RESEARCH

Assessment of habitat change and threats to the greater one-horned rhino (*Rhinoceros unicornis)* in Pabitora Wildlife Sanctuary, Assam, using multi-temporal satellite data

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Abstract

Pabitora Wildlife Sanctuary (WLS), located in north-eastern India, is a prime habitat for *Rhinoceros unicornis*, Indian or greater one-horned rhinos. With a population of 84 rhinos, Pabitora WLS has the proud legacy of sheltering the highest density of Indian rhinos in the world. Although the total notified area of the sanctuary is 38.80 km^2, the state government of Assam is yet to handover an area of 11.07 km^2 to the sanctuary authority. As such, the Department of Environment and Forests, Assam presently manages a total area of only 27.73 km^2. Only 12.57 km^2 has been found to be suitable as rhino habitat. Satellite imagery from 1977, 1999 and 2004 was analysed for assessment of rhino habitat change in Pabitora WLS. Results indicate that there is a substantial increase in woodland (34.51%) accompanied by decline in alluvial grassland (68%) from 1977 to 2004 within the sanctuary area of 38.80 km^2. This change of habitat is mostly because of the natural succession process, local livestock grazing and improper management of the grassland habitat. In this paper, we recommended a set of habitat management protocols for the restoration of key habitats in Pabitora WLS.

Key words: Indian rhino, Pabitora, habitat change, remote sensing, threats

Résumé

Le Sanctuaire de la Faune (SF) de Pabitora, situé au nord-est de l'Inde, est un habitat principal du *Rhinocéros unicornis*, le grand rhinocéros unicorne ou indien. Ayant une population de 81 rhinocéros en 2006, le SF Pabitora a le fier héritage d'abriter la densité la plus élevée de rhinocéros indiens dans le monde. Bien que la superficie totale notifiée du sanctuaire soit 38,80 km^2, le gouvernement de l'état d'Assam doit encore remettre une superficie de 11,07 km^2 à l'autorité du sanctuaire. Par conséquent, le Département de l'Environnement et des Forêts de l'Assam ne gère actuellement qu'une superficie totale de 27,73 km^2. On trouve que 12,57 km^2 seulement conviennent comme habitat au rhinocéros. Les images satellitaires de 1977, 1999 et 2004 ont été analysées pour évaluer le changement de l'habitat du rhinocéros dans le SF Pabitora. Les résultats indiquent qu'il y a une augmentation substantielle de la zone boisée (34,51%) accompagnée d'un déclin des herbages alluviaux (68%) entre 1977 et 2004 au sein du sanctuaire de 38,80 km^2. Ce changement d'habitat est principalement dû au processus naturel de succession, au bétail local qui paît et à une mauvaise gestion de l'habitat des herbages. Dans ce document,

nous avons recommandé un ensemble de protocoles de gestion de l'habitat afin de restaurer des habitats clés dans le Sanctuaire de la Faune de Pabitora.

Introduction

The detection of rates and patterns of landscape change is considered an important theme in ecological research for several reasons (Roy and Tomar 2001; Nagendran et al. 2004). Time-series analysis of remotely sensed images enables us to identify trajectories of land cover change at the landscape level (Zheng et al. 1997; Srivastava et al. 2002; Ostrom and Nagendran 2006). The state of Assam in India has a proud legacy of successfully conserving the Indian rhino (Talukdar 2000) and currently a total of 2006 animals are found in Assam according to a census carried out by the Assam Forest Department. There have been marked changes in rhino habitat across Assam over the past few decades due to shifting river courses as well as natural and man-made alterations (Talukdar and Sarma 2007). Pabitora WLS is regarded as having the highest density of Indian rhinos in the world (Talukdar et al. 2007) and hence intense scientific monitoring is needed to ensure long-term conservation of the rhino.

Study area

The Pabitora WLS falls between the latitude of 26 12'N and 26 15'N and between the longitude 91 57'E and 92 50'E. The biogeographic zone of Pabitora WLS is termed the North-East Brahmaputra Valley. The sanctuary area is flat with a gentle east to west inclination excluding the Bur-Mayong hillock. Being low-lying, the region is subject to annual flooding with water present year-round in lakes and swamps. This makes Pabitora WLS an ideal area for rhinos as well as migratory waterfowl. The average annual rainfall is between 2000–2300 mm and the average winter temperature is 8 C and it rises up to 37 C in summer. Relative humidity ranges from 60% in March to 95% in July (Fig. 1).

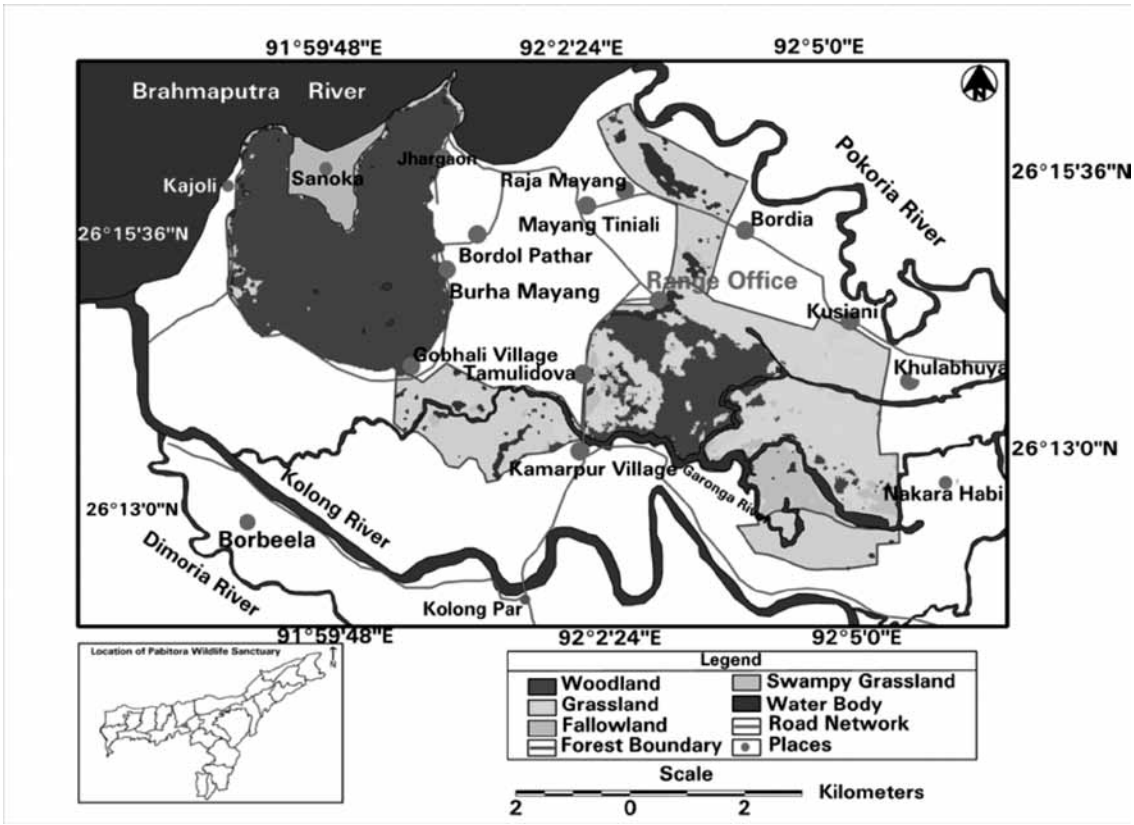

Figure 1. Location of Pabitora Wildlife Sanctuary.

Data set used

For this study primary data used were multi-dated satellite images, Survey of India (SOI) topographical maps, ground control points (GCPs) and other data that were collected from the extensive ground truth survey. The satellite images used in this study are Landsat Multispectral Scanner (MSS) imagery of 1977, Landsat Thematic Mapper (TM) imagery of 1987 and 1999 and Indian Remote Sensing Satellite (IRS) 1D LISS III imagery of 2004 (Table 1). The Survey of India topographical sheets no. 83 B/3 and 83 B/4 at 1:50,000 scale have also been used for geometric correction of the satellite images and to prepare the base map and the vector layers—i.e. district and forest boundaries, drainage, location of places, etc.

Table 1. Satellite data used for the study

Data type	Path/row	Date of acquisition
Landsat MSS	136/42	08 February 1977
Landsat TM	136/42	12 January 1987
Landsat TM	111/53	08 February 1999
IRS 1D LISS III	142/42	12 February 2004

Methodology

The Pabitora WLS was extensively surveyed using transect data sampling techniques from January 2004 to April 2005. A total of 15 transects were either walked or covered on elephant back in order to include the entire WLS. Ground verification was carried out using an e-trex Global Positioning System (GPS) receiver. A total 134 GPS points was collected from different vegetation types as visualized in the field. From each GPS location, the following information was recorded: a) latitude and longitude, b) elevation, c) type of vegetation and d) details of habitat characteristics within the vicinity. For change detection we used four satellite images: 1977 (Landsat MSS), 1987 (Landsat TM), 1999 (Landsat TM) and 2004 (IRS 1D LISS III) (see Table 1).

The 1:50,000 Survey of India topographical sheets 78 N/15, 78 N/16, 83 B/3 and 83 B/4 were utilized in the preliminary processing of the satellite

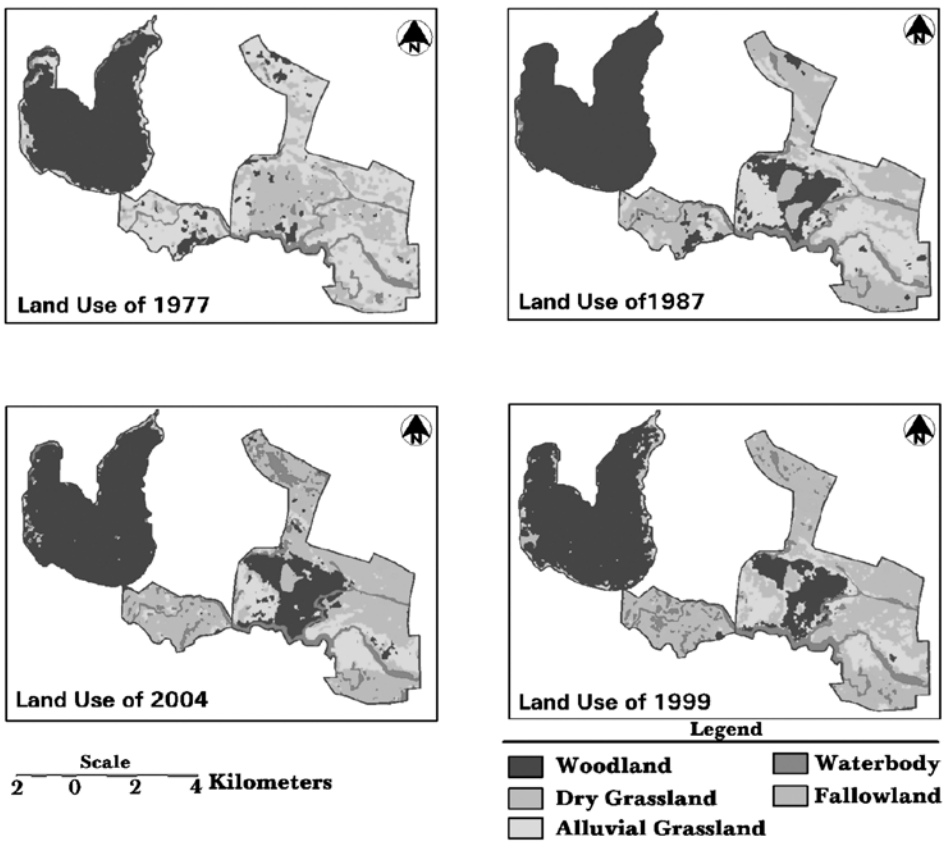

Figure 2 Land use and land cover changes in Pabitora WLS.

data. The satellite images were rectified or geometrically corrected using GCPs obtained from topographical sheets and the GPS points collected from the field. Points such as intersection of the roads, river junctions and permanent establishments were identified on the topographical sheets as GCPs. Using polynomial equations the scene was geometrically corrected and geo-referenced into the latitude/longitude co-ordinate system using a polyconic projection system. The pixels of the satellite images were re-sampled using a maximum likelihood algorithm and the study area was extracted from the scene using a digitized sanctuary boundary from the Survey of India topographical sheets. Sub-pixel image to map accuracy was achieved through repeated attempts. Histogram matching was done to correct the radiometric differences, when present. Using GCPs, training sets were generated for different land-cover and land use types and the image classifications based on a combination of visual and digital classification schemes. Finally the four satellite imageries falling in different dates were superimposed to detect the changes in land use over a period of time. The output resolutions of the classified images were at 23 m. All image processing was done using ERDAS 9.0 software.

Results and discussion

The present study, based on satellite images and intense ground corroboration, reflects the rapid changes in rhino habitat in Pabitora WLS between 1977 and 2004 (Fig. 2). The changes can be seen in the satellite images of 1977, 1987, 1999 and 2004 and calculated in the classified land use maps. During field surveys, it was observed that the moist alluvial grassland has been declined in the WLS due to the impacts of subsequent floods and silt deposits in 1998 and 2004, followed by intense cattle grazing that has increased from about 500 cattle in 1996 to more than 3000 in 2005. The moist alluvial grassland ecology has a direct bearing on the annual floods. Flooding is the causative factor for creation, maintenance and eradication of moist alluvial grasslands. In Pabitora WLS, due to successive flooding in 1998 and 2004, the grassland growth was significantly reduced and it suffered from excessive cattle grazing from the fringe villages (Table 2 and Fig. 3). As such, the suitable rhino feeding sites have been declining. The deposition of silt has also reduced the size of wetlands and thus reduced the area earlier covered with moist alluvial grassland, which is regarded as a highly suitable feeding habitat for rhinos in the WLS. The accumulation of water hyacinth and other aquatic plants has been found to reduce the area of moist alluvial grassland as observed in our field visits to the WLS since 1998. Over-grazing of the grassland areas and direct heat from the sun thus further reduces the moisture content of the soil that enables moist grasses to grow. There has been a transformation of moist to dry grasslands in the WLS and thereafter from dry grassland into woodland.

It has also been observed that flooding has led to new depressions in the earth, which has led to the formation of new water bodies in the north-eastern part of the sanctuary. This is visible in comparing the satellite images of 1999 and 2004. Water bodies in the WLS increased from 2.17% of the total geographical area of the WLS in 1999 to about 2.39% in 2004. Further, it has been found that woodland and fallow land has increased within the WLS over the years (Table 2 and Fig. 3) while moist and dry grasslands have declined; this could have triggered food scarcity for rhinos during drier winter months (November to March), forcing a significant number of rhinos to

Table 2 Trend of land use change in Pabitora Wildlife Sanctuary

Land use class	Year						
	Area in sq. km				Net change (area in sq. km)		
	1977	1987	1999	2004	1977–1987	1987–1999	1999–2004
Woodland	11.1	12.87	14.72	16.95	1.77	1.85	2.23
Moist alluvial grassland	16.25	10.67	5.57	5.2	-5.85	-5.1	-0.37
Dry grassland	8.06	10.42	11.25	6.51	2.36	0.83	-4.74
Water body	1.53	1.65	2.17	2.39	0.12	0.52	0.22
Fallow land	1.86	3.19	5.09	7.75	1.33	1.9	2.66

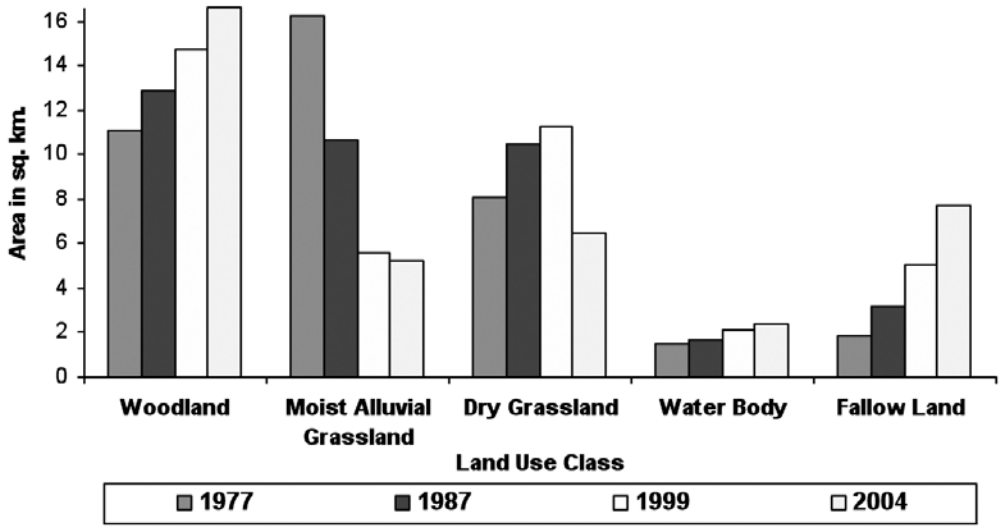

Figure 3. Change in rhino habitat in Pabitora WLS.

stray out of the WLS in search of food in nearby crop fields (Talukdar et al. 2007). As the rhino population in Pabitora has been found to increase steadily over the decades—from an estimated 54 in 1987 to about 81 in 2006 (Talukdar 2006)—adaptive management of habitat becomes fundamental to provide required space and food for the growing number of rhinos within the WLS. Thorough research is needed to find out ways and means to control the spread of weeds within the WLS and to restore the grassland habitat favoured by rhinos. In 2009, 84 rhinos were estimated in Pabitora WLS by the Assam Forest Department.

Main challenges faced by the Pabitora WLS and its management

a) Pressure of increased human population

One of the major problems that Pabitora WLS is facing is the tremendous increase of human population in the surrounding villages. The Pabitora WLS is surrounded by 28 villages in which the human population has increased from 9571 in 1971 to about 23,724 in 2001 (Assam Government census data).

b) Livestock grazing pressure

The main livelihood of the communities surrounding Pabitora WLS is crop-based agriculture and diary farming, both of which depend upon cattle. We observed that on average more than 3000 cattle enter the WLS (as observed during the study period of January 2004 to April 2005 (Talukdar and Sarma 2007). Therefore, the grazing pressure over the rhino habitat in the sanctuary is intense, which is also recognized as an important factor forcing about 15–20% of the rhinos to stray out of the WLS. The current population of rhinos in Pabitora is 84 (Table 3).

c) Insufficient suitable habitat for rhino

The rhinos in Pabitora WLS have been found eating grasses such as *Cynodon dactylon, Hemarthria compressa, Hymenachne pseudointerrupta, Imperata cylindrica, Leersia hexandra, Phragmites karka, Saccharum spontaneum, Sclerostachya fusca, Vetiveria zizanioides*, etc. Further it has been found that fodder such as *Alpinia nigra, Amaranthus spinosus, Asparagus racemosus, Hydrilla verticillata, Potamogeton crispus, Vallisneria spiralis* are also palatable to rhinos.

Table 3. Rhino census in Pabitora Wildlife Sanctuary

Year	Adult	Sub Adult	Calf	Total
1987	36	13	5	54
1993	32	5	11	56
1995	42	17	9	68
1999	43	12	19	74
2004	47	11	21	79
2006	48	12	21	81
2009	59	8	17	84

Source: Assam Forest Department

During the study it was observed that the Pabitora WLS is also facing the problem of declining suitable habitat for rhino. It has been found that the area of moist alluvial grassland, which is highly suitable for rhinos, has declined from 16.25 km^2 in 1971 to only 5.2 km^2 in 2004 (Table 2). Similarly the fallow land has increased in the sanctuary from 1.86 km^2 in 1971 to 7.75 km^2 in 2004. This indicates that the suitable habitat for rhinos in Pabitora has been shrinking due to inadequate resource management as well as the natural succession process that ultimately leads to rhinos straying out of the sanctuary

Impact of habitat change on poaching of rhinos in Pabitora WLS

Poaching is the major threat to the rhinos in Pabitora WLS, with 50 animals poached between 1988 and 2006—both within and outside the WLS (Table 4). As the area of Pabitora is small and the rhino population is steadily increasing, plus suitable habitat declining, the straying of rhinos from the WLS into surrounding areas has also been increasing. Twenty-seven rhinos were poached outside the WLS (Table 4) while 23 rhinos were poached within. Fortunately, not a single rhino was poached in 2007 or 2008 in Pabitora WLS due to efficient management of ex-poachers and a community programme initiated by forest officials in and around Pabitora WLS.

The changes in grassland dynamics within the sanctuary have forced more rhinos to stray out of the reserve, thus significantly increasing the risk of poaching. The mapping of rhinos' movement patterns outside the reserve was undertaken to assist the Pabitora WLS authorities to set up more anti-poaching camps outside the WLS to halt further rhino poaching attempts. It has been found that although Pabitora WLS is only 38.80 km^2, the rhino zone of influence is about 257.31 km^2 (Fig. 4).

We recommend that the Government of Assam increase the manpower in Pabitora WLS to cover the total zone of influence and temporary camps established outside the WLS along stray rhino

Table 4. Poaching and natural deaths of rhino in Pabitora WLS (Source: Assam Forest Department)

Year	Death of rhinos in Pabitora WLS	
	Poaching	Natural death
1987	2	0
1988	3	5
1989	4	1
1990	2	2
1991	1	1
1992	3	2
1993	4	1
1994	4	2
1995	2	1
1996	5	2
1997	3	2
1998	4	2
1999	6	3
2000	2	1
2001	0	1
2002	1	2
2003	2	3
2004	1	3
2005	2	4
2006	1	2
2007	0	3
2008	0	8
2009	0	2

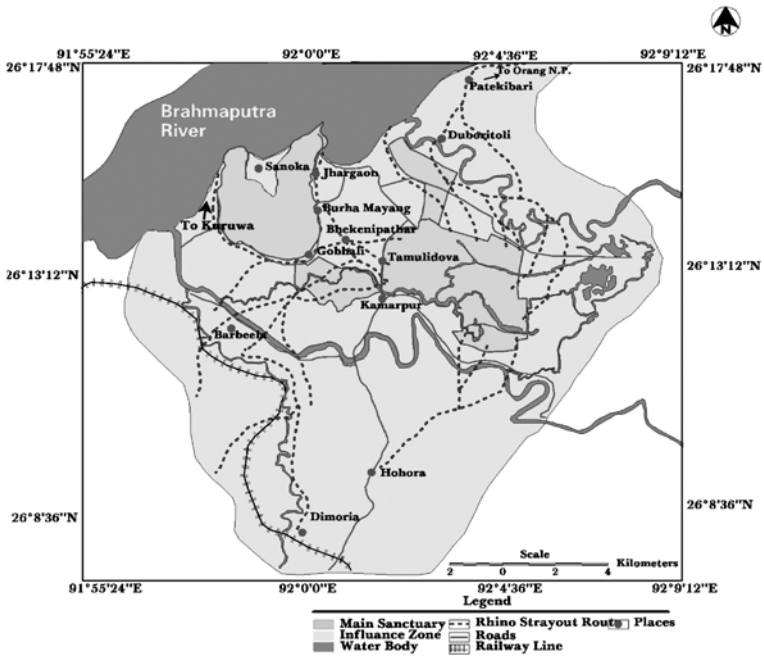

Figure 4. Rhino stray-out routes and zone of influence of Pabitora WLS.

routes. Furthermore, the rhino population in Pabitora WLS could be reduced by translocating rhinos from Pabitora to other areas previously inhabited by rhinos like Manas National Park (NP) and Laokhowa WLS. Bearing in mind the need to translocate rhinos to increase the amount of viable habitat for rhinos in Assam, a joint initiative known as Indian Rhino Vision 2020 (IRV 2020) was established in 2005 with the government of Assam, the International Rhino Foundation, WWF and the U.S. Fish and Wildlife Service, IRV 2020 aims to: (1) increase the rhino population to 3000 in Assam by the year 2020 and (2) increase the area of rhino occupancy within Assam through translocation.

On 11 April 2008, two male rhinos were captured in Pabitora WLS under the auspices of IRV 2020 and translocated to Manas NP. There are plans to translocate 18 more rhinos into Manas from Pabitora WLS and Kaziranga NP in 2009. With the increased rhino population in Pabitora, there are ample opportunities to move some rhinos out of Pabitora WLS in order to establish a healthy rhino population in suitable protected areas within Assam. The success of the first two rhinos translocated into Manas has opened the gate for future well-planned translocations of rhinos in Assam.

Conclusion

With changing habitat in Pabitora WLS, scientific measures are needed to increase the quality of rhinos' feeding habitat within the sanctuary through careful manipulation of the habitat and preventing livestock grazing inside the sanctuary. A water holding mechanism within the sanctuary during winter is crucial to keep moist grassland available during the dry season, which will reduce the number of rhinos straying out of the sanctuary and thus exposing the species to poaching. It is recommended that the Assam Forest Department implement adaptive habitat management of rhino grassland habitat to prevent rhinos from leaving the sanctuary for food. The matter is being taken up with the Assam Forest Department for urgent action to ensure long-term conservation of rhinos and their habitat in Pabitora WLS. Further, to reduce pressure on limited grassland habitat—and keeping in view the increasing rhino population—translocation of 15–20 rhinos out of WLS to other protected areas of Assam would further enhance rhino conservation. This effort will also maintain the optimal carrying capacity of rhinos within Pabitora, which will ensure long-term conservation of rhinos in the WLS.

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