



# Assessing and managing the rising rhino population in Kaziranga (India)



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## ABSTRACT

The greater one-horned rhinoceros (*Rhinoceros unicornis*) is a flagship species, and yet is poorly known unlike its African cousin. The species future is now under a growing threat, judging by the prospect of a legalization of the horn trade that has been the subject of recent debate, coupled with the fragmentation of the animal's habitat. In this study, we analyze the rhino habitat and assess its dynamics in the Kaziranga National Park (KNP), Assam, India. To compensate for the limited size of the data available, we use some numerical models and propose some original spatial analyses and indicators.

Our findings point to a healthy and increasing rhino population in a density-dependent scenario. An increase of at least 30% in the rhino population is expected in the coming twelve years, mainly as a result of the effective implementation of wildlife protection laws in the country. Kaziranga's grasslands have been quite stable in the past (7% between years, in average, and less than 19% at most), and are expected to remain so in the near future, especially in the core area of the KNP. In the absence of a detailed suitability map and known carrying-capacity values, we identified the areas most favoured by the rhinos, and developed a so-called "preference map". We conclude by stressing the need to realistically combine the existing conservation strategies while increasing the monitoring effort on the species distribution.

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## 1. Introduction

Although all rhinoceros species are flagship species in their respective habitats, and are on the IUCN Red List (Talukdar et al., 2013), our understanding of the population ecology of this megafauna group is limited to some species only. While the African black (*Diceros bicornis*) and white rhinos (*Ceratotherium simum*) have been well studied in terms of demography and ecology (Ferreira et al., 2012; Tatman et al., 2000; Walpole et al., 2001, and references therein), the three Asian rhinos (*Dicerorhinus sumatrensis*, *Rhinoceros sondaicus*, and *Rhinoceros unicornis*) are still poorly known. Of these, the unicorn or greater one-horned rhino, the subject of this paper, lives in the northern part of India and neighbouring territory, and its demography, behaviour, and relationship with its habitat deserve much more attention than is apparent in available literature (Acevedo, 2005; Dinerstein, 2003;

Laurie, 1982; Srivastava, 2002). One may recall some African studies (Conway and Goodman, 1989; Harley et al., 2005), and in particular those touching on the poaching pressure for their horns (Poudyal et al., 2009). We discuss here the likely future of the unicorn rhino population living in the Kaziranga National Park (KNP), Assam, India, with a close look at its demography and habitat dynamics using original methods and indicators adapted to the meagre dataset available.

The KNP is a key protected area located in the Brahmaputra plains in north-eastern India, and is part of a rich biodiversity hotspot (Myers et al., 2000). Apart from the unicorn rhino (population estimated at 2329 individuals in the March 2013 census), Kaziranga is home to what is probably the densest tiger population in the world, and to a complex food web encompassing several wild species. It simultaneously provides ecosystem services for a large human population dependent on the KNP forests for their livelihood (Saikia, 2009; Srivastava, 2002). While the authorities have made efforts to protect the various fauna and their habitat, they would have had greater success if they were equipped with a better understanding of the rhino–habitat relationship and its direct implications for this species viability (Mathur et al., 2005b).

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As things stand, however, we still do not have adequate information about the species basic biology, specifically on the existence of a density-dependent effect, or the importance of territoriality (Brodie et al., 2011; Dinerstein, 2003; Garawad, 2009), and about how this mega-herbivore affects habitat quality and habitat availability when the population density increases (e.g. Fritz et al., 2002). While some studies of the unicorn rhino do exist for the Indian and Nepalese parks (Acevedo, 2005; Kushwaha et al., 2000; Mathur et al., 2005b; Subedi et al., 2013), they show deficiencies, such as a narrow geographical focus or remoteness in time, which diminish their usefulness in arriving at a generalization of the rhino's behaviour and its relationship with its habitat.

What will be its IUCN status in the years ahead, after its present-day *vulnerable* state? The direction of the rhino's future demography, and of the dynamics of its habitat (i.e. whether the habitat will shrink and/or change in composition), will be mainly shaped by the existing poaching pressure and other mainly anthropogenic threats. Conversely, even a small increase in the population would call for a careful management of its spatial distribution to ensure a stable local population with minimal inbreeding (Dinerstein and Mc Cracken, 1990; Mathur et al., 2005b). In parallel, the dynamics of its habitat, more specifically its possible reduction and simultaneous fragmentation, may have a considerable influence on the population's long-term viability. The methods we indicate of projecting useful information on the rhino's demography are such as could be utilized in the case of other mammal populations.

Developments in regard to the horn trade, illegal globally, and our ability to build robust networks of protected areas, will remain the major elements among human impacts on the rhino's future (Biggs et al., 2013; Collins et al., 2013; Litchfield, 2013). The rhino does not enjoy the protection that Indian tradition accords to the elephant and the tiger, while Assamese society does show a strong attachment to the animal. The recently observed increase in the pressure on the African species should serve to echo the risk to the present relatively safe situation of the Asian populations (Syangden et al., 2008). Sustainable management of these species may need some complementary and sometimes controversial decisions (van Aarde et al., 1999; Van Aarde and Jackson, 2007).

Our objective were threefold: (i) to develop a demographic model from the available census data to prefigure the most probable scenario in the KNP; (ii) to analyze the KNP landscape's dynamics using remote sensing data and generic multiscale methods (Gaucherel, 2010; Gaucherel et al., 2010); (iii) to discuss the future of the rhino population in the light of changes in the KNP's vegetation.

We hypothesized that the KNP's rhino population remained relatively stable or was slowly increasing, and would continue in that direction. We developed several population-dynamics models to simulate the species demography, basing them on the data from the censuses carried out in the KNP that covered approximately three-year periods. Another hypothesis was that the rhino habitat was decreasing in size, partly due to competition with other mega-herbivores of the KNP and to the Brahmaputra's erosion in past years (Mathur et al., 2005a). From the KNP land-cover maps, we developed spatial analyses to document the habitat structure in space, in time, and at various scales (Gaucherel, 2010; Gaucherel et al., 2010). These two hypotheses (i.e. a stable rhino population and a decreasing surface habitat) combine to give the intuitive idea that the rhino population in this site is vulnerable. We finally combined these analyses in a context of scarce data on the basis of a ranking index with the intention of capturing the focal species preferences (Johnson, 1980), and building a robust and coherent image of its probable future in the KNP and further away.

## 2. Materials and methods

The Kaziranga National Park is located in the north-eastern state of Assam in India, and covers approximately 430 km<sup>2</sup> (Fig. 1a, see Appendix A in Supplementary materials). The Brahmaputra river's dynamics generates floods that affect the KNP's unique landscape and its wet, alluvial plain ecosystem. The oldest protected area in India, the KNP was declared a reserve forest in 1908, and was notified as a World Heritage Site by UNESCO in 1985. The KNP's landscape is highly heterogeneous and mainly covered by scrublands (19.7%), grasslands (39.6%), and woodlands (32.6%), as shown by diachronic Landsat images (Hazarika and Saikia, 2005) (Fig. 1). Land-cover and vegetation types were retrieved from supervised and unsupervised classifications of these Landsat images (Appendix A). Available population data in KNP allowed us to compute averaged population parameters such as the fertility, mortality, and poaching rates, and the sex ratio despite their obvious variations in time (Table 1, Fig. 2). Detailed sighting events (i.e. occurrences transformed into frequencies) of rhino individuals in the various land covers were not available at KNP, and we used sightings of the Chitwan National Park (CNP) (DNPWC, 2009) to compute the rhino preferences. The CNP, which is approximately 800 km away from KNP, indeed is a relatively similar though more forested landscape than KNP (Shrestha and Dangol, 2006).

We developed Leslie-Matrix projection models to quantify the population dynamics of the rhino species in the KNP (Caswell, 1989; Poudyal et al., 2009). Instead of developing a detailed spatially explicit population model (Rétho et al., 2008), for which data were not available, we intended to build a preliminary model to estimate the main demographical rates within the park. In the absence of a clear demonstration of a regulation of the density-dependent population of the unicorn rhino (Brodie et al., 2011; Dinerstein, 2003; Laurie, 1982; Ripley, 1952), we developed two (density-independent (DI) and density-dependent (DD)) models for this population (Appendix B). Both the models were developed for females, and were based on a two-stage matrix *L* (for calf and adult classes), fed by the above estimated parameters, and calibrated with a trial-and-error procedure on the basis of observed abundances and root-mean-square-errors (RMSEs). Both models covered a time span of 200 years, starting with the census year 1966. The DD model was based on a somewhat natural and robust Ricker function to mimic the fertility rate according to the population abundance (Caswell, 1989; Ricker, 1954). In addition to a detailed sensitivity analysis to assess the impact of each model's parameter, we estimated and compared the rhino's growth rate  $\lambda$  in year 2013 in Kaziranga for both models.

We proposed detailed spatial analyses of the KNP's landscape dynamics to then relate them to the rhino's presence and habitat utilization (Appendix C). We first estimated the KNP's land-cover changes computed with Cohen's Kappa, bearing in mind the rhino's need for a habitat mosaic (Dinerstein and Price, 1991; Kushwaha et al., 2000). We then estimated the KNP's grassland dynamics through comparisons of grassland-density maps for all the available dates to identify the rhino's most favoured habitat for its short grasses and wallowing grounds (Garawad, 2009). All these spatial analyses were based on two methods that have been extensively described and applied to ecological questions (Gaucherel, 2007, 2010; Gaucherel et al., 2008, 2010). Both the methods (multiscale heterogeneity map (MHM) and comparison map and profile (CMP)) are based on the principle of a circular moving window simultaneously crossing the images to be analyzed (MHM uses a single image, Gaucherel et al., 2007) or compared (CMP compares two images), combined respectively with specific textural or similarity indices. They lead to local and quantitative analyses, which become multiscale when the number of the moving window sizes varies.

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