elucidate how large mammalian herbivores (rhino and elephant) influences forest structure and canopy composition by the vertical growth of sapling that is frequently browsed and trampled.

Bist (1994) studied rhino range areas habitat status and entire wild rhino population of West Bengal. He reported that gradual loss of rhino habitat was due to the extension of agriculture and establishment of tea gardens, encroachment in rhino habitat due to the influx of refugee from Bangladesh, river erosion due to five fast flowing river traversing into North Bengal and improper forestry practices.

Barua (1998) mentioned about rhino habitat degradation of Pobitora Wildlife Sanctuary due to annual flood, invasion of invasive species like *Albezzia procera* in grassland and cattle grazing.

Kushwaha *et al*. (2000) studied the land area change and rhino habitat suitability in Kaziranga NP. They found that Kaziranga NP is by and large suitable for rhinoceros. As per the study, they identified 27% of park areas was unsuitable for rhinoceros and suggested proper scientific management of such habitats.

Banerjee *et al*. (2001) studied habitat used by rhinoceros and other sympatric herbivores in Kaziranga NP and provided scientific insight to manage habitat and herbivore population.

Kandel (2003) studied rhinoceros' foraging activity in correlation with different habitats of Chitwan NP. He observed that maximum proportion of time spent feeding was in the grassland followed riverine mixed forest in the ecotone. Rhinos used riverine mixed forest a lot for resting during afternoon hours.

Dinerstein (2003) reported home range changes of adult males and adult females in relation to different seasons at Chitwan NP. He observed that annual home range of adult males were larger than that of adult females.

Rawat (2005) critically analysed vegetation of rhinoceros at North Bengal. He reported that continuous intervention necessary to check weed invasion in rhino preferred grassland and water bodies. He urged long term monitoring of vegetation/habitat and water courses with the support of remote sensing technology for future predict of rhino habitat trend.

Bairagee *et al.* (2003) reported dominant tall grassland species influences on rhinoceros habitats at Pobitora WLS. According to this study, grass species *Imperata cylindrica* is significantly dominant in disturbed and managed areas. But in unmanaged and undisturbed areas, the growth pattern of this species was observed to be slower and assemblages pattern of species was dominated by other grass species along with forbes.

Kandel and Jhala (2008) studied eight free ranging rhinoceros habitat preferences at Chitwan NP and they observed that rhinoceros used grasslands, riverine mixed forest, and ecotones and were not observed to use Sal forest.

The study by Agarwal *et al*. (2010) was aimed to identify suitable habitat area for rhinoceros using the geo-spatial tool. They used seven variables i.e. road network, railway network, national highway, digital elevation model (DEM), land use land cover

(LULC), settlement and protected area as important factors in determining the rhinoceros habitat area.

Hazarika and Saikia (2011) studied rhinoceros' habitat utilization and seasonal ranging pattern of RGONP. They reported that the rhinos showed seasonal variations of habitat and wet grassland, water bodies are used by rhinoceros throughout the year.

Bailey (2011) studied seasonal changes of habitat condition and ranging pattern of rhinoceros at Chitwan NP. He designed his study with the support of econometric model to understand rhinoceros crop damage pattern in fringe village areas and villagers' responses on such incidence.

Bhatta (2011) studied ecological aspects of Pobitora WLS rhinoceros and mentioned the seasonal ranging pattern of male and female rhinoceros. He reported the habitat of Pobitora degraded due to improper management of habitat, invasion of weeds, cattle grazing and numerous anthropogenic pressure. The study revealed that park management control was mainly protection based and less priority were given to habitat management.

Subedi (2012) studied invasive species' impacts on rhinoceros habitat in Chitwan NP. He reported the influence of seasonal variations in habitat preferences. He found three to six folds increment in home range sizes in Chitwan rhinos compared to previous studies which may be attributed to habitat degradation due to the invasion of invasive species, plant succession and low density rhino population.

Sarma *et al.* (2012) studied rhinoceros habitat utilization pattern considering hydrology, flood impact and spread of invasive species mimosa at RGONP. They found that rhinos used wet alluvial grassland in all round the years. They also reported that habitat utilization pattern of rhinoceros is dependent upon food, grass cover, and water.

Thapa *et al.*(2014) used geographical information system (GIS) and remote sensing to build habitat suitability model for the rhinoceros and provided management implications to Chitwan NP. They suggested that several variables such as land cover types, water availability, topography, altitude, human activities and their impact on species and habitat are significant in predicting suitable habitat for rhinoceros.

2.4.2 Habitat Preference Studies on Translocated Indian Rhinoceros

Jnawali (1995) studied population ecology of translocated rhinoceros at Bardia NP with particular emphasis on habitat preferences, ranging behavior and food ecology of donor population of Chitwan NP. He reported average larger home range size of rhinoceros at Bardia then donor population (Chitwan rhinos). He also observed seasonal home range size varied 13.3km^2 to 21.2km^2 which was >8 times larger than donor population. This finding attributed to low rhinoceros density and sex ratio at Bardia NP.

Jnawali and Wegge (1995) worked on nine radio-collared rhinoceros habitats use and speciation pattern which was similar to earlier works by Jnawali (1995).

Fjellstad and Steinheim (1996) compared rhinoceros and elephants' habitat preferences in Babai Valley Bardia NP. They stated that rhinoceros and elephants both preferred tall grass flood plain and Khair-Sisoo forest. An elephant usually prefers savannah woodland whereas rhino prefers moist riverine forest.

Steinheim *et al*. (2005) worked on dry season habitat use of rhinoceros at Bardia NP. They also studied how rhinoceros and sympatric species of elephants shared their space in the same habitat.

In Manas, habitat preferences studies for translocated rhinos are in the nascent stage. Patar *et al.* (2007) studied on habitat suitability for rhino at Manas NP before

translocation. They have found suitable habitat prevail in Manas for the reintroduction of rhinoceros. They suggested scientific management of grassland habitat of Manas as well as water bodies for better productivity of rhinoceros and other herbivores.

Bezbarua (2008) conducted the study at Manas with the support of earlier research, base map, satellite imagery and ground survey before rhino translocation. As per the study, he observed rhino's favorable habitats prevail in Bansbari and Bhuyanpara ranges of MNP.

Thapa *et al.* (2009) conducted a study on habitat preferences of translocated rhinoceros in Bardia NP and Shuklaphanta WLS based on direct observation and survey on rhino sign from the period of 2003-2005. They found that rhinoceros were used grassland intermixed with wetlands and riverine forests.

Tripathi (2012) studied ecological requirements of rhino enclosure areas from January to December 2011 in Dudhwa NP and subsequently provided habitat management recommendations for better productivity of rhino stocking areas. He reported that water bodies were heavily silted and therefore suggested to prepare more perennial water sources for better productivity of habitat.

2.5. Studies on Food Preferences and Association Pattern of Rhinos

2.5.1. Studies on general food preferences and association pattern

There are fewer studies on food preferences and association pattern of greater one-horned rhinoceros.

Starcey (1951) mentioned the difference in feeding habits of three Asian rhinoceros species. He stated that Indian rhinoceros have high crowned grinding teeth so they are able to adapt in grazing. Other two species (Javan and Sumatran rhinoceros)

are mainly browser with short-crowned teeth and are mainly confined to tree forest zones.

Barhmachary *et al.* (1971) studied the grass species preferences by a rhino at Jaldapara NP and they also identify faecal remains with microscopic slides. They suggested that microscopic identification of faecal remains were the most comprehensive methods to understand rhinoceros food habit.

Buechner and Mackler (1975) did a study on the mother-calf relationship of Indian rhinoceros and their feeding pattern. They mentioned that the mother and calf are a common association of rhinoceros besides temporary association observed among sub adult rhinoceros and adult male and female during mating seasons.

Laurie (1978) mentioned that rhinos eat 183 species of plants belonging to 57 families. He reported that grasses constitute of 70-89% of their diet. He observed that rhinos have a very temporary association and commonly associated with wallowing and grazing activates. But mother and young calf have a longer period of association observed at Chitwan NP. Similar to other previous workers, he also observed temporary association among subadult rhinoceros and adult male and female during mating seasons.

Jnawali (1986) did a study on the diet analysis of Indian rhinoceros by faecal analysis in Chitwan NP. He observed that grasses are the main constituent of diet as observed by Barhmachary *et al.* (1971); Laurie (1978).

Jnawali (1995) recorded 283 rhino preferred food plant species available at Chitwan NP. He recorded 131 tall grass species in Chitwan. He mentioned that *Saccharum sp. Narenga porphyrocoma* (among grasses) *Trewia nudiflora, Litsea*

monopetal, Coffea bengalensis and *Murraya paniculate* are common food plants for rhinoceros.

Dutta (1991) stated as Indian rhinos are primarily a grazer, grass plays a major role in its food requirements. He mentioned that during the floods at Kaziranga NP, animals are forced to change their food habit for a limited period due to the scarcity of grasses. During that period, rhinoceros turn into a semi-browser. He again reported that Indian rhinoceros have very loose social bonding. Adult male and a female associate during the mating period and mother and calf are found to be associated till the age of average three years.

Mary *et al.* (1998) studied food preference of rhinos in Kaziranga NP in respect to different seasons. They reported 47 preferable species at Kaziranga. They observed that short and open grassland, water bodies with rich aquatic fodder determine the distribution of animals.

Dinerstein and Wemmer (1988) studied rhinos' fruit eating habit of *Trewia nudiflora* tree at Chitwan Valley. They observed that rhinoceros play a crucial role in the dispersal of this species.

Talukdar (1999) did study on the population pattern of rhinoceros and its association with cattle at Pobitora Wildlife Sanctuary. He indicated cattle grazing, weed invasion in the grassland areas were a major threat to rhino habitat.

Banerjee *et al*. (2001) did a study on association pattern of elephants and other herbivores at Kaziranga NP. They noticed that larger herbivores commonly shared their grazing spaces without disturbing each other.

Patar (2005) did study on the food preferences and association pattern of Indian rhinoceros. He also mentioned seasonally preferred and most preferred grass species of

rhinoceros in Kaziranga NP. He documented 47 rhino preferred plant species in Kaziranga NP. He reported that nearly 77% of the rhino's diet consisted of four grass species,i.e.*Arundo donax, Hemarthria compressa, Erianthus sp., and Cynodon dactylon.* Patar (2005) highlighted that most valuable species, in terms of bulk contribution to the rhino's diet in the short grass area were *Hemarthria compressa, C. rubrobrunnea* and *Arundo donax.*

Kandel and Jhala (2008) estimated food habits of rhinoceros from 11.101 bite counts from 7 rhinoceros from different habitats of Chitwan NP. They were observed to eat 42 different plant species by Rhinoceros. They highlighted the importance of few food plants like *Saccharum spontaneum, Phragmites karka and Imperata cylindrica* which constitute more than 65% of the dry matter intake by rhinos. They also reported the relative importance of short grasslands and riverine mixed forest habitats for effective conservation of rhinos.

Konwar *et al.* (2009) did study on the rhinoceros food availability at PWS. They identified 32 food plant species preferred by rhinos among which 15 were grasses, 4 shrubs, 5 aquatic hydrophytes and 8 tree species.

Bhatta (2011) recorded 163 species of rhinoceros preferred plants. In the same study, he mentioned interspecies and intraspecies association pattern of rhinoceros in PWS.

Hazarika and Saikia (2012) recorded 138 species of preferred food plants by rhinos in RGONP. They identified 75 species of grasses, 27 species of herbs-shrubs, 27 species of trees and 9 species of aquatic plant species. They noticed that grass species alone have enough to provide food for rhinoceros at RGONP. They also reported soil licking and crop raiding incidences of rhinoceros at the fringe of RGONP.

Thakur *et al.* (2014) studied nutrient analysis of grass species consumed by rhinoceros at Chitwan NP. They selected 8 most preferred grass species of rhinoceros at Chitwan. Among these grasses, they found highest calcium content in *Cynodon dactylon* .

2.5.2. Food Preferences and Association Pattern Studies on Translocated Indian Rhinoceros

There are very limited studies on translocated rhinoceros' food preferences and association pattern. Jnawali (1995) recorded 179 numbers of rhinoceros' preferred species at Bardia NP. He recorded 79 tall grass species and among them, *Saccharum spontaneum* and *Mallouts phillippinensis* were found more abundant at Bardia.

Fellstad and Steinheim (1996); Steinheim *et al. (*2005) studied the dry season diet of an Indian elephant and Indian rhinoceros in Bardia NP. They stated that rhinoceros consumed food by 63% graze and 28% browse, while elephant consumed 65% browse and 24% graze.

Dinerstein (2003) did study on the seasonal preferences of rhinoceros food plants in Bardia NP and compared research findings with Chitwan NP rhinoceros. He mentioned that the diet of rhinoceros was diverse, but 10 plant species were found to be similar with both two sites and constitutes 75% of the total volume of diet in both areas. He also observed seasonal variations on food plant preferences in both two sites. According to his observation rhinoceros in Bardia NP ate the highest proportion of available plants (24%) during the cool season, but Chitwan NP rhinoceros consumed highest proportion (11%) during monsoon season.

Wegge *et al.*(2006); Pradhan *et al.*(2008), studied microhistrological analysis of faecal material to compare early dry season diet of rhino and other sympatric ungulates

inhabit in the same alluvial grassland habitat of lowland Nepal of Bardia NP. They observed that grasses constitute bulk diet of the animal.

Tripathi (2013) did studies on social organization Indian rhinoceros in Dudhwa NP. He mentioned that Rhino Rehabilitated Area (RRA) of Dudhwa comprises of higher level of woodland and typical low lying wet tall and less moist short grasslands. He reported 55 species of rhinoceros preferred food plants inside RRA. These include 23 species of grass and herbs, 8 species of aquatic plants, 12 tree species, 5 species woody climbers and shrubs and 1 species of ferns.

Chapter 3
Materials and Methods

3.1 Study Area

Manas National Park is one of the most stunning and pristine wildlife habitats in the world. MNP is situated at latitude 26°30′ N to 27°00′ N and longitude 91°51′ E to 92°00′ E. It is located in the foothill zone of the Himalayas on the north bank of Brahmaputra Valley and falls within the district's boundaries of Chirang and Baksa along the international boundary between India and Bhutan (Fig. 3.1).

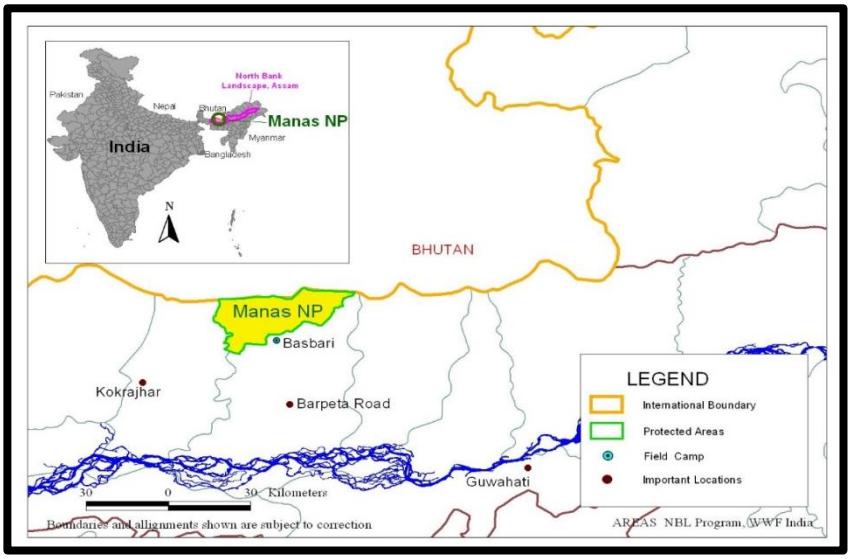


Fig. 3.1 Manas National Park (Source WWF-India)

MNP has good rhino habitat and prior to 1989, more than 100 rhinos were estimated there. The entire population of Manas was wiped out due to poaching in the early nineties (Vigne and Martin, 1994; Menon, 1996; UNEP, 2012).

In a motive to increase the rhino population in Assam, the Government of Assam, with support from International Rhino Foundation (IRF), World Wide Fund for Nature (WWF) and the United States Fish and Wildlife Service (USFWS), launched the Indian Rhino Vision 2020 (IRV2020) in the year 2005 to help the existing rhino population and to reintroduce rhinos into protected areas from which they were exterminated in the recent past. The program is aimed to achieve a population of 3000 rhinos by the year 2020 at seven Protected Areas in Assam.

As a part of IRV2020 range expansion program in Assam, 18 rhinos were translocated to Manas National Park from PWS and KNP during the period 2008 to 2012 (Singh *et al.,* 2012). Newly released rhinos under wild to wild translocation program require extensive post-release monitoring and research on their behavioral attributes in a novel environment (IUCN, 2012). Therefore, MNP was selected as a study area for the present research work.

Table 3.1 Details of Greater one-horned rhinoceros translocated to MNP under the program IRV 2020.

Batch no.	Translocated rhinos			Place of Origin	Date of release
	No.	Description	Code Nos.		
1	2	Two adult males	R1, R2	PWS	12 Apr 2008
2	2	Adult female with female calf	R3, R4	PWS	28 Dec 2010
3	4	Adult female with male calf One adult male One adult female	R6, R7 R5 R8	PWS PWS PWS	18 Jan 2011
4	2	Two adult females	R9, R10	PWS	9 Jan 2012
5	4	Adult female with female calf Adult female with male calf	R12, R11 R13, R14	KNP KNP	20 Jan 2012
6	4	Adult females with male calf Adult female with male calf	R15, R16 R17, R18	KNP KNP	12 Jan 2012

MNP has an area encompassing 500 km^2 and has the unique distinction of being a UNESCO (Natural) World Heritage Site. It is the core area of Manas Tiger Reserve Chirang-Ripu Elephant Reserve, Manas Biosphere Reserve and as well as an Important Bird Area (Swargowari, 2012) (Appendix II).

The sanctuary area was also inscribed in the list of World Heritage Site in 1985 for its outstanding universal value. Manas is a site with outstanding universal value under the UNESCO Natural Criteria: (vii), (ix) and (x)**.** MNP has been evaluated to meet these outstanding values on the following basis:

(vii) The reserve contains superlative natural features of exceptional natural beauty in terms of its scenic attraction of forested hills, alluvial grassland, and semi-evergreen forests.

(ix) The Manas River is an outstanding example of the geological process and biological evolution with its huge depositional load and shifting river channels.

(x) Manas provide critical and viable habitat for more rare and endangered species than any other protected areas of the Indian Subcontinent's. It is the only and the best remaining natural area where sizable populations of several species can continue to survive. (Debonnet and Herve, 2008).

3.2 Relief

The park is situated in a gentle slope from the foothills of Bhutan on the north to south direction. The northern belt of the track with major grassland areas of Manas is almost flat and well drained. The natural gradient of the land is a gentle sloping towards south and area along the southern boundary is flatter and get waterlogged during the rains.

The fast flowing Manas river, on entering the plains from the steep hills, loses its speed and as a result, deposits enormous quantities of boulders, stones, sand, silt and other debris that are carried down by the water and this leads to the formation of alluvial terraces, comprising deep layers of rocks and sands deposits.

Over the limestone and sandstone bedrock of the *bhabar savanna* area in the north, this has formed shifting river channels and swamps and a soil of porous alluvial terraces of coarse detritus under layers of sandy loam and humus where the water level

is very low. The Terai grasslands in the south consist of deep deposits of fine alluvium with underlying pans where the water table lies near the surface, making it potentially useful farmland. Elevation ranges from 50m MSL on the southern boundary to 250m MSL along the Bhutan hills.

3.3 Climate

The climate of Manas is moist tropical with an annual rainfall of 3000 mm - 4000 mm. The climate can be divided into four distinct seasons based on the variation in the rainfall, temperature, and winds (Borthakur, 1986).

Winter (December - February)

The season is characterized by cool weather and fog. The temperature remains 20°C ± 5°C. January is the coldest month. Average total rainfall is 114 mm with a relative humidity of 77% ± 5.

Pre-Monsoon (March - May)

It is a transitional period between relatively dry winter and hot summer and is characterized by a rapid rise in temperature. As the season advances, the amount and frequency of rainfall increases due to frequent thundershowers with hailstorms. Average total rainfall during the season is 518.70 mm. The season is marked progressively by a greater number of cloudy days. Average temperature and humidity in this season are 23°C ±5°C and 70% ±5 respectively.

Monsoon (June-September)

It is the major rainy season of the year. The average monthly rainfall is 2860 mm. The average temperature during this season is 27.17°C with an average diurnal range of over 6°C. The humidity increases to 82% ± 5. August is the hottest month.

Retreating monsoon (October-November)

Towards the end of September, the monsoon weakens with an abrupt retreat followed by fair weather. With the advancing of the season, the temperature falls and moving mist and fog appears. The average temperature is 27°C ±2. The average monthly rainfall is 1400 mm and the rainy days become fewer. Relative humidity is 82% ± 5.

3.4 Natural Vegetation

Manas National Park represents unique Tropical Humid Forest Biome under the Brahmaputra valley [9a] province of the biogeographic zonation of India, in the Indo-Malayan realm (Myers, 2000). The Forests of Manas National Park are classified into six types in accordance with the classification system of Champion and Seth (1968). These are as follows:

(a) Sub-Himalayan High Alluvial Semi Evergreen Forests

The canopy of this forest occurs in the northern belt of the Park. There is an emergent layer of Bhelu (*Tetrameles nudiflora*) trees which is typical to this type. Below this emergent layer of deciduous species, the top storey is formed by Badam (*Mansonia dipikae*), Bogijam (*Eugenia jambos*), Bonsum, Amari (*Amoora wallichii*),

Bogipoma (*Chukrassia tabularis*), Khokan (*Duabanga grandiflora*) etc. The middle storey is made up of Jia (*Lannea grandis*), Udal (*Sterculia vilosa*), Gohera (*Zanthoxylum rhetsa*), Brajanali, and Lauraceous plants etc. The ground cover is made up of evergreen shrubs. Climbers are abundant and some of the species met with such formation are *Vitis, Thunbergia, Piper* and *Mikania* sp. etc.

(b) Eastern Bhabar Sal Type Forests

The Pure patches of Koroi (*Albizia procera*) occur in the moister parts along the banks of streams and rivers. Koroi occasionally predominates such patches and associates are Simul (*Bombax ceiba*), Jam (*Eugenia jambolana*), Gamari (*Gmelina arborea*) and Udal (*Sterculia vilosa*). The middle storey is made up of young Bhelkhor, *Macaranga* species and occasionally Palash (*Butea monosperma*). The ground cover consists of fern, *Colocassia sp Solanum sp* etc. with occasional *Zizyphus sp* and *Eupatorium odoratum* in open locations. Infestation of the climber *Mikania scandens* is rather heavy and it forms a thick cover on the ground.

(c) East Himalayan Moist Mixed Deciduous Forest

The canopy formed by this type of forest occupies some of the hill slopes near the northern boundary and the plain in bhabar areas. This type also occurs as strips and belts along the watercourses in the midst of Savannah formations. The forests appear to be transitional in nature and are likely to pass on to the next stage (Semi evergreen) in presence of favourable circumstances like protection from fires in course of succession. Some of the other top storey species met within the above formation are *Premna sp* Kathia, Koroi (*Albizia procera*), Kanchan (*Bauhinia purpurea*), Hatipolia (*Pterospermum acerifloium*), Dudhi, Siris (*Albizia lebbek*), Brajanali (*Zanthophy*

lumrhetusa) etc. The middle storey is occupied by sapling of Sida, Bohera (*Terminalia bellerica*), Hilikha (*Terminalia chebula*), Simul (*Bombax ceiba*), Parali, Jia, Poma, Kuhir, and Hatipolia etc.

(d) Low Alluvial Savannah Woodland

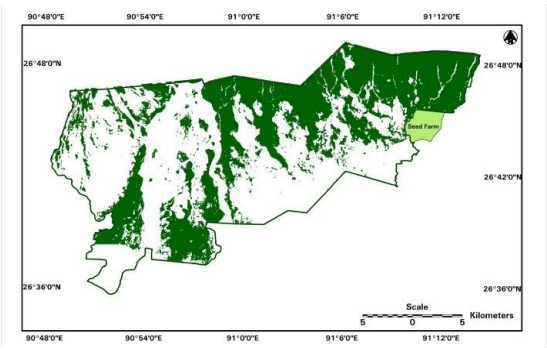
This type of forest occupies the extensive area, which is subject to annual fires. Very scattered and stunted growth of Sida, Udal, Oxi, Kum and occasional Gamari is a common site in such areas. Due to the absolute open conditions, no differentiations between top-storey and mid-storey are practicable. However, smaller saplings of tree species mentioned above along with Amlakhi (*Emblica officinalis*), Khair (*Acacia catechu*), Gundali etc. are also observed in this canopy. Rare and solitude Sal (*Shorea robusta*) trees as well as in small groves are found in a few locations in the Park. Grasses occurring in this type are *Imperata cylindrica, Saccharum sp., Narenga porphyracoma, Arundinella bengalensis, Brynea bengalensis, Grewia sapida, Premna herbacea* etc. and terrestrial orchids are characteristic associates in this grassland.

(e) Assam Valley Semi-Evergreen Forests

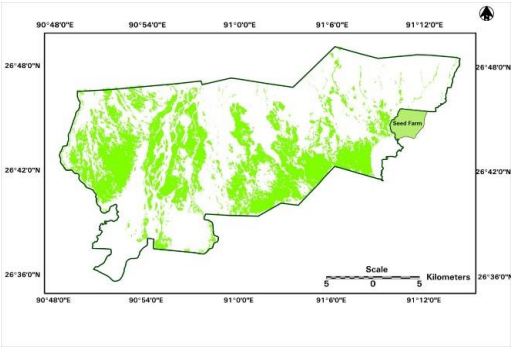
This type occupies in patches in the of terrain belt of the Park. The top storey species in this canopy are Paruli, Hatipolia, Owtenga (*Dillenia indica*), Poma, Uriam (*Bischofia javanica*) etc. The middle storey is made up of Kuhi, Kathia Koroi etc. The ground cover is represented by *Leea* sp *Desmodium sp* and *Alipinia sp* and various monocots. Epiphytic orchids like *Cymbidium aloifolium, Acampe multiflora, Dendrobium aphylum, Dendrobium jenkinsii, Aerides multiflora, Rhynchostylis retusa,* etc. are wide spread.

(f) Eastern Wet Alluvial Grassland

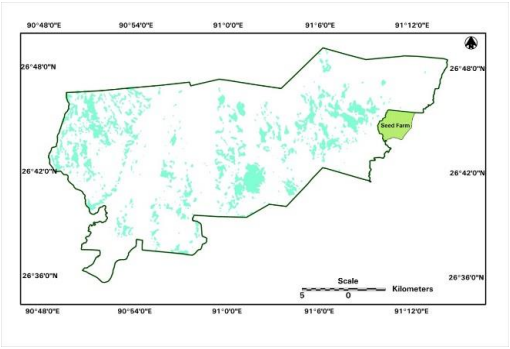
On heavily drained and low-lying locations, there is a change in the composition of the vegetations and in such locations occasional Koroi, Urium (*Bischofia javanica*), Owtenga (*Dillenia indica*), Bhelkor and Simul (*Bombax ceiba*) are common. Some of the grasses found in such areas are *Saccharum sp, Apludaa ristata*, *Erianthus sp* etc. In the extreme form of this type of forest, perennial water bodies (swamps) and trees such as *Salix sp* and *Polygonum sp* are present.



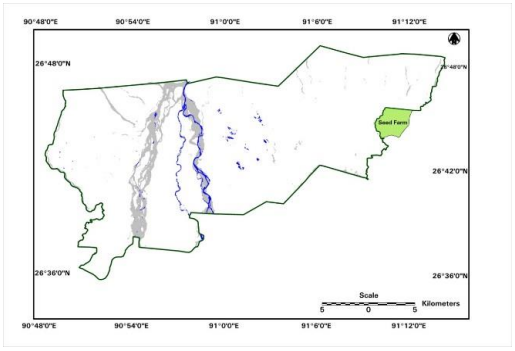
Wood land distribution MNP



Grassland distribution of MNP



Swampy areas of MNP



River sand and water bodies

Fig. 3.2 Vegetation Distribution Patterns of MNP (Source Aaraynak)

3.5 Wild Fauna

MNP is famous for its rich faunal biodiversity, including species such as rhino (*Rhinoceros unicornis),* tiger (*Panthera tigris tigris*), pygmy hog (*Sus salvanius*), golden langur (*Trachypithecus geei*), hispid hare (*Caprolagus hispidus*), Bengal florican (*Houbarogsis bangalensis*), and white-winged wood duck (*Cairina scutulata*). The Manas National Park harbours 61 species of mammals, 450 species of birds, 42 species of reptiles, 9 species of amphibians, 79 species of fishes and more than 200 species of butterfly and 100 species of invertebrates.

3.6 Materials and Methods

This study was carried out in Manas National Park within the period of six years 2008 to 2013. Rhinos were radio-collared with very high frequency (VHF) radio collars (African Wildlife Tracking) at capture sites (KNP and PWS). During the study period, one UHF (Ultra High Frequency) radio collar was also used experimentally to track rhino locations. Tracking of the rhinos was carried out using directional antennae (Telonics RA-14K antennae, 148–152 MHz) and VHF radio receiver to record the data (Communication Specialists, R-1000 receiver, 148–152 MHz).For UHF data download, Console (Del: 5G68WF1) was used. A directional compass was used to triangulate Rhino locations in dense and tall vegetation and Windows software Locate II and Locate III was used to obtain spatial information.

All data was accumulated for comparison and preparation of comprehensive rhino monitoring guide for Manas Rhino Monitoring Team (Ghose and Dutta, 2014). Five pairs of camera trap *Cuddeback Capture* (with the passive infra-red sensor and white flash 3MP resolution) were used to observe rhinos in some of the logistically

difficult to access areas. Rhinos were ear-notched as per IUCN-AsRSG methods at the capture site for better identification after the radio collar stopped functioning.

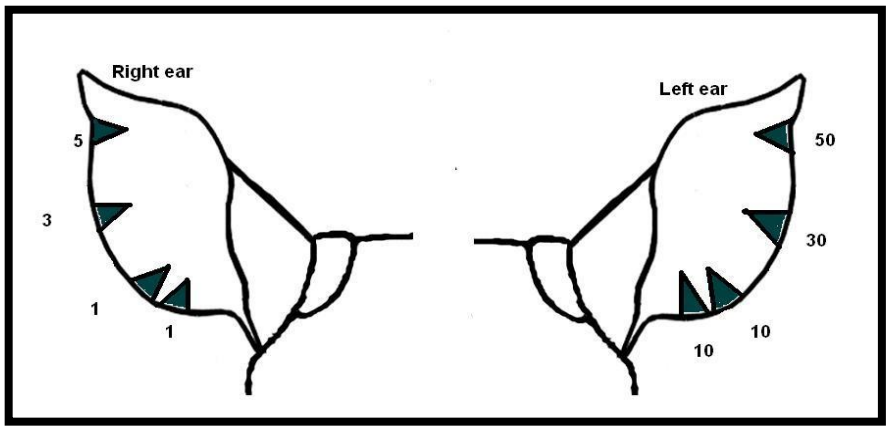


Fig. 3.3 GoH Ear Notching Method (AsRSG)

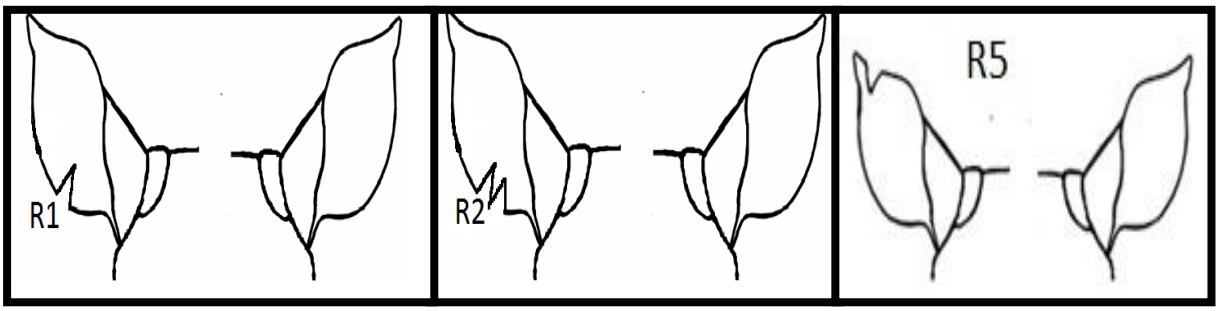


Fig. 3.4 Ear Notch of Adult Males R1, R2 and R5

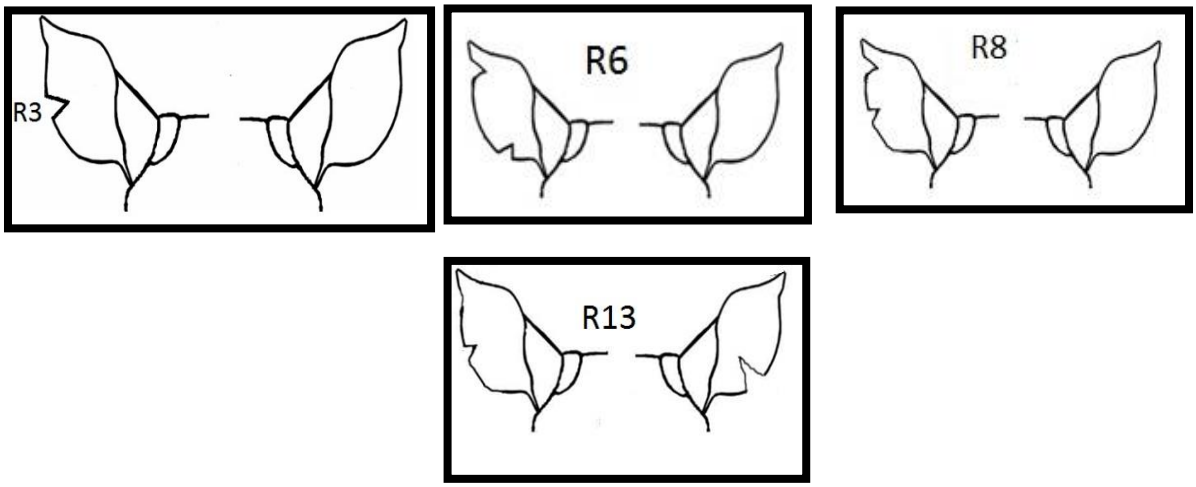


Fig. 3.5 Ear Notch of Adult Females R3, R6, R8 and R13

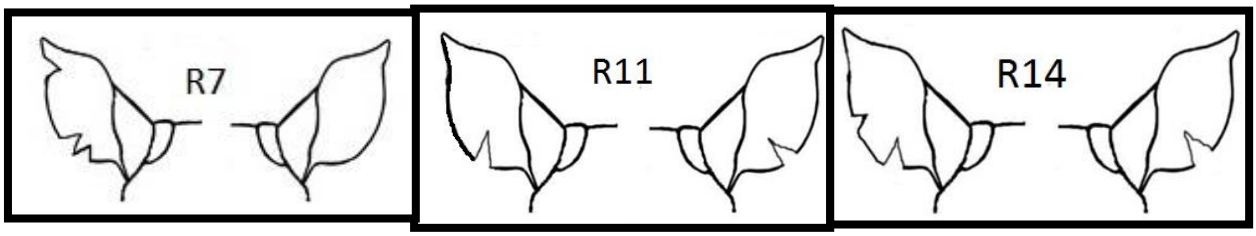


Fig. 3.6 Ear Notch of Rhino Calves R7, R14 and R11

Immediately after release, rhinos were tracked and located daily at three times viz. morning, afternoon and evening (i.e. from 06:00 -10:00hrs, 10:00– 14:00hrs and 14:00- 18:00hrs). Sometimes rhinos were also located at night (i.e. 18:00-06:00hrs), depending on the accessibility.

According to IUCN, Guidelines for the *in situ* Reintroduction and Translocation of African and Asian rhinoceros, 2009, this post release rhino monitoring and research approach was divided into two phases- 90 days 'Settling in phase' and long duration seasonal monitoring. Intensive immediate post release (90days) monitoring was carried out to detect problems in individual rhino, allowing prompt remedial and or veterinary action to be taken where appropriate (Emslie *et al.,* 2009).

During the monitoring process, patrolling elephants were used, as well as a four-wheel jeep, motorbikes, and bicycles; sometimes the researcher went on foot to track the rhinoceros and establish GPS coordinates (Photograph 3.10). The monitoring data were collected by the homing-in technique and, when the terrain was impassable, GPS coordinates and rhino locations were obtained by triangulation (Kenward,2001); Freegard, 2009). The possible path taken by the animal was retraced the next day for confirmation of coordinates.

Additional information like the presence of food resources, dung heap, resting and wallowing sites and preferred pathways or *dandi* were also assessed. For continuous tracking (24 hr), the maximum times allotted between locations were 15 minutes.

In addition to recording the location of the rhino being tracked, frequencies of all other rhinos were scanned to determine if any animal was present in the area. The location and distances were determined by receiver's signals. The Strong sound indicates the presence of rhinos in areas around ~300-100m. If such signals were found, receiver *noise button* (Commonly called as 'Gang') was lowered and rhino's direction was closely observed by moving directional antennae. Later on expected location was determined with the support of maximum signal intensity found as per antennae direction. For every location, time, weather condition, vegetation type, nearby anti-poaching camp name or presence and proximity of any other rhino and animals like elephant, buffalo, wild boar even cattle were recorded.

All focal occurrences behaviour sampling (Altman, 1974) was conducted whenever a direct observation was possible. The focal observation was carried out using binoculars (Nikon 10X 40 and 8X21 DH Super Mini Compact) and spatial ancillary information was recorded with handheld GPS unit (Gramin, *GPS map 60CSx*). In the focal sampling, all occurrences of specified actions of one individual were recorded during a predetermined sample of one hour. All occurrences sampling- as per this method, focused on a particular behavior rather than a particular animal.

Behavioral categories were broadly defined as grazing, wallowing, walking, browsing, and resting (Table 3.2). Behavioral states were recorded if they lasted more

than one minute (Kandel, 2008). All data were recorded and analyzed with the support of MS Excel (Zar,2010).

Table 3.2 Ethogram of Rhinoceros Behaviour

Sl No	Type of Behaviour	Description
1	Grazing	Approach grasses and taking in mouth (Laurie,1982; Jnawali,1995)
2	Browsing	Approach bush, tree twigs, taking into mouth by standing or walking (Laurie,1982; Owen and Smith,1988)
3	Wallowing	Almost all parts of body dip into mud and water (Laurie,1982; Dinerstein,2003; Hazarika and Saikia,2012)
4	Resting	Animal in resting position (lying and sitting) inactive and relaxed (Laurie,1982)
5	Walking	Animal moving attentively (Laurie,1982; Dinerstein,2003)

Food plant preferences recorded through direct focal observation (Wallmo and Jeff,1970; Laurie,1982; Kandel *et al*., 2008). With the support of elephant ride and help of binoculars, the rhinos were observed at very close distances (5-10m) (Kandel *et al.*, 2008). Whenever it was required to identify forage species, direct observation was followed by onsite inspection, taking photographs/ video and later identified with a published checklist. (Kandel *et al*., 2008).

ArcGIS 9.2 and ArcView 3.2a (ESRI, 2006) were used to plot and analyse spatial data. Two non-parametric methods, the Minimum Convex Polygon (MCP) (Mohr, 1947) and the Fixed Kernel Density (FKD) (Worton, 1989) were used to

estimate home range size. The 100% MCP (a polygon containing all location estimates, where all vertices are convex) has the advantage of being simple to construct and because its use has a long history, it often enables comparisons to be made with previous work (Harris *et al.*, 1990). To remove the effect of exploratory movements and outlying fixes we computed the 95% MCP (Kernohan *et al*.,2001; White and Garrott ,1990).

The kernel is a nonparametric, probabilistic method, which calculates home range boundaries based on the complete utilization distribution (Worton, 1989). It is one of the best-known density estimation methods in statistics, introduced in the late 1950's for the analysis of time series data (Bowman and Azalini, 1997) and first introduced in the ecological literature by Worton (1987, 1989). The kernel method is useful for identifying areas on the landscape that are of great importance to the individual. The kernel can account for multiple centres of activity (Powell, 2000; Kenward,2001; Kernohan *et al.*,2001), is robust to change in the spatial resolution of the data (Hensteen *et al.,* 1997) and is becoming the methods of choice for modern studies of animal-habitat relationships (Marzluff *et al.,* 2004). The density of the kernel at any location in the home range is a function of how much time the animal spent in that location (Seaman and Powell, 1996).

The smoothing parameter or bandwidth is the critical components in kernel density estimation (Silverman, 1986). Two methods have been evaluated in ecological studies (Kernohan *et al.,* 2001): the Reference methods and the Least Square Cross Validation (LSCV). In this study, FKD 95% estimator was chosen using the Least Square Cross Validation (LSCV) procedure. This method is recommended by many

previous workers (Seaman and Powell, 1996; Seaman *et al.*, 1999; Powell,2000; Hemson *et al.*,2005; Borger *et al*.,2006). The FKD method provide area estimates with very little bias when LSCV was used to select the smoothing parameter (Kernohan *et al.*,2001; Silverman,1986).

Isopleths provides the area of activity hence called the core area. A point of inflexion was used to determine the core area with an area of probability by plotting percentage of FKD at different contour levels against the kernel area. The resulted graph is also called as 'Isopleths Graph' (Powell,2000; Kie *et al.,* 2010). 95% isopleths of the utilization distribution was used as the animal's home range and the 50% isopleths as the core area (CA) (Powell, 2000). As mentioned earlier, radio-telemetry data from 2008-2013 was used to determine the core area isopleths graph of rhinoceros. Program CALHOME (Kie *et al.,* 1996) and ArcGIS 9.2 (ESRI 2006) with Hawth's Tool and Home Range Tool (Rodgers *et al.,* 2007) were used to estimate the core area home range.

Association pattern rhinos were recorded as per focal observation. Animal found in close proximity (within 10m) were recorded as an association (Patton *et al.*, 2012). Association pattern of translocated rhinos and free ranging rehabilitated rhinos were also recorded. Other wild animals association was also recorded as per focal observation (Buechner *et al.*,1975; Talukdar,1999; Patar,2005; Bhatta, 2011; Tripathi, 2013) Rhino's stray occurrences were also recorded during this period.

Bonferroni confidence interval is generally used to know the preference of location types. Neu *et al.* (1974) and Byers and Steihorst (1984) described a statistical method for calculating simultaneous confidence intervals for use with utilization-

availability data. The chi-square test is used to initially determine whether there is a significant difference between the expected utilization of habitat types (based on the frequency of availability) and the observed frequency of usage (Byers and Steihorst., 1984). If the chi-square test indicates a statistically significant difference between expected and observed usage, *Bonferroni confidence* intervals is used to determine which habitat type(s) are being preferred. Neu *et al.* (1974) and Byers and Steihorst. (1984) both used the availability of data in terms of area and the number of individuals encountered in each area.

Simultaneous *Bonferroni confidence* intervals were calculated using the observed proportion of utilization of each habitat type separately. The observed proportion of utilization in each habitat type was the observed usage in that habitat type, divided by the total number of observations in all habitat types. Confidence intervals were calculated using the following formula:

$$\overline{p}_i - Z_{\alpha/2k}\sqrt{\overline{p}_i(1-\overline{p}_i)/n} \le p_i \le \overline{p}_i + Z_{\alpha/2k}\sqrt{\overline{p}_i(1-\overline{p}_i)/n}$$

Where: ***pi*** is the observed proportion of utilization for the *l is the* habitat type, ***Z*** is the z-score based on the chosen ***a*** level (e.g. 0.05) divided by two times the total habitat types (***k***).***n*** **i**s the total number of all observations in all habitat types. If the expected proportion of observations is outside the confidence interval of the observed proportion, it could be determined as the significant difference between expected usage and observed usage, indicating that there was a habitat preference. Habitat information was derived from a satellite image of habitat data from IRS P6 LISS III Satellite Image of November 2013.

3.7 Study Animals

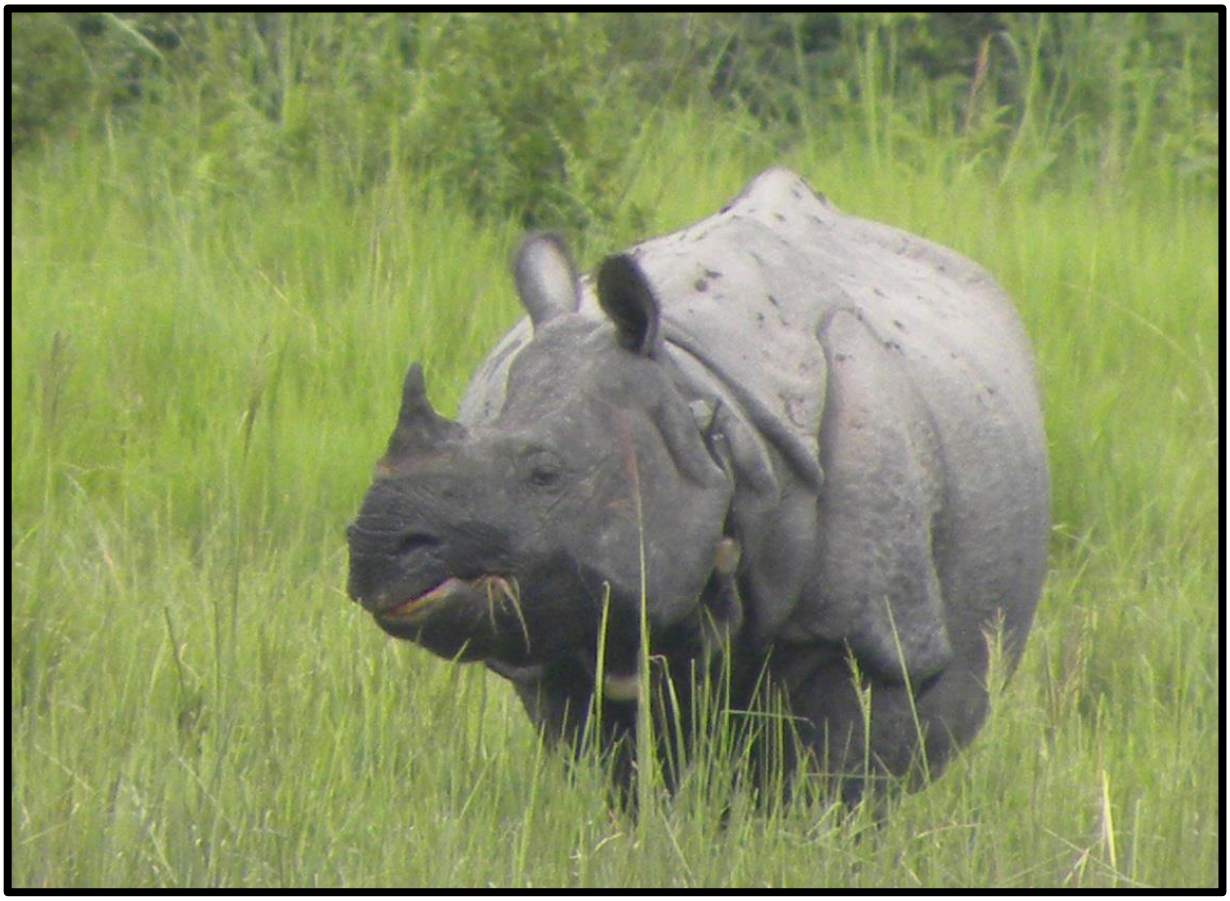
During translocation, eighteen rhinos were released at MNP (10 from PWS and 8 from KNP). After release, rhinos were distributed at different locations of MNP (Table 3.1). Some such areas were very inaccessible and logistically, it was not possible to go there for regular study. As eight of the total eighteen rhinos moved to such inaccessible part of the park, there were only 10 rhinos which can be accessed for the study. Among the rhinos, there were three adult males (R1, R2 and R5), four adult females (R3, R6, R13 and R8) and three calves (R7, R14 and R11).

Photograph 3.1 Rhino-1 (*Sat hazar*), Adult Male Rhino

Date of Release at Manas: 12th April 2008

Approximate age 12 and ½ Years

Place of Origin: Pobitora Wildlife Sanctuary



Photograph 3.2 Rhino-2 (*Iragdao*), Adult Male Rhino

Date of release at Manas 12th April 2008

Approximate age: 10 and ½ Years

Place of Origin: Pobitora Wildlife Sanctuary

Photograph 3.3 Rhino-3 (*Laisri*), Adult Female Rhino

Date of release at Manas: 27th December 2010

Approximate age 12 and ½ Years

Place of Origin: Pobitora Wildlife Sanctuary

Photograph 3.4 Rhino-5 (*Manas*) Adult Male Rhino

Date of release: 17th January 2011

Approximate age: 10 years

Place of Origin: Pobitora Wildlife Sanctuary

Photograph 3.5 Rhino-6 (*Xavira*) Adult Female (Cow) andRhino-7 (*Syria*) Male Calf

Date of release: 17th January 2011

Approximate age of cow 13 years and calf 2½ Years

Place of Origin: Pobitora Wildlife Sanctuary

Photograph 3.6 Rhino-8 (*Giribala*) Adult Female

Date of release: 17th January 2011

Approximate age: 12 years

Place of Origin: Pobitora Wildlife Sanctuary

Photograph 3.7 Rhino-11 (*Maidangsri*) Female (Calf)

Date of release: 19th February 2012

Approximate Age: 2½ years

Place of Origin: Kaziranga National Park

Photograph 3.8 Rhino-13 (*Swamli*) Adult Female (Cow) andRhino-14 (*Adidiga*) Male Calf

Date of release: 19th February 2012

Approximate age of cow 13 years and calf 2½

Year Place of Origin: Kaziranga National Park

Photograph 3.9 Release of Rhino 13(adult female) and 14 (male calf) at Manas NP

Photograph 3.10 Rhino Tracking from the Top of Vehicle

Photograph 3.11. Manas National Park