Behaviour and habitat preferences of translocated rhinos (*Rhinoceros unicornis*) at Manas National Park, Assam, India

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Abstract

Manas National Park (MNP) is located in the foothills of the Himalayas along the border between India and Bhutan. The original greater one-horned rhino population (*Rhinoceros unicornis*) of the Park was annihilated in the year 2000 by poaching. Less than a decade later, a new rhino population was reintroduced with the support of Indian Rhino Vision 2020, as part of a wider programme that included infrastructure improvements, anti-poaching schemes, and other management interventions. Between 2008 and 2021, 22 rhinos were translocated to MNP from Kaziranga National Park (KNP) and Pobitora Wildlife Sanctuary (PWS). Post-release monitoring was carried out over a six-year period, from 2008–2013, during which 10 animals (three adult males, four adult females, and three calves) were monitored continuously, using radio telemetry to track collared animals, and direct observation to monitor their behaviour. The study period yielded 4,941 radio-tracked locations and 3,711 observations, which provided sex/age specific seasonal data on activity patterns, home ranges, association patterns, habitat preferences, and 'stray incidents' when animals wandered outside the Park boundaries. Some differences from behaviour patterns observed in high flood-risk areas such as KNP and PWS were attributable to MNP's slightly higher elevation that protects rhinos from annual river floods. Overall, however, the translocated rhinos did not exhibit significant differences in their behaviour and ranging patterns compared to wild rhino populations documented in previous studies. This suggests that the translocated rhinos were able to adapt effectively to their new environment. The first calf was born to a translocated adult female in 2011 and, by 2022, the population of rhinos in MNP was estimated at 50 individuals, including 38 calves born following the reintroduction. This study demonstrates the potential of well-managed translocation schemes to contribute to the recovery of endangered rhinos.

Résumé

Le parc national de Manas (MNP) est situé sur les contreforts de l'Himalaya, le long de la frontière entre l'Inde et le Bhoutan. La population originale de rhinocéros indiens (*Rhinoceros unicornis*) y a été totalement exterminée par le braconnage en 2000. Moins d'une décennie plus tard, un nouveau groupe y a été établi avec le soutien du plan Indian Rhino Vision 2020, dans le cadre d'un programme plus vaste qui associait améliorations des infrastructures, projets de lutte contre le braconnage et autres interventions de gestion. Entre 2008 et 2021, 22 rhinocéros ont été transférés à Manas depuis le parc national de Kaziranga (KNP) et la réserve de Pobitora Wildlife Sanctuary (PWS). Après leur introduction, une surveillance a été menée jusqu'en 2013, six années durant lesquelles dix sujets (trois petits et sept adultes, dont trois mâles et quatre femelles) ont porté un collier de suivi. Leurs déplacements ont été inspectés en continu grâce à un système de radiopistage et leur comportement a été rapporté par observation directe. L'étude a produit 4 879 lieux radiopistés et 3711 observations, qui ont permis de fournir, par saison, des données spécifiques au sexe et à l'âge des individus sur les patterns d'activité, les zones et préférences d'habitat, les modes d'association et les « incidents isolés » (rhinocéros s'aventurant au-delà des frontières du parc). Quelques variations quant aux schémas comportementaux relevés dans des zones à haut risque d'inondation telles que KNP et PWS sont attribuables à l'altitude légèrement supérieure de MNP, qui, de fait, protège les animaux des crues annuelles

de la rivière. De manière générale, pour autant, les rhinocéros transférés n'ont pas montré de différences significatives dans leur attitude ou leurs aires d'habitat par rapport aux populations de rhinocéros sauvages répertoriées dans de précédentes études. Ces constatations indiquent que ces rhinocéros transférés se sont acclimatés efficacement à leur nouvel environnement. Une femelle adulte transférée a donné naissance au premier bébé du parc de Manas en 2011 et en 2022, la population était estimée à 50 individus, dont 38 petits nés après la réintroduction. Cette étude démontre le potentiel d'une translocation conduite selon des modèles de gestion adaptés, pour contribuer au rétablissement de ces animaux en danger d'extinction.

Introduction

The greater one-horned rhino (GOH; *Rhinoceros unicornis* Linnaeus, 1758) is a threatened mega-herbivore in the family Rhinocerotidae belonging to the order Perissodactyla (odd-toed ungulates). The global wild population of GOH was 4,023 in June 2022, of which 3,271 (81.3%) resided in India's national parks and wildlife sanctuaries (Sharma 2022). During the 16th–19th centuries, rhinoceroses were a favourite target of hunters, who regarded the animals' imposing size and appearance as a testimony to their abilities. This intensive hunting played a significant role in the decline of rhino populations in the region (Dutta 1991). In addition, the species' range and population have gradually diminished over the time due to habitat fragmentation, driven by rapid socio-economic change, and poaching. Being a K-selected species (long gestation, long calving intervals, slow maturity, and single offspring) has made rhinos vulnerable to these pressures (Dutta 2018). By the end of the 19th century, the GOH rhino population in India was limited to Assam's Brahmaputra valley, Northern Bengal, Northern Uttar Pradesh, Bihar, and a small population in southern Nepal. GOH populations are now confined to small, isolated protected areas, resulting in genetic drift, making surviving populations vulnerable to stochastic environmental events (Dutta 2018). Additionally, the concentration of remaining animals in small home ranges increases competition for space and resources, leading to clashes and injuries. This highlights the need for range expansion through translocation to ensure longer-term species conservation.

Translocation involves releasing an animal into the wild to re-establish or increase its population, and also to avoid diverged and isolated genetic lineages. It is a valuable tool for the recovery of species in response to multiple conservation challenges (Griffith et al. 1989). Post-translocation monitoring plays a pivotal role in the success of rhino conservation initiatives, to ensure that the translocated animals thrive in their new environment (Emslie et al. 2009). It enables tracking of behavioural adaptations and reproductive success and allows managers to detect and respond promptly to potential poaching threats (Dutta 2018). Furthermore, conducting a comprehensive assessment of survival and health is vital for early identification of any health-related risks (Jnawali 1995; Emslie et al. 2009). To evaluate the suitability of rhino habitats and the availability of essential resources, rigorous monitoring and continuous observation are essential.

Manas National Park (MNP) is located in Assam, India along the international border with Bhutan. MNP has suitable rhino habitat and prior to 1989 there was a population of over 100 rhinos. By the year 2000, the entire rhino population of the MNP had been exterminated by poaching. In 2005, the government of Assam, with support from the 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 (IRV-2020) programme. The objective was to protect the current rhino populations in Assam and relocate rhinos to protected areas (PAs) where they previously inhabited. The programme aimed to achieve a population of 3,000 rhinos in seven PAs in Assam by 2020. Under IRV-2020, 22 rhinos were translocated from Kaziranga National Park (KNP) and Pobitora Wildlife Sanctuary (PWS) to MNP between 2008 and 2021.

This study had the following objectives: to ascertain (i) the behaviour of translocated rhinos in MNP; and (ii) their utilization of habitats in the Park. In this way, the study aimed to improve the understanding of the adaptation and habitat preferences of translocated rhinos in MNP.

Study area

MNP was listed as a UNESCO World Heritage Site in 1985 and is the core area of the Manas Tiger Reserve (MTR). MNP is located in the foothills of the Himalayas in the northern Brahmaputra valley and is situated between latitude 26°30' and 27°00' N and longitude 91°51' and 92°00' E (Fig. 1). The climate is tropical; the monsoon (June–September) is the hottest season with high humidity and the wettest period of the year, while winter (December–February) is characterized by cool, dry weather and fog. The pre-monsoon season (March–May) and the retreating monsoon (October–November) are transitional periods (Barthakur 1986). Average monthly temperature and rainfall range between 27 ± 6°C and 2,860 mm respectively during the monsoon and 20 ± 5°C and 114 mm respectively during winter months.

The MNP comprises alluvial grasslands, a semi-evergreen forest, and moist and dry deciduous forests, located at between approximately 50 and 250 m AMSL. The Manas–Beki river system provides a constant source of water for the diverse wildlife and vegetation of the Park. MNP is famous for its rich floral and faunal biodiversity, with notable fauna including threatened species such as tiger (*Panthera tigris tigris*), pygmy hog (*Sus salvanius*), golden langur (*Trachypithecus geei*), hispid hare (*Caprolagus hispidus*), Bengal florican (*Houbaropsis bengalensis*), and white-winged wood duck (*Cairina scutulata*).

The MNP was declared a sanctuary in 1928 with an area of 360 km^2. Prior to the declaration of the sanctuary, it was a reserved forest known as the Manas Reserve Forest (RF) and the North Kamrup Reserve Forest, established in 1905 (area: 500 km^2), and declared a national Park in 1990. (Wikipedia 2023). In 2016, 350 km^2 of the Manas Reserve Forest was added to MNP, marking the first stage of planned rhino range expansion. The MNP is bounded to the north by Royal Manas National Park of Bhutan and to the east and west by buffer zones of the MTR. The southern boundary of the MNP is contiguous with densely populated human settlements and agricultural areas. There are three forest ranges within MNP, namely, Panbari (Western Range), Bansbari (Central Range) and Bhuyanpara (Eastern Range).

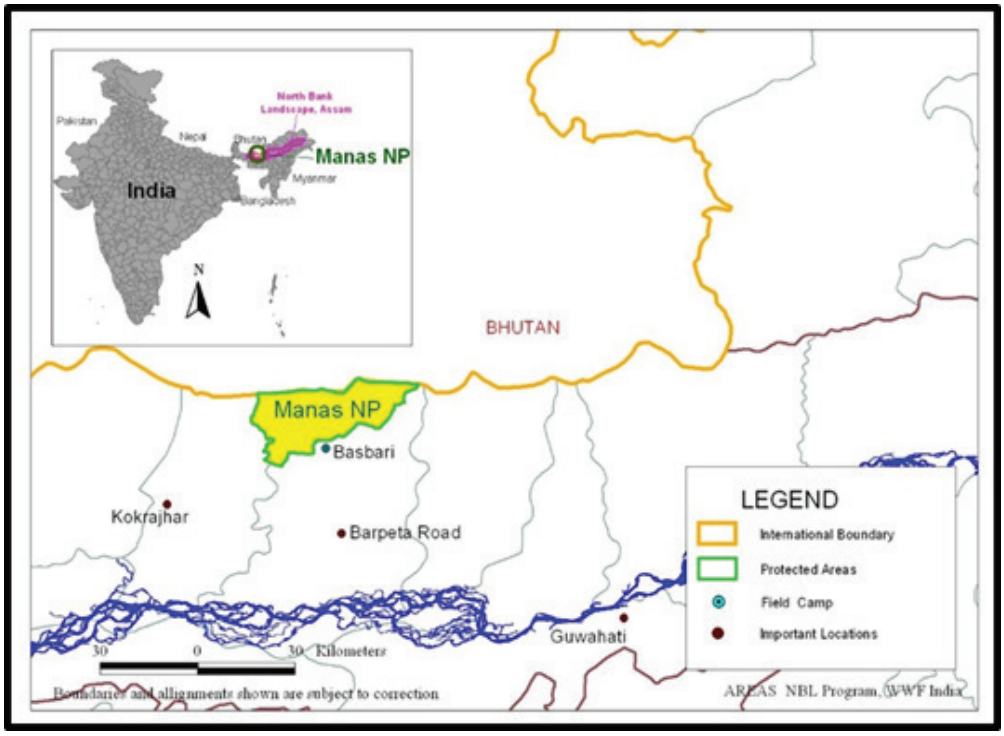

Figure 1. Location of Manas National Park. (© *WWF-India*)

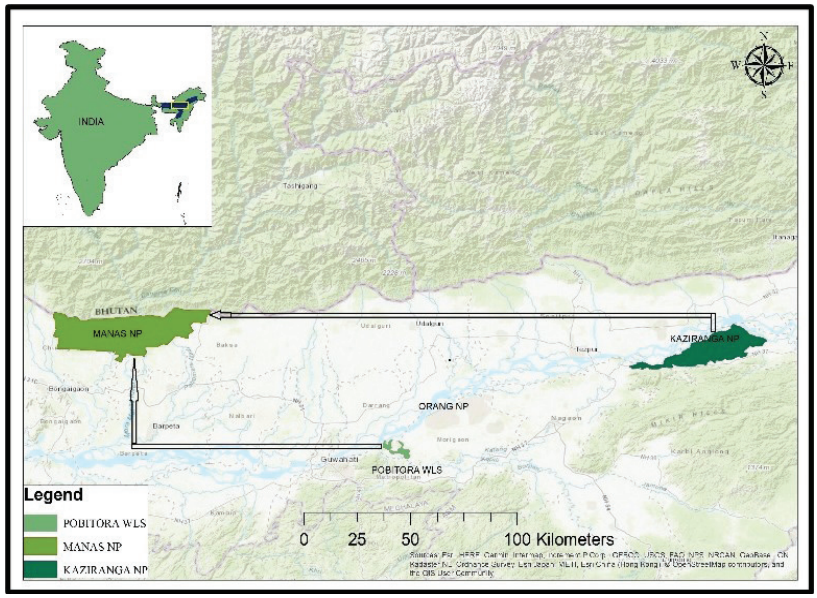

Figure 2. Translocated rhinos source sites KNP and PWS with MNP.

Material and methods

Ten translocated rhinos in MNP were studied to document their behaviour over a five-year period from 2008 to 2013. The number of rhinos monitored increased over the study period, starting with rhinos R1 and R2, the first to be reintroduced. In total 18 rhinos were released: 10 rhinos from PWS and eight rhinos from KNP (Fig. 2), (Table 1). However, due to the difficulty of accessing some of the terrain, such as swamps and rivers, only 10 rhinos were located consistently and could be monitored: three adult males (R1, R2 and R5), three adult females with calves (R3, R6 with calf R7, and R13 with calf R14; Fig. 3) and one solitary female (R8). R3 and her calf R4 separated after translocation, and the calf was not part of the monitoring study.

Rhinos were radio collared using high-frequency (VHF) radio collars at the capture sites (KNP and PWS). The tracking of the rhinos was carried out using directional antennae (Telonics RA-14K antennae, 148–152 MHz) and VHF radio receivers to record the data (Communication Specialists, R-1000 receiver, 148–152 MHz). A directional compass was used to triangulate rhino locations in dense and tall vegetation, and Windows software Locate II and Locate III were used to obtain spatial information. Camera traps were used to monitor rhinos in more inaccessible areas. The rhinos were ear-notched following the IUCN-AsRSG methods (Fig. 4) at the capture sites to ensure permanent identification, complementing the use of radio collars for real-time tracking and monitoring. As a result, rhinos could be recognized even if their radio collars stopped working (Dutta 2018). Immediately on release, the rhinos were monitored three times a day, in the morning (06:00–0.00), midday (10:00–14:00) and late afternoon (14:00–18:00). Sometimes, they were also located at night (18.00–06:00), depending on accessibility. During the monitoring process, patrolling elephants were used, as well as four-wheel jeeps, motor bikes and bicycles (Fig. 5); sometimes rhinos were tracked on foot to acquire GPS coordinates.

Behaviour sampling (Altman 1974) was conducted whenever a direct observation was made. Following this method, which focuses on a particular behaviour rather than a particular rhino, all occurrences of specified actions were recorded during a predetermined sample period of one hour. Behavioural categories were broadly defined as: grazing, wallowing, walking, browsing, and resting (Table 2). Temporal activity refers to actions or events that occur over a specific period of time or are related to time. Behavioural states were recorded if they lasted more than one minute (Kandel and Jhala 2008). All data were recorded and analysed with the support of MS Excel.

Table 1. Translocated rhinos details from the year 2008–2013

Batch No.	Details of Translocated rhinos			Place of origin	Date of release at MNP
	No. of Rhinos	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	R6, R7	PWS	18 Jan 2011
		One adult male	R5	PWS	
		One adult female	R8	PWS	
4	2	Two adult females	R9, R10	PWS	9 Jan 2012
5	4	Adult female with female calf	R12, R11	KNP	20 Jan 2012
		Adult female with male calf	R13, R14	KNP	
6	4	Adult females with male calf	R15, R16	KNP	12 March 2012
		Adult female with male calf	R17, R18	KNP	

Figure 3. Release of Rhinos 13 and 14 at Buraburijhar, MNP.

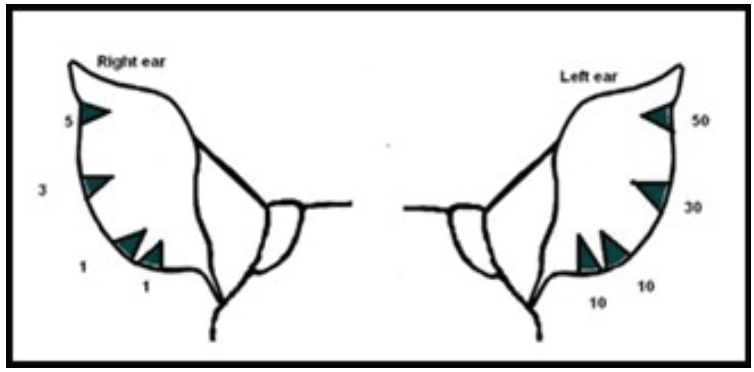

Figure 4. GOH ear notching method (Courtesy of AsRSG).

Spatial data were plotted and analysed using ArcGIS 9.2 and ArcView 3.2a (ESRI 2006). Two non-parametric techniques were used to estimate home range size: minimum convex polygon (MCP) (Mohr 1947) and fixed kernel density (FKD) (Worton 1989). The animal's core area encompassed 50% of its utilization distribution, while its home range extended to 95% of the distribution (Powell 2000). The core area home range was estimated using CALHOME (Kie et al. 1996); ArcGIS 9.2 (ESRI 2006), Hawth's Tool, and Home Range Tool (Rodgers et al. 2007). Bonferroni confidence interval was used to determine habitat preference (Neu et al. 1974; Byers et al. 1984). Habitat information was derived from a satellite image of habitat data from IRS P6 LISS III of November 2013.

Results

The study period yielded 4,941 radio-tracked locations, 4,879 locations were used for home range analysis (1,822 locations for three adult male rhinos; 1,842 for four adult females; 1,015 for two male calves; and 200 locations for one female calf) and repeated locations were discarded for some of the analyses. In terms of seasonal behavioural analysis, 1326 locations were recorded in the pre-monsoon period, 1840 during the monsoon, and 642 and 1133 locations in the receding monsoon and winter season, respectively. Tracked rhinos could not always be observed directly due to difficult terrain and dense vegetation. The study yielded a total of 3711 observations: 1089 in the pre-monsoon period, 1323 during the monsoon, and 491 and 808 observations in the receding monsoon and winter season, respectively.

Table 2. Ethogram of rhinoceros' behaviour

Type of behaviour	Description
Grazing	Approached grasses and observed with fodder in mouth
Browsing	Approached bushes, tree twigs, observed with fodder in mouth while standing or walking
Resting	Rhino in resting position (lying or sitting), inactive and relaxed
Walking	Rhino moving attentively
Wallowing	Almost all parts of body immersed in mud and water

Figure 5. Rhino tracking from the top of a range patrol vehicle at Kuribeel area, MNP.

Behaviour in first 90 days after release

Observations of rhinos during the 90-day monitoring period after release were incorporated into seasonal data (see below), but also analysed separately to assess behaviour during the settling-in phase. In total, the 10 rhinos were located 891 times during their respective initial monitoring periods. The three adult males accounted for 33% (n = 294), the four adult females for 41% (n = 362) and the three calves for 26% (n = 235) of observations. In this period, non-uniform and unusual patterns of behaviour was observed among adult males, adult females and calves (Table 3).

Seasonal activity patterns of rhinos

Pre-monsoon period

During this season (March–May), rhinos were tracked 1,326 times and observed 1,089 times (82%). There were 237 (18%) instances in which rhinos couldn't be found due to difficult terrain and dense vegetation. Adult males, adult females and calves were observed on 425 (39%), 398 (37%), and 266 (24%) occasions respectively. No marked behavioural variations were observed among the three age/sex groups, based on the average time engaged in different activities as a proportion of the total observation time (Table 4).

Monsoon period

During the monsoon (May–September), rhinos were tracked 1,840 times and observed 1,323 times (72%). It was not possible to locate rhinos on 517 occasions (28%) during the study period. Adult males, adult females, and calves were observed on 654 (49%), 367 (28%) and 302 (23%) occasions respectively (Table 3). During the monsoon, a non-uniform pattern of behaviour was observed among all age groups.

Retreating monsoon

This is a short season (October–November). During this period, rhinos were tracked 642 times and observed 491 times (76%). There were 152 (24%) instances in which rhinos were not located during searches. Adult males, adult females, and calves were observed on 186 (38%), 171 (35%) and 134 (27%) occasions, respectively (Table 5). During this season, no specific behavioural variations were observed among the three groups of rhinos.

Winter season

During the dry winter season (December–February), rhinos were tracked 1,133 times and observed 808 (71%) times. The rhinos were not found 325 times (29%) during the search. Adult males, adult females, and calves were observed on 464 (57%), 161 (20%) and 183 (23%) occasions, respectively (Table 4). During the winter season, distinct variations in behaviour were observed among the three age groups of rhinos.

Temporal activity pattern of rhinos

During the pre-monsoon season, in response to an increase in rainfall and temperature compared to the preceding winter months, rhinos of all age groups became more active in the morning and in the evening. In the monsoon season, adult males were more active during the morning and night, while adult females and calves were active during the morning and afternoon (Table 6).

Rhinos of all age groups were more active in the morning and afternoon during the retreating monsoon. During winter, rhinos of all ages were found to be active in the morning and afternoon, with very few activities at night (Table 7).

Home ranges, ranging areas and association patterns of translocated rhinos

An asymptote curve was generated to understand the relationship between the number of data points (locations) collected at 10-day intervals and the corresponding home range size, calculated as 100% MCP, for adult male and female rhinos. The analysis indicates that adult male rhinos tend to establish their home range at approximately 210 distinct locations, and at this point, they occupy an estimated average area of 130.30 km^2. In contrast, adult female rhinos reach a similar stabilization point at approximately 270 locations, where their habitat utilization levels off. At this stage, they occupy an average area of 67.71 km^2. Based on analysis of tracked locations, adult males' home ranges, calculated as 100% MCP, ranged from 93.35 km^2 to 207.50 km^2, those of adult females from 35.31 km^2 to 134.14 km^2, and those of rhino calves from 53.75 km^2 to 111.36 km^2 (Table 8).

During the pre-monsoon period, adult males and females were observed to be associated in an area of approximately 64.8 km^2 in the central Bansbari range (Fig. 6). In the monsoon period, their association was observed in a reduced area of approximately 56.0 km^2

Table 3. Percentage of total observation time (mean ± SD) that GOH engaged in different activities, during the first 90 days after translocation

	Settling-in phase		
Activity	**Adult males**	**Adult females**	**Calves**
Grazing	45 ± 3	47 ± 1	45 ± 1
Browsing	8 ± 1.1	7 ± 1	10 ± 2
Resting	15 ± 3.1	12 ± 2	12 ± 4
Walking	13 ± 1.6	17 ± 5	17 ± 5
Wallowing	19 ± 1	17 ± 2	16 ± 4

Table 4. Percentage of total observation time (mean ± SD) that GOH translocated to MNP engaged in different activities, during pre-monsoon and monsoon seasons

	Pre-monsoon			Monsoon		
Activity	**Adult males**	**Adult females**	**Calves**	**Adult males**	**Adult females**	**Calves**
Grazing	44 ± 6	61 ± 2.6	61 ± 3	54 ± 4.2	69 ± 4	59 ± 1.4
Browsing	12 ± 2.07	6 ± 1.8	6 ± 0	0	0	5 ± 3.2
Resting	6 ± 3	6 ± 1.5	6 ± 3	1 ± 0.5	4 ± 2	6 ± 1.4
Walking	13 ± 1.6	17 ± 5	17 ± 5	20 ± 4	17 ± 4	24 ± 13.1
Wallowing	25 ± 6.3	10 ± 0.4	10 ± 3	25 ± 1.3	10 ± 1	6 ± 2

Table 5. Percentage of total observation time (mean ± SD) that GOH translocated to MNP engaged in different activities, during retreating monsoon and winter seasons

	Retreating monsoon			Winter		
Activity	**Adult males**	**Adult females**	**Calves**	**Adult males**	**Adult females**	**Calves**
Grazing	65 ± 4	67 ± 9	83 ± 1.6	37 ± 3.25	51 ± 3.3	53 ± 2.7
Browsing	13 ± 7	0	1 ± 0.8	23 ± 2.1	12 ± 7.05	10 ± 3.2
Resting	2 ± 1	1 ± 1	3 ± 1	11 ± 2.1	5 ± 1.9	8 ± 1.04
Walking	12 ± 4	20 ± 10	9 ± 3	15 ± 3	23 ± 4.06	20 ± 3
Wallowing	8 ± 5	12 ± 4	4 ± 2.4	14 ± 0.7	9 ± 1.9	9 ± 2.1

Table 6. Time (mean ± SD) engaged in temporal activities by translocated GOH in the MNP, during pre-monsoon and monsoon seasons

	Pre-monsoon			Monsoon		
Time slot*	**Adult males**	**Adult females**	**Calves**	**Adult males**	**Adult females**	**Calves**
Morning	8 ± 0.1	7 ± 0.1	6 ± 0.4	5 ± 0	5 ± 0.1	5 ± 4
Mid-day	3 ± 0.2	2 ± 0.2	4 ± 0.4	3 ± 0.2	2 ± 0	2 ± 0.1
Afternoon	7 ± 0.1	8 ± 0.1	8 ± 0.2	4 ± 0.2	8 ± 0.1	8 ± 0.1
Night	3 ± 0.2	2 ± 0.1	2 ± 0.4	8 ± 0.1	5 ± 0.2	5 ± 0.4

*Time slots: Morning 06:00–10:00; mid-day 10:00 am–14:00; afternoon 14:00–18:00; night 18:00–06:00.

(Fig. 7), in the same area. During the retreating monsoon, the corresponding area was approximately 53.8 km^2, covering the central areas of Bansbari and some parts of the eastern Bhuyanpara range. In the winter season, while rhinos ranged widely over the Bansbari and Bhuyanpara ranges, with a total association area of about 80.7 km^2, they were mainly found to concentrated in Bansbari and limited areas of Bhuyanpara.

The total area covered by all individual rhinos within the MNP was 280 km^2 with the central area of Bansbari range serving as the core zone. However, males spent much of the time in the eastern the Bhuyanpara range, where females were absent (e.g. the 80% range area of adult male R5 was located in the Bhuyanpara range), while calves also occupied the western Kahitama area of the Bansbari range (e.g the 70% range area of female calf R11 was in this area) (Fig. 8).

A rhino is considered 'stray' when it ventures outside the boundary of a protected area. There were 195 'stray' incidents recorded among the rhinos during the period of 2008–2013. Stray incidents were more frequent among adult males (n = 121) than adult females (n = 74). Out of 195 incidents, 95% (n = 186) took place in nearby areas (within 1–2 km distances) of MNP boundary, mainly in monsoon season (Fig. 9).

Habitat preferences

The translocated rhinos spent most of their time in grasslands and swampy habitats. They sought out relatively scarce swampy habitats and spent relatively little time in woodland habitats, even though these cover a large part of the MNP. Adult males showed a particular affinity for swampy habitats; more so than females and calves (Tables 9, 10, 11).

Discussion

This study utilized a comprehensive data set obtained from continuous monitoring activities conducted day and night over a period of six years (2008–2013), which gave a solid foundation for analysing the home ranges of translocated rhinos and yielded valuable insights into their behaviour and habitat use throughout different seasons.

To ensure the safety and well-being of the translocated rhinos in their unfamiliar surroundings, strict monitoring measures were implemented immediately after their release in MNP. Subsequently, the rhinos embarked on a journey of exploration, seeking optimal habitat within and around the release site, as would be anticipated. It is understood that this period of acclimatization facilitates gradual adaptation to the new environment. R1 and R2, the first rhinos reintroduced to MNP, exerted a profound influence on the establishment of home ranges and the subsequent behaviour of the other 16 translocated rhinos, including the other eight rhinos observed in this study. There were no distinct behavioural variations during the 90-day settling-in phase compared with those observed in wild rhino behaviour studies such as Laurie (1982); Hazarika (2007); Dutta et al. (2017); Dutta (2018).

A distinct seasonal variation in activities (Tables 4 and 5) was observed among rhinos. Maximum grazing activity was observed in the monsoon and in the retreating-monsoon season, and minimum grazing during the winter season. The adult rhinos were not observed to browse during the monsoon season. These patterns differ from those observed in areas with high flood risks such as KNP, PWS, and Orang NP. MNP's slightly higher elevation protects rhinos from annual river floods. Furthermore, the grasslands in MNP provide rhinos with an abundant and succulent source of food, so browsing is unnecessary during the monsoon season. Hazarika (2007) and Laurie (1982) both mention that

Table 7. Time (mean ± SD) engaged in temporal activities by translocated GOH in the MNP, during retreating monsoon and winter seasons

	Retreating monsoon			Winter		
Time slot	**Adult males**	**Adult females**	**Calves**	**Adult males**	**Adult females**	**Calves**
Morning	6.9 ± 0.2	6.3 ± 0.1	7 ± 0.1	6 ± 0.1	7 ± 0.4	7 ± 0.4
Mid-day	3.6 ± 0.1	1.6 ± 0.4	2 ± 1	4 ± 0.1	3 ± 0.2	4 ± 0.1
Afternoon	6.1 ± 0.1	9 ± 0.1	9 ± 0.2	9 ± 0.2	8 ± 0.3	3 ± 0.2
Night	4.5 ± 0.2	2 ± 0.2	3 ± 0.1	1 ± 0.1	2 ± 1	2 ± 0.1

grazing and browsing activities vary with available grass and its palatability. In MNP, there is a scarcity of naturally palatable grasses during the dry season, which explains the lower grazing activity observed in winter, compared to other seasons. During this season, the population becomes more dependent on browsing tree saplings, creepers, shrubs, and other vegetation for food.

Resting activity was at a maximum during the dry winter season and the pre-monsoon season. The rhino calves were often observed to rest after exploring a new territory with their mother. However, adult females with calves remained vigilant, showing minimal resting behaviour and their care for their offspring was constant (Dutta et al. 2017; Dutta 2018).

Table 8. Home ranges of translocated rhinos

Rhino ID	Gender/age	100% MCP home range
R1	Adult male	93.35
R2	Adult male	168.95
R3	Adult female	95.40
R5	Adult male	207.50
R6	Adult female	35.31
R7	Male calf	53.75
R8	Adult female	96.13
R11	Female calf	90.66
R13	Adult female	134.14
R14	Male calf	111.36

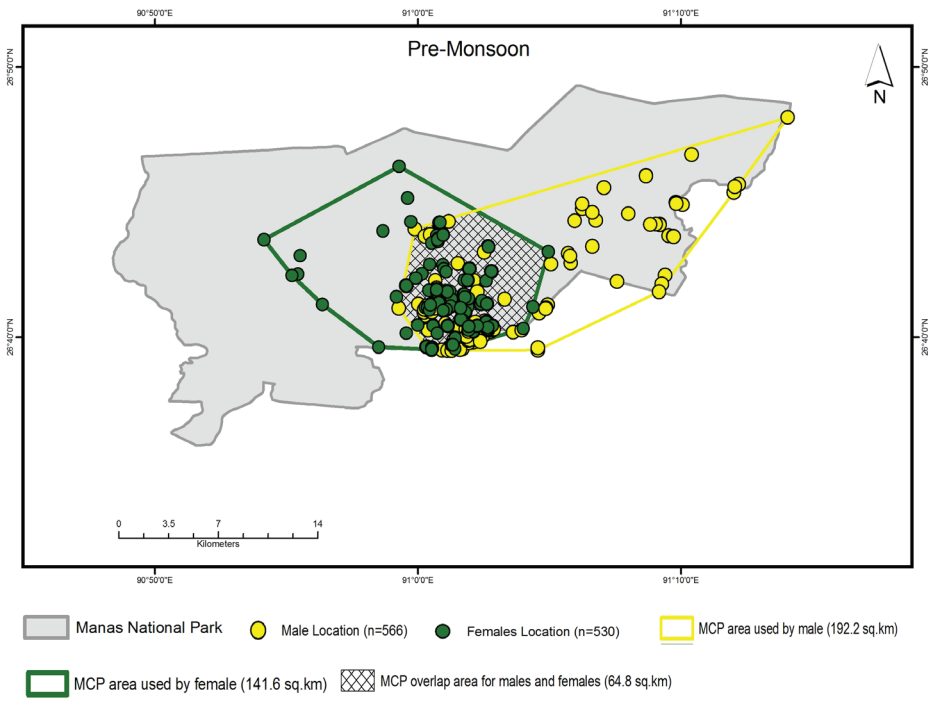

Figure 6. Areas of association of adult male and female rhinos before the pre-monsoon.

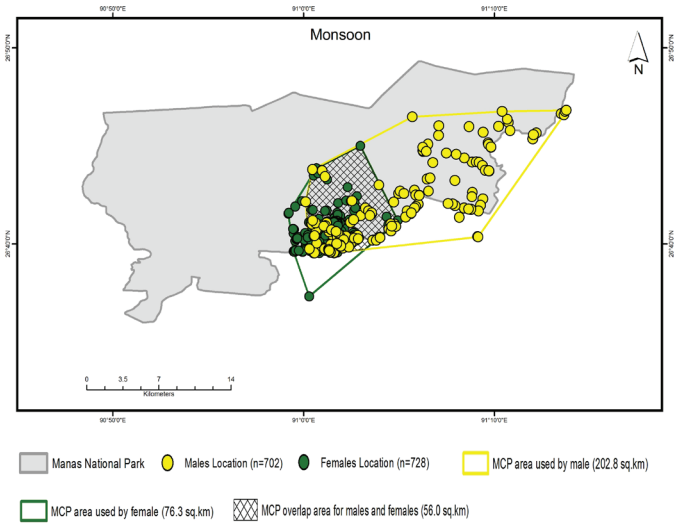

Figure 7. Areas of association of adult male and female rhinos during the monsoon.

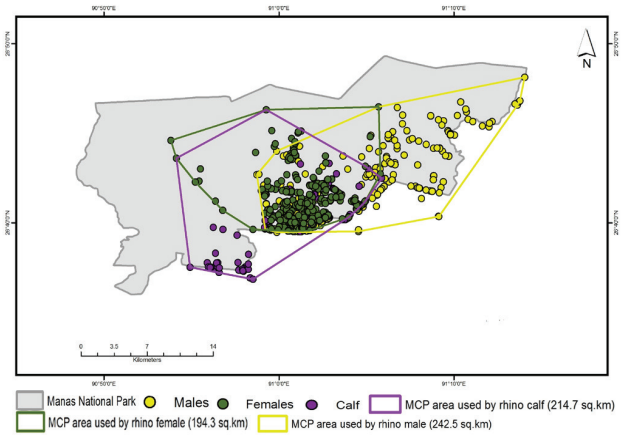

Figure 8. Total ranging areas of rhinos in MNP.

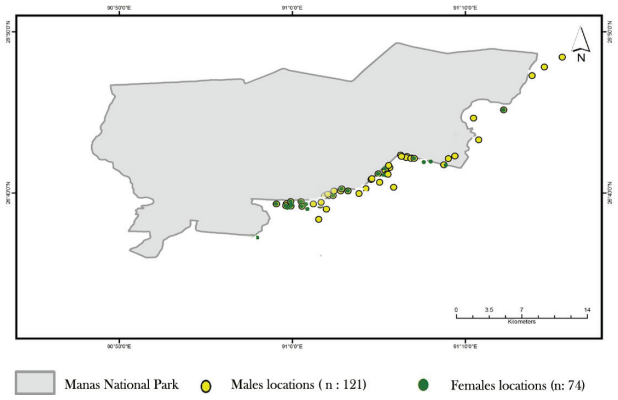

Figure 9. Stray zones of rhinos.

Table 9. Utilization availability data for habitat types in the MNP (adult males)

Habitat types	Total area (km^2)	Proportion of total area	Expected no. occurrences*	Observed no. of instances	Observed proportion
Grassland	206.30	0.43	811	965	0.51
Swamp	17.50	0.04	68	655	0.35
Water bodies	22.55	0.05	88	95	0.09
Woodland	233.20	0.49	917	172	0.05
Total	479.55	1.00	1,884	1,887	1.00

*I.e. if the animals showed no preference for one habitat over another.

Table 10. Utilization availability data for habitat types in the MNP (adult females)

Habitat types	Total area (km^2)	Proportion of total area	Expected no. occurrences	Observed no. of instances	Observed proportion
Grassland	206.30	0.43	787	1384	0.76
Swamp	17.50	0.04	66	271	0.15
Water bodies	22.55	0.05	86	83	0.04
Woodland	233.20	0.49	889	92	0.05
Total	479.55	1.00	1,828	1,830	1.00

Table 11. Utilization availability data for habitat types in the MNP (rhino calves)

Habitat types	Total area (km^2)	Proportion of total area	Expected no. occurrences	Observed no. of instances	Observed proportion
Grassland	206.30	0.43	522	881	0.72
Swamp	17.50	0.04	44	216	0.18
Water bodies	22.55	0.05	57	70	0.06
Woodland	233.20	0.49	590	47	0.04
Total	479.55	1.00	1,213	1,214	1.00

In their new habitat, adult males were observed to move from one place to another, seeking food or interacting with adult females (Dinerstein 2003). A noticeable increase in walking activity was observed among adult males during the monsoon season, indicating active movement within the habitat ranges. This trend also led to an increase in the incidents of straying during this time-frame. However, as time progressed, the number of rhinos straying decreased, suggesting gradual adaptation and settlement in their new habitat within MNP.

Overall, no marked differences were observed in the behaviour patterns (grazing, browsing, wallowing, walking, resting) of translocated rhinos in MNP, compared to the behaviour of other wild rhinos as reported by Laurie (1982), Jnawali (1995) and Dinerstein (2003) in Nepal; and Dutta (1991), Patar (2004), Bhatta (2011) and Hazarika (2007) in Assam. The behavioural similarity between translocated rhinos and wild rhinos indicated that rhinos had adapted well to the new environment in MNP.

The core home ranges of translocated rhinos in MNP varied among seasons and age groups (Figs. 6–7). Adult males typically have the most extensive and variable core home ranges, while adult females tend to occupy smaller, yet still variable core home ranges, with calves maintaining relatively small and consistent core home ranges. These core home range patterns illustrate the rhinos' habitat preferences and are critical for understanding their use of habitat and resources and for effective conservation management of the Park's rhino population (Dutta 2018).

Translocated rhinos showed a strong preference for grassland and swamp habitats for rhinoceros and were seldom observed in woodland habitats. In the grassland and swamps, a large number of natural water bodies are present which were extensively used by rhinoceros mainly for wallowing and rest. However, large water bodies like the river Beki were generally avoided by the rhinos, except for occasional drinking. This seasonal habitat shift observed in MNP is similar to those recorded by Subedi (2012) and Adhikari (2015) in Chitwan NP and by Bhatt (2011) in PWS.

Rhinos tended to associate in central areas of the Bansbari range, which could be due to the highly nutritious food quality, and quantity of food, as well as more secure protection measures. Females accompanied by male calves formed prolonged associations, while other associations between individuals were relatively shorter. Adult males R1 and R2 formed a social bond at the start of the study period when other rhinos were absent. The frequency of association between adult males and adult females varied. In Bansbari, adult male R2 and adult female R6 formed a common association that lasted for about 14–20 days. This occurred just 90 days after the release of R6 and culminated with her mating with R2 and the birth of a male calf in 25 months 5 days. During much of study period R2 shared a home range with R6 (and her male calf R7) and no conflict between them was observed.

During and after the study period, courtship and mating became frequent among translocated rhinos. All courtship observations were recorded in the late evening or at night. The maximum pre-mating courtship pairing was observed from pre-monsoon to monsoon season (March-September) and most births occurred in the retreating monsoon seasons. Translocated female rhinos gave birth in thick grassland and dense woodland within secluded areas of the Park. Their offspring may have been protected due to this coveting behaviour. Owen-Smith (1988) mentions similar site selection seclusion of adult female white rhinos in South Africa in their natural habitat. Thirty-eight calves were born after the rhino reintroduction at MNP between 2011 and 2021.

Conclusion

According to the official record for 2022, there are now 50 rhinos in total in MNP, including 38 calves born after reintroduction. Going forwards, the newly established rhino population should continue to thrive in MNP with effective anti-poaching measures, effective habitat management, community engagement, disease surveillance, India-Bhutan cooperation, and collaborative efforts.

Compared with the behaviour of rhino populations in the wild documented in previous studies, the translocated rhinos did not exhibit significant differences in their behaviour and ranging patterns. This suggests that the translocated rhinos were able

to adapt effectively to their new environment after relocation. The success of the rhino reintroduction programme has enhanced GOH conservation in India and provided valuable procedural and technical guidelines for future rhino translocation programs.

The establishment of the GOH population at MNP through the wild-to-wild translocation programme under IRV-2020 opened a new dimension in the conservation efforts for the largest of the Asian rhinos three species. Translocation has resulted in the revival of the entire Park infrastructure, anti-poaching schemes, management interventions, and recovery of other wildlife populations. Tourism has also been revived in MNP, and local communities have started benefiting from this. However, anthropogenic pressures and inadequate habitat management practices have continued to affect rhinos' ranging and habitat preferences, as well as their preferred food plants. This study strongly emphasizes the need for continued protection of rhinos.

Specifically, to ensure the future survival and well-being of the newly established rhino population at MNP, several crucial measures are recommended. These include the implementation of genetic management plans to maintain genetic diversity and prevent inbreeding; sustainable habitat management practices to restore preferred rhino habitats; and the establishment of a robust disease surveillance system to safeguard against potential health threats. Furthermore, community engagement initiatives should empower local communities with a sense of pride and responsibility for rhino conservation, and anti-poaching efforts must be fortified to protect the population from poaching threats. Sustainable tourism management should be prioritized to minimize disturbances to rhinos while generating revenue for conservation. Transboundary cooperation between India and Bhutan can greatly benefit interconnected wildlife and ecosystems, and collaboration among governments, conservation organizations, and local communities is essential for effective conservation of this iconic species.

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