Indian Rhino Vision 2020 Population Modeling Workshop

FINAL REPORT FROM THE WORKSHOP HELD 4-5 NOVEMBER 2014
Guwahati, Assam, India

Edited by
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Compiled by the Workshop Participants

IRV 2020

Department of Environment & Forests, Govt. of Assam

WWF

INTERNATIONAL RHINO FOUNDATION

BODOLAND TERRITORIAL COUNCIL

CONSERVATION BREEDING SPECIALIST GROUP

Reference:

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FINAL REPORT
5 June 2015

Dr. Bibhab Talukdar, Chair of the IUCN Asian Rhino Specialist Group (AsRSG) welcomed the group, and participants introduced themselves. A list of participants is included as Appendix I.

BACKGROUND

The greater one-horned, or Indian rhino is one of the two greatest success stories in rhino conservation (the other one being the southern white rhino in South Africa). With strict protection from Indian and Nepalese wildlife authorities, greater one-horned rhino (GOHR) numbers have recovered from fewer than 200 earlier in the 20th century to as many as 3,333 today. However, even with population increases, poaching pressure has remained high.

More than 70 percent of the world's Greater One-horned rhinos (GOHRs) inhabit Kaziranga National Park in Assam, India. Having most of the animals in one population puts it at risk from catastrophes such as floods or disease outbreaks, which could lead to a serious population decline.

Indian Rhino Vision 2020

In 2005, the Assam Forest Department, in partnership with the International Rhino Foundation (IRF) and WWF-India, launched Indian Rhino Vision 2020 (IRV 2020) which was also supported by the Bodoland Territorial Council (BTC), US Fish & Wildlife Service and other organizations. The goal of Indian Rhino Vision 2020 is to reduce risks to India's rhino population by ensuring that the animals are spread throughout multiple parks with enough habitat to encourage population growth. The program's vision is to expand the number of GOHR to 3,000 individuals spread over seven protected areas by the year 2020. This will be accomplished through translocations from Kaziranga and Pabitora to other appropriate protected areas and by enhancing protection to the rhinos and their habitats in their existing PA's. Since 2008, IRV 2020 partners have moved 18 rhinos to Assam's Manas National Park, and are now planning phase II of the program, moving at least ten animals, initially, to the Laokhowa-Burhachapori complex by the winter of 2015-16.

Rhinos were once common in both Manas and Burhachapori, but violent civil conflict beginning in 1989 caused massive damage to the parks' infrastructures and resulted in the loss of their rhino populations. IRV 2020 has been well on the way to rebuilding the population in Manas. Unfortunately, eight of the translocated animals have been poached from the population.

Another ten hand-reared animals rescued from Kaziranga during floods have also been released into the park; one of those animals has died. Eleven calves also have been born; two were orphaned by poaching and now are being hand-reared.

THE WORKSHOP

The workshop was developed to review progress with IRV 2020 translocations to-date:
(a) discussing and determining the real numbers needed for the long-term success of the IRV 2020, taking into account our experience in Manas with poaching losses;
(b) modeling predicted population growth rates and the numbers of rhinos needed to make translocations a success; and
(c) discussing ways to ameliorate known threats as well as unforeseen events.

The workshop focused primarily on Manas and Burachapori, but other areas also were discussed and modeled.

The workshop began with a series of presentations to discuss the current situation and to outline current and future challenges.

IRV 2020 Overview – *Mr. R.P. Agarwalla, IFS, Chief Wildlife Warden, Assam*

The IRV 2020 Vision is to have 3,000 rhinos in seven protected areas in Assam by 2020. The program's primary objectives are to enhance protection to rhinos, undertake range expansion programs (translocations) and to manage habitats.

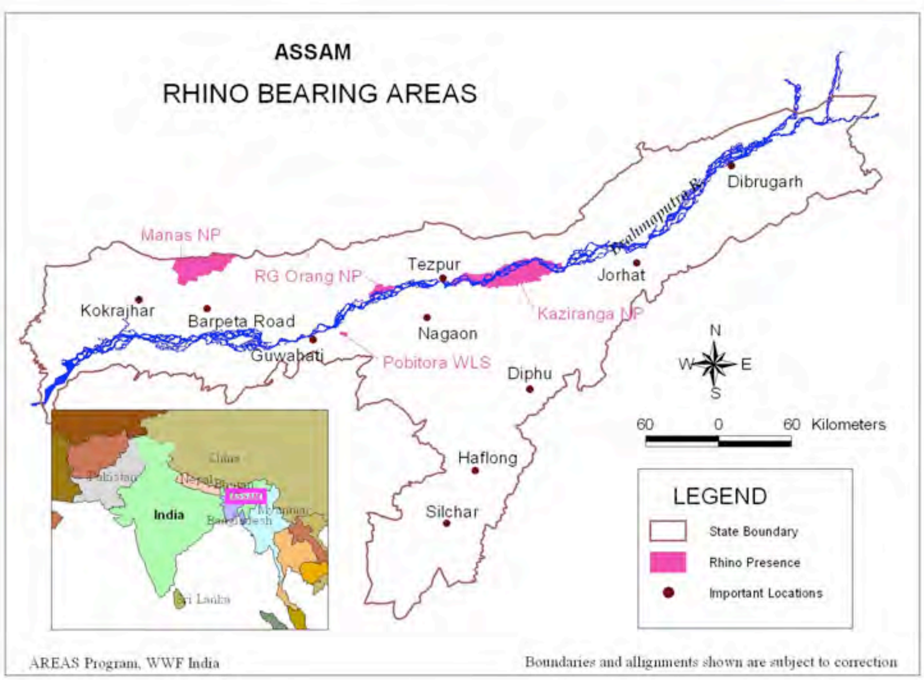


Figure 1. Map of Assam showing National Parks and Wildlife Sanctuaries currently holding populations of Greater One-Horned rhinos. Figure based on map created by the WWF AREAS Program.

Rhinos presently inhabit four areas in Assam: Kaziranga, Orang, Pabitora, and Manas (Figure 1). IRV 2020 is targeting Burachapori Wildlife Sanctuary, Laokhowa Wildlife Sanctuary and Dibru-Saikhowa NP for future translocations.

The true success of the IRV 2020 program is that rhinos have returned to Manas. Four males and six females were translocated from Pobitara, and three males and five females from Kaziranga for a total of 18 animals. The animals have adapted well, with 11 calves born. Manas had its status as a World Heritage Site renewed in 2011; the translocations greatly assisted this process.

IRV 2020 provided a boost in terms of infrastructure development, manpower deployment (e.g., home guards and others), community support mobilization and tourism growth in Manas (Figure 2).

Figure 2. IRV 2020-funded infrastructure improvement in Manas National Park

Support has been provided to all the rhino bearing protected areas for enhanced protection. Security has been enhanced in Orang National Park, with special support from IRV 2020.

Laokhowa-Burachapori Wildlife Sanctuary now is being prepared to receive rhinos. A security assessment has been completed, and a boma has been designed. We initially planned to move animals late in 2014; more realistically those translocations will take place in early-mid 2015.

Rhino rescue operations are an important component of IRV 2020 (Figure 3). When poaching takes place, orphans sometimes need rescue and rehabilitation. Floods also sometimes lead to a crisis that require the rescue of affected individuals. At times there is long-distance straying that requires rescue as well.

Figure 3. Rhino rescue operations are common during the rainy season.

Telemetry and camera traps have been used to document rhino ranging. Law enforcement and monitoring using SMART have been implanted in Kaziranga and Manas. There have been trials of Unmanned Aerial Vehicles (UAVs) in Kaziranga, and we are hopeful that we will be able to use these drones shortly for overall monitoring in Kaziranga.

The laws have been strengthened under the 2009 Wildlife Protection Act (Assam amendment). The penalty for offence committed relating to any animal in Schedule I or Part II of Schedule II of Wildlife (protection) Act for second or subsequent offence has been raised to minimum of 7 years but may extend to life imprisonment and fine of not less than 75,000 rupees.

Forest guards also have been empowered. For effective coordination between Civil, Police and Forest Administration to prevent rhino poaching and control wildlife crime, the Government of Assam has constituted coordination committees chaired by very senior Superintendent of Police of the concerned districts for Kaziranga and Manas National Parks. Additional support for control of poaching in Kaziranga and other rhino bearing protected areas has been provided by placing 535 Assam Forest Protection Force personnel equipped with 200 SLR rifles. Plans are in place to acquire and deploy more sophisticated arms like AK series rifles. Trained armed Home Guards are also being deployed for additional protection.

The government has engaged the services of the Central Bureau of Investigation to establish forward and backward linkages to crime. A central intelligence wing also has been established in the Chief Wildlife Wardens office.

Staff motivation is critical to effectively fighting wildlife crime. The Government has initiated steps to motivate the staff in the rhino bearing areas by providing them a special package during the Magh Bihu celebrated in Assam during January 2014.

A major challenge is how to contain poaching; almost all poaching events involve guns, where previously poaching was carried out using electrocution or pit traps.

Poaching remains the single biggest threat for rhinos. Eight translocated rhinos were poached in Manas between October 2011 and November 2014. All the dominant males were killed and there is now no breeding male. A total of twenty-four rhinos have been poached in Assam during 2014 (up to 3 November). Figure 4 shows the poaching trends in Assam from 1985-2013.

On a brighter note, there have been 11 births in Manas National Park, and plans are underway to build a boma in Burachapori Wildlife Sanctuary for the release of animals in 2015.

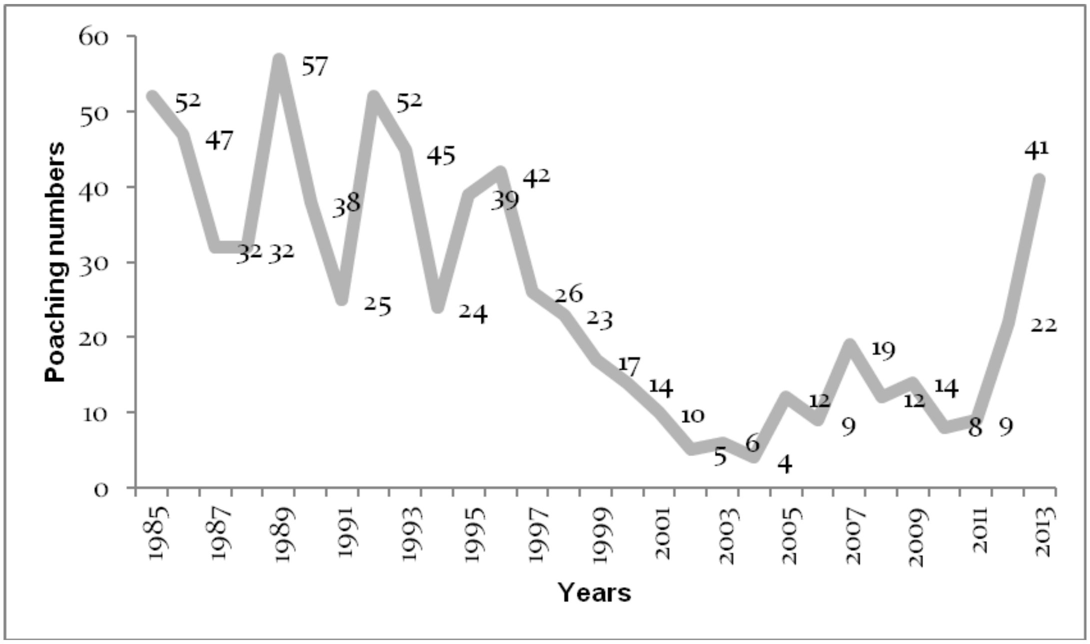


Figure 4. Rhino poaching in Assam, 1985 – 2013.

Kaziranga National Park – Mr. M.K. Yadava, IFS, Director, Kaziranga National Park

Kaziranga National Park is comprised of the original core park, and has since been expanded with six additions (Figure 5).

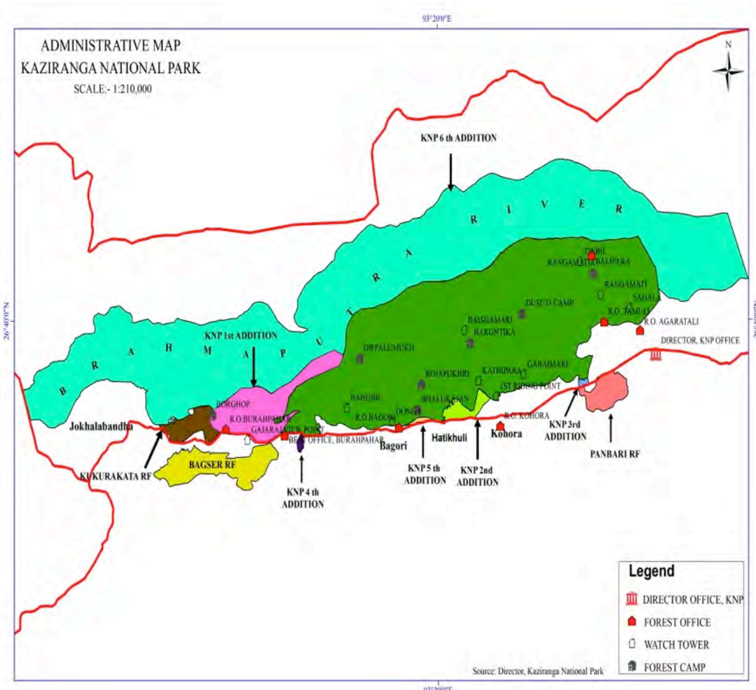


Figure 5. Map of Kaziranga National Park and additions.

Threats to Rhinos in Kaziranga

The primary threats to rhinos in Kaziranga have to do with limited carrying capacity (K). At present there is 0.18 km sq. per rhino; there could be 0.38 km sq. per rhino in the park, if the full six expansion areas could be handed over to the national park. There is great need for additional extensions of the park to accommodate the growing rhino population.

Habitat loss, including degradation and fragmentation of habitat, specifically loss along the southern riverbank is another important threat. The actual loss of land has been 165 sq. km. over a period of couple of decades. Overgrazing, loss of grasslands, issues of water in the park, woodlands taking over grasslands also pose a threat.

Poaching is a continual threat, which shows no signs of abatement. Finally, there are significant threats from unplanned economic growth all around Kaziranga. If this continues it will be difficult to reach 0.38 sq. km needed per rhino in the park.

Monitoring and Census

There is a total visual count once of the park's rhinos every 3 years. There is 100% recording of mortality. It would be useful if methods to estimate ages of animals could be developed; it would also be useful to estimate newborns each year and track them for at least a few months. A genetic evaluation of the population is also a priority.

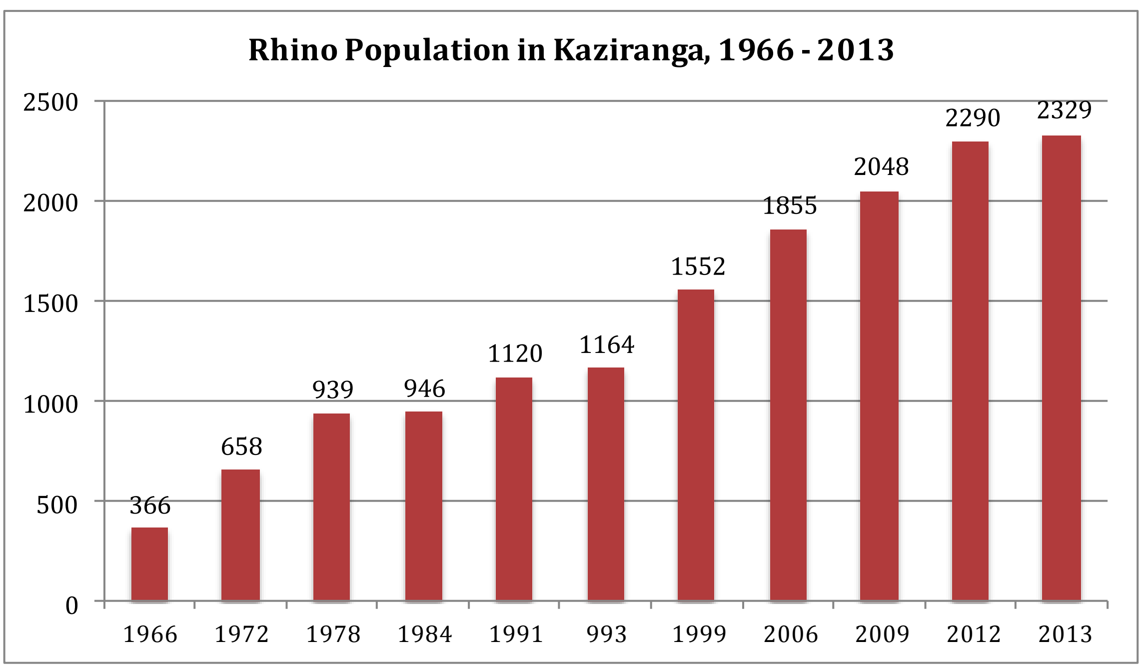


Figure 6. Rhino Population Trends in Kaziranga National Park, 1966 – 2013.

In 1996, there were 366 rhinos in Kaziranga, the most recent survey in 2013 showed 2,329 (Figure 6.) A breakdown of males and females is shown in Table 1, and females and calves in Table 2.

Table 1. Breakdown among males and females in the Kaziranga population, 2006 – 2013

Year	Observed Adult Male	Observed Adult Female	% Female in Observed Population	No. of Un-sexed adults	No. of Females in Un-sexed Adults	Total Estimates Females
2006	481	640	57.09	208	119	**759**
2009	597	710	54.32	200	109	**819**
2012	658	819	55.45	186	103	**922**
2013	645	810	55.67	267	149	**959**

Table 2. Number of females in the popualation and calves per female from 2006-2013.

Year	Total Female Population	Calf <1 yr.	Calf per Female
2006	759	105	0.1383
2009	819	100	0.1222
2012	922	172	0.1084
2013	959	135	0.1043

Figure 7 shows that the highest years poaching were in the late 1980s and early 1990s, with poaching numbers again beginning to rise in 2011. These data are similar to what has been seen for African rhinos as well, with enormous poaching mortalities in those same time frames, and a lower rate from about 1998 through 2005.

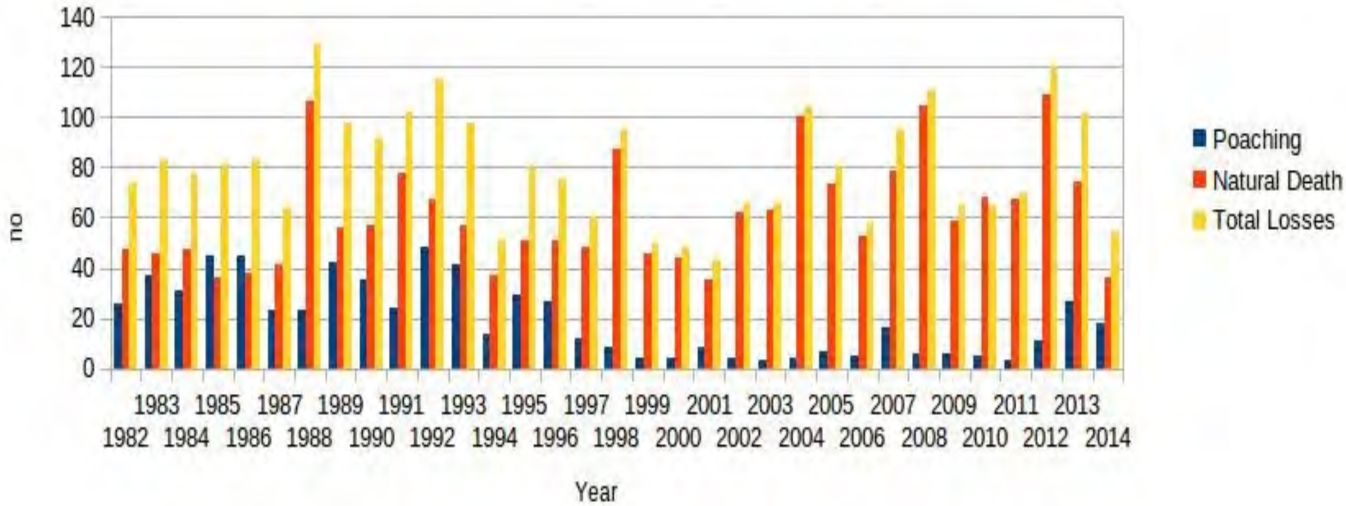


Figure 7. Losses in the Kaziranga rhino population, 1982 – 2014, broken down by poaching deaths and natural deaths.

Figure 8 below shows the percent gain and loss for Kaziranga's rhino population from 1982 through 2014. The net growth rate is 7.25%. These data merit a discussion as to whether, without expansion of the park or translocation of animals to other suitable sites, the population may at some point become unviable.

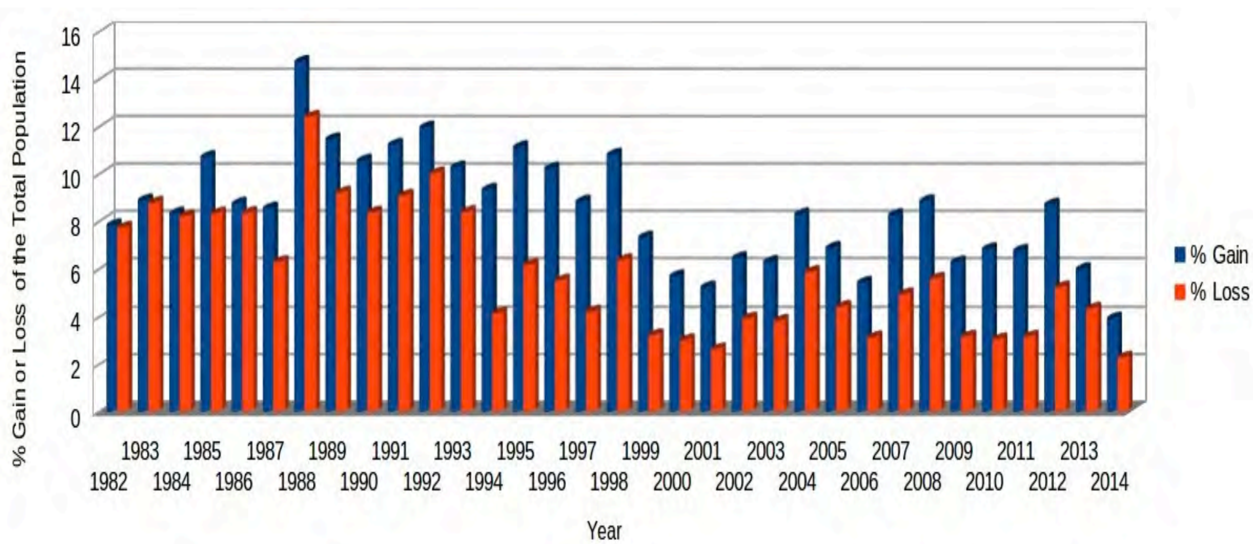
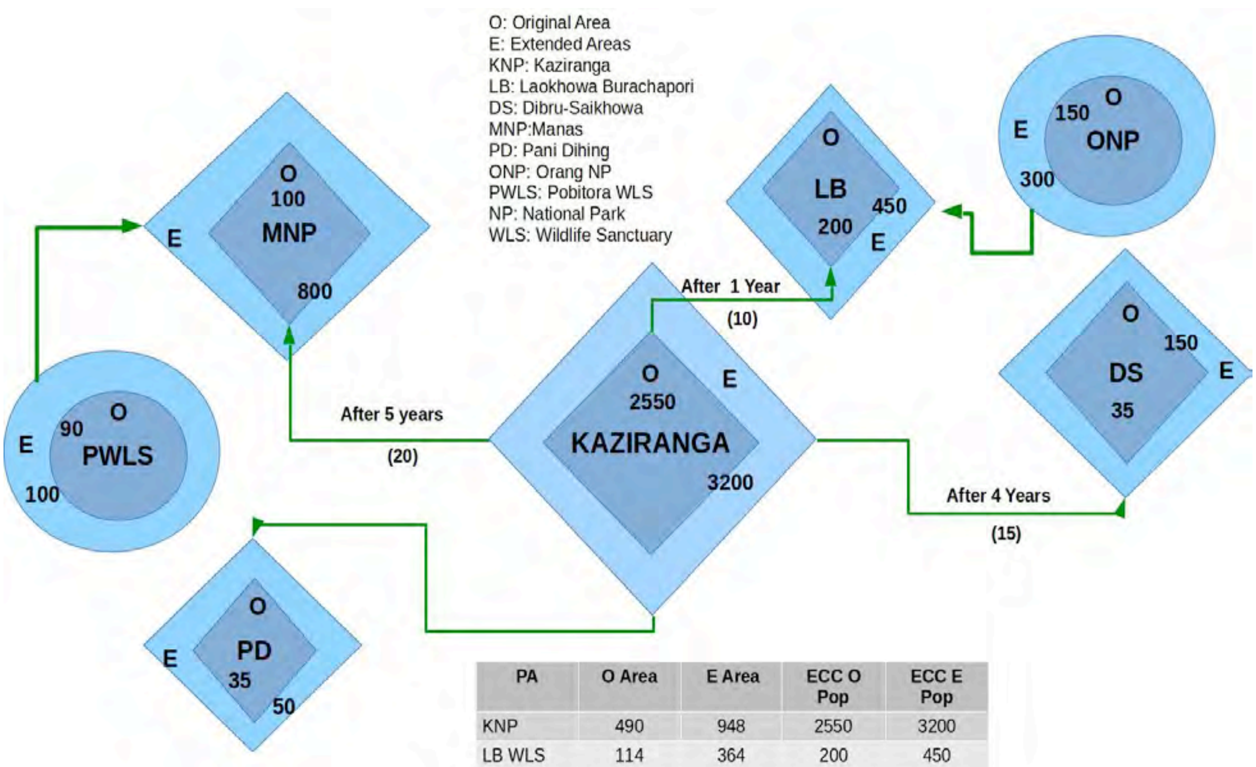


Figure 8. Kaziranga rhino population percent gain and loss figures from 1982 – 2014.

Conclusions for Kaziranga

The current population in Kaziranga is about 2,329 animals, with an average annual loss of 80 animals, with an average net gain of 39. The average number of new entrants into the population is 119. Preliminary modeling suggests that by 2020 the Kaziranga rhino population will be roughly 2,602, and by 2031 2,031. However, the park's carrying capacity (K) has been estimated to be 2,500. Therefore, at least 25 rhinos need to be translocated annually to other sites, or additional land needs to be acquired. However, net gain cannot be allowed to dip below 2.75 meaning the net gain in Kaziranga should not be allowed to go below ~10 animals.

We need to think beyond the current plans to translocate animals, including crossing state and perhaps eventually national borders (Figure 9), creating larger populations and corridors in which rhinos can move. Many of the current rhino areas, e.g., Manas, Pabitora, and Orang, do not have room for expansion.



PA	O Area	E Area	ECC O Pop	ECC E Pop
KNP	490	948	2550	3200
LB WLS	114	364	200	450
DSNP	340	765	35	150
MNP	840	2837	100	800
PD WLS	34	50	35	50
ONP	79	220	150	300
PWLS	39	45	90	100
TOTAL	**1936**	**5229**	**3160**	**5090**

Figure 9. Conceptual figure with current and potential rhino range expansions possibilities, including (in table insert) the carrying capacity of each area.

MANAS NATIONAL PARK – Sonali Ghosh, Deputy Director, Manas Tiger Reserve

Manas currently has six national designations:

1. Tiger Reserve (1973)
2. World Heritage Site (1985)
3. Biosphere Reserve (1989)

4. National Park (1990)
5. Elephant Reserve (2002)
6. Important Bird Area (2007)

Work is underway to obtain additional international designations such as a transboundary landscape/World Heritage Site (TraMCA), RAMSAR site, and the second largest tiger conservation landscape (SOURCE) site. Manas is home to 22 of India's most threatened species of mammals. In total, there are nearly 60 mammal species, 42 reptile species, 7 amphibians and 500 species of birds, of which 26 are globally threatened. Plant diversity includes 89 tree species, 49 shrubs, 37 under-shrubs, 172 herbs and 36 climbers. The park also is home to 15 species of orchids, 18 fern species and 43 species of grasses.

Figure 10 shows a map of Manas National Park.

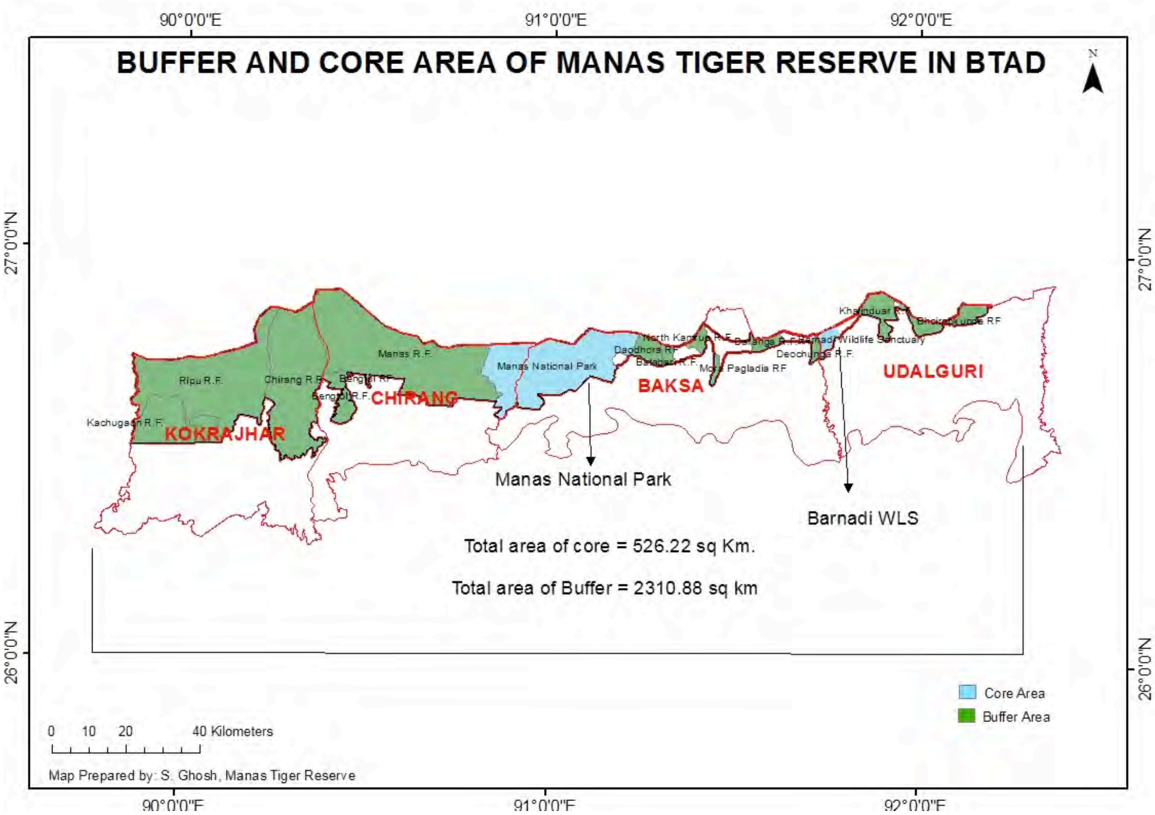


Figure 10. Map of core area and buffer zone, Manas National Park.

In 1966, Manas held 15 GOHRs, and by 1990, the population reached between 85 and 100 animals. During that time frame the rhino population was 15 (in 1966), growing to 85-100 in 1990. By 1995 only 30 were left and the last rhino was poached in 2001 in eastern range. By the mid-2000s, during a period of severe civil conflict, it was confirmed that rhinos had been extirpated from the park.

Beginning in April 2008, under Indian Rhino Vision 2020, four males and six female rhinos were translocated from Pobitara, and three males and five females were translocated from Kaziranga. A total of 18 animals were moved to Manas. The animals adapted well, with 11 calves born. Manas had been on the Endangered World Heritage Site list since 1992; bringing rhinos back assisted in the park being taken off the Endangered list and its status as a World Heritage Site renewed in 2011.

To support the current population, the USFWS is funding joint patrolling for home guards and park guards. SMART patrolling also has been implemented, with 160 volunteers supported. A rhino identification manual also is being developed.

Table 3 shows the number of rhinos that have been moved into the park since 2006. The first animals moved were three rescued hand-reared animals that resided in a 1-ha pen in the park. Table 4 shows the number of animals that had been poached in the park from this new population. Only adult animals, moved as part of Indian Rhino Vision 2020, have been killed so far. These animals are adults with fully formed horns, which represent a better profit for poachers.

Table 3. Animals moved to Manas National Park under Indian Rhino Vision 2020 as well as rescued, hand-reared animals.

Wild-to-Wild Translocation		Rescue-and-Rehabilitation	
Year	**No. of Rhinos**	**Year**	**No. of Rhinos**
2008	**2**	**2006**	**3**
2010	**2**	**2012**	**2**
2011	**4**	**2013**	**1**
2012	**10**	**2014**	**3**
Total	**18**	**Total**	**9**

Table 4. Animals lost to poaching (all from the IRV 2020 translocations) and rhino births, 2011 - 2014.

Year	No. of Rhino Deaths	No. of Rhino Births
2011	**1**	
2012	**1**	**1**
2013	**5**	**10**
2014	**1**	
Total	**8**	**11**

2014 releases. Three 5-year-old male rhinos were brought in from the rescue center and were released on 20 October 2014. They were confined in a boma in the park prior to release.

Figure 11. Young male rhinos prior to release, October 2014.

A Manas Rhino Conservation Plan is in preparation. A strategy for combatting encroachment is in place, comprised of short-term actions such as eviction notices and subsequent evictions, deployment of additional 50 home guards and constructing temporary camps, boundary demarcation using trenches and solar fencing. Longer-term actions concerning encroachment control are still under discussion.

Anti-poaching Efforts and Needs

Anti-poaching remains a key focus, with recognicaiton that anti-poaching staff need to be increased significantly and that staff morale is in need of a boost. Currently, antipoaching units operate over 500 sq. km. of the park. There are 58 anti-poaching camps, each covereing an average agread of between 8-10 sq. km. These staff are supported by 10 vehicles, 28 elephants, and cover four ranges. The average permanenet staff per camp is 2-3 men. There is a need to increase intelligence operations, create new camps, expand SMART patrolling,and to issue better arms to the anti-poaching units (by the district administration. Recent poaching events have been atributed to a growing insurgency movement in the area.

LAOKHOWA-BURACHAPORI WILDLIFE SANCTUARY COMPLEX – P. Sivakumar, IFS, Conservator of Forest, Nagaon Wildlife Division

The contiguous Laokhowa and Burhachapori Wildlife Sanctuaries (Figure 12) of Assam are two important protected areas of central Assam. Laokhowa Wildlife Sanctuary (LWS) is located between latitudes 26°28'31.85"N to 26°32'13.95"N and longitudes 92°37'57.91"E to 92°47'23.27"E having a total area of 70.1 sq.km in Nagaon district. Burhachapori Wildlife Sanctuary (BWS) is located between the latitudes 26°30'34.16"N to 26°33'48.96"N and longitudes 92°34'27.31"E to 92°46'10.667"E with a total area of 44.06 sq.km in Sonitpur district.

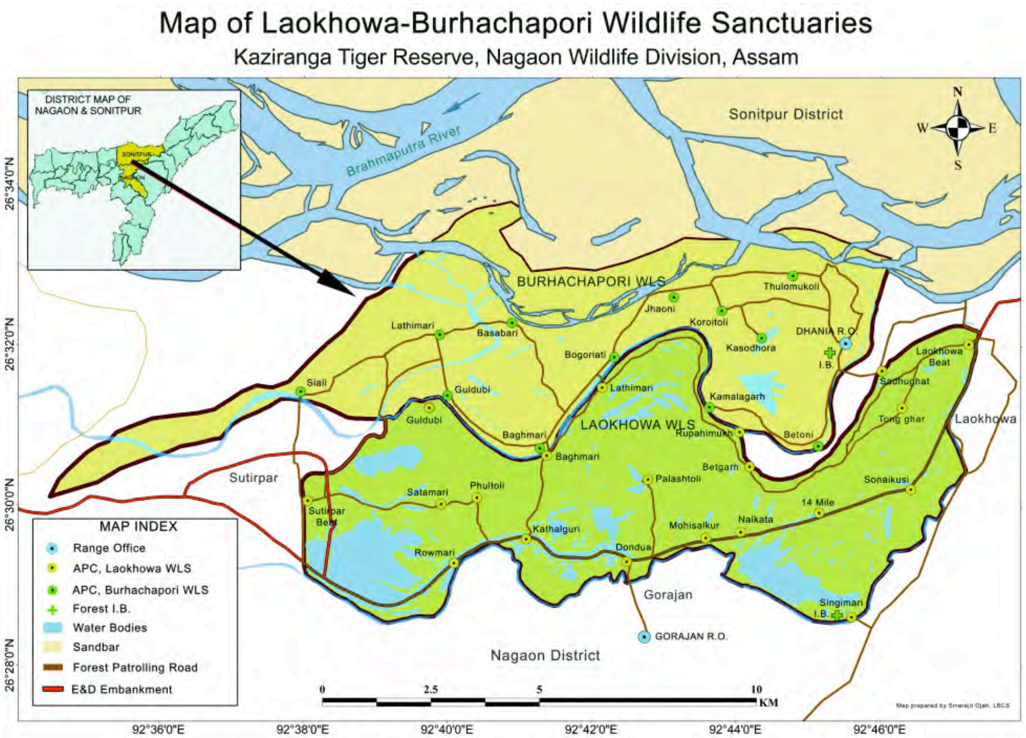


Figure 12. Map of the Laokhowa – Burhachapori complex.

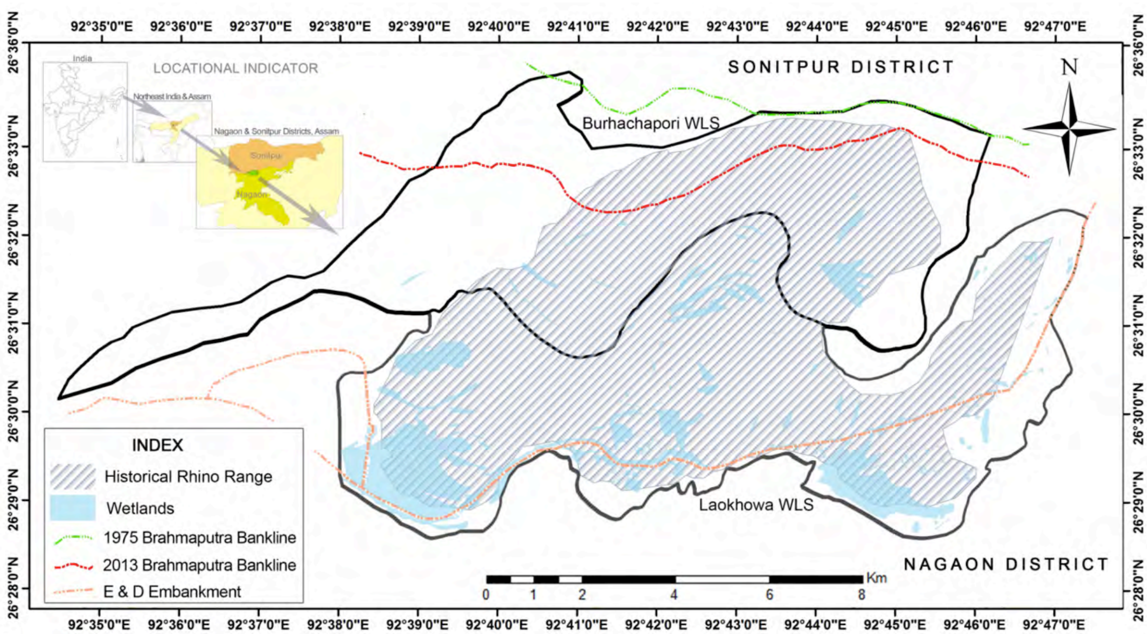


Figure 13. Map of the historical rhino range in Laokhowa-Burhachapori prepared on the basis of focused group discussions and field work conducted with frontline forest staff who served in Laokhowa and Burhachapori prior to 1983 and with fringe village elders.

Both Laokhowa and Burhachapori are historically important protected areas. The importance and biological value of the PAs can be gauged from the fact that in Laokhowa was notified as a Proposed Reserve Forest (PRF) along with Kaziranga in the year 1905 based on its then rhino population. In 1955, this area held 41 animals (25.12.1). In the early 1980s, the area held more than 70 rhinos. However, due to the unstable political situation of the state during 1983-84, the period of Assam Agitation, poachers killed more than 40 rhinos within a matter of weeks. The rest of the surviving rhinos fled to nearby safer PAs such as Orang and Kaziranga. Figure 14 shows mortality rates and causes from 1980 through the population's extirpation in 1991.

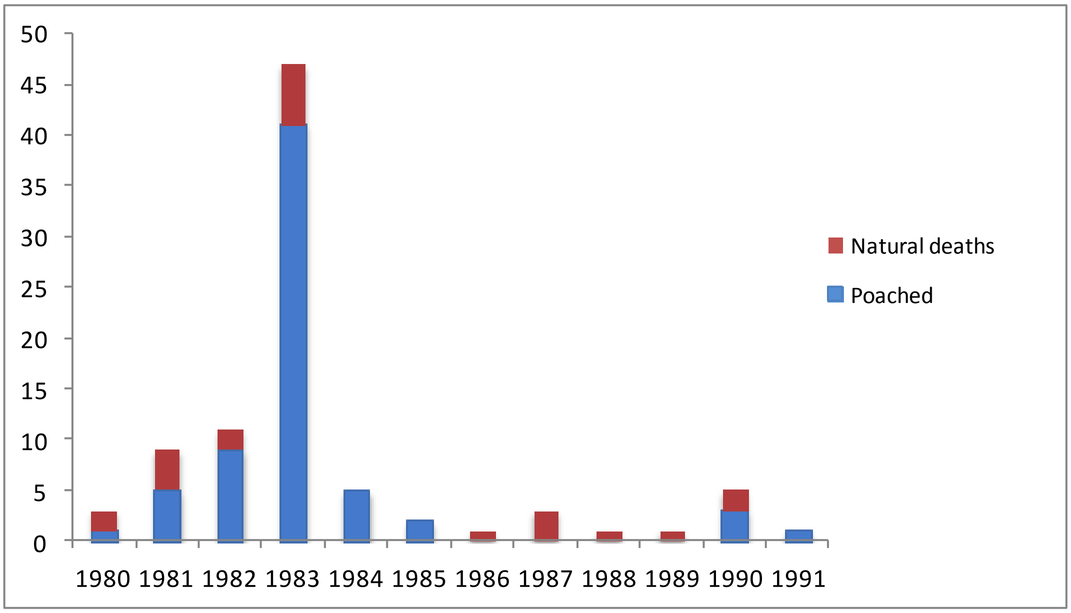


Figure 14. Mortality in Laokhowa Wildlife Sanctuary, 1980-1991 (from TRAFFIC – India)

Land use in the Laokhowa-Burhachapori changed significantly from the late 1970s to the late-2000s (Figure 15). Patterns of temporal change in land use and land cover classes of Laokhowa Wildlife Sanctuary show that there has been a gradual decline in the woodland from 1979 through 2008 and that this loss of woodland stabilized from 2008 onwards. Grassland area showed a steady increase throughout the same period. On the other hand, areas under non-forest activities (encroachment, forest and taungi village area) showed a slight decrease after 2008.

Woodland cover in BWS decreased exponentially until 2008 and after this period through 2013, woodland cover shows an increase. Grassland areas also increased after 2008. Interestingly, the area under sand deposit in BWS shows a constant increasing trend throughout the same timeframe. After 2008, the area under non-forest activities (encroachment, forest, and village areas) shows a significant decrease.

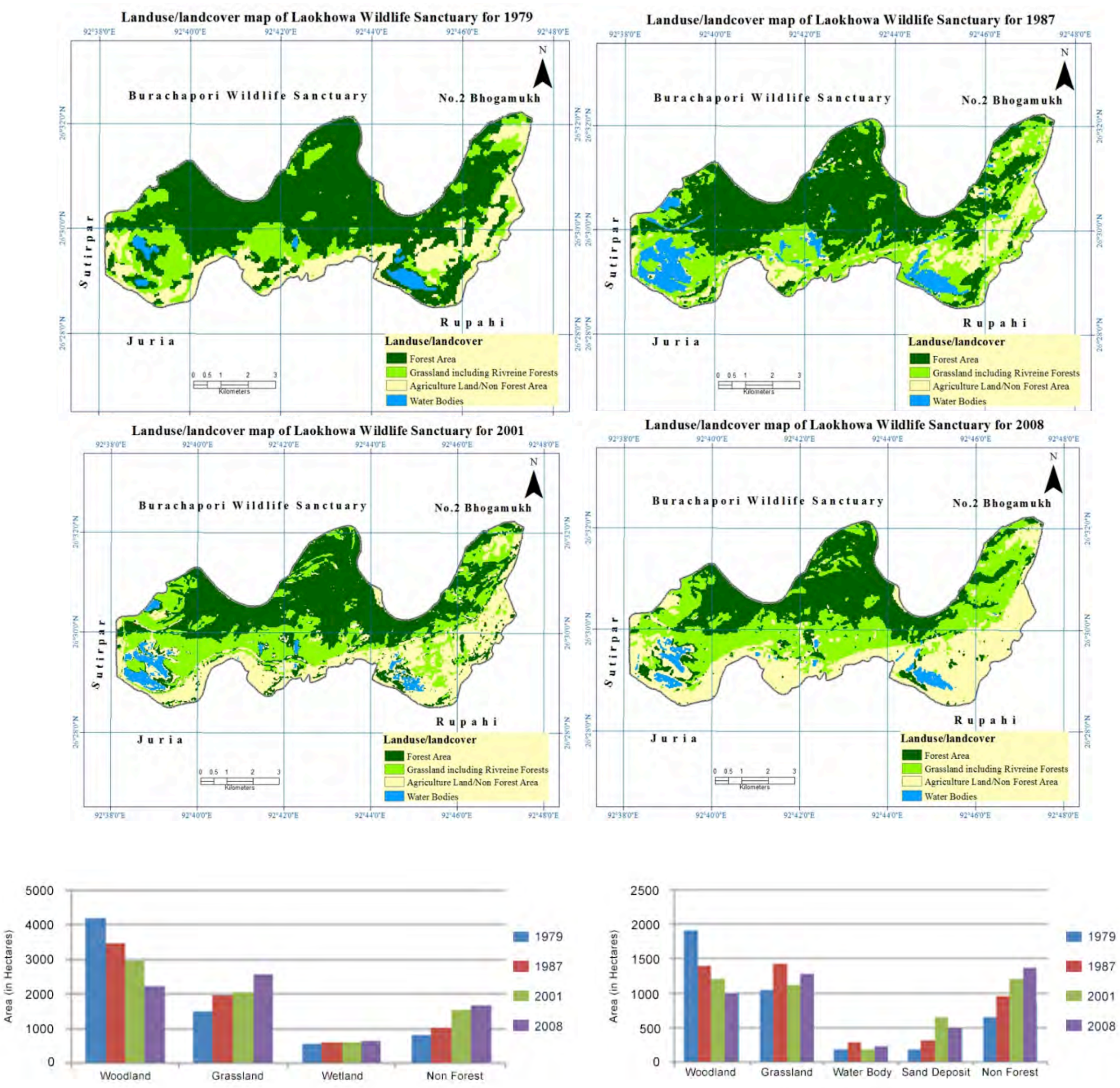


Figure 15. Land use and land cover change in Burhachapori Wildlife Sanctuary 1979 – 2008. (Based on Landsat Imageries, Source: NWLD & Smarajit Ojah, 2012)

In the 1990s, important threats/events affecting rhinos were:

- exponential human population increase
- a high rate of dependency by local communities on the sanctuary's resources
- poaching
- encroachment
- cattle grazing
- illegal timber and non-timber forest product extraction
- corridor degradation

Current threats include high human population dependence on the sanctuary, encroachment in fringe areas, grazing and illegal fishing, flood and erosion, corridor degradation and a vulnerable riverine area.

The Importance of the Laokhowa - Burhachapori Corridor

Nestled between the Kaziranga National Park to its east and Orang National Park to its west, the Laokhowa Burhachapori Wildlife Sanctuary along with the adjacent Brahmaputra riverine tract acts as migratory corridor for wild animals of Kaziranga and Orang (Figure 16). This Brahmaputra Riverine area is widely used by rhinos, among others, for migration among the Protected Areas (Figure 17).

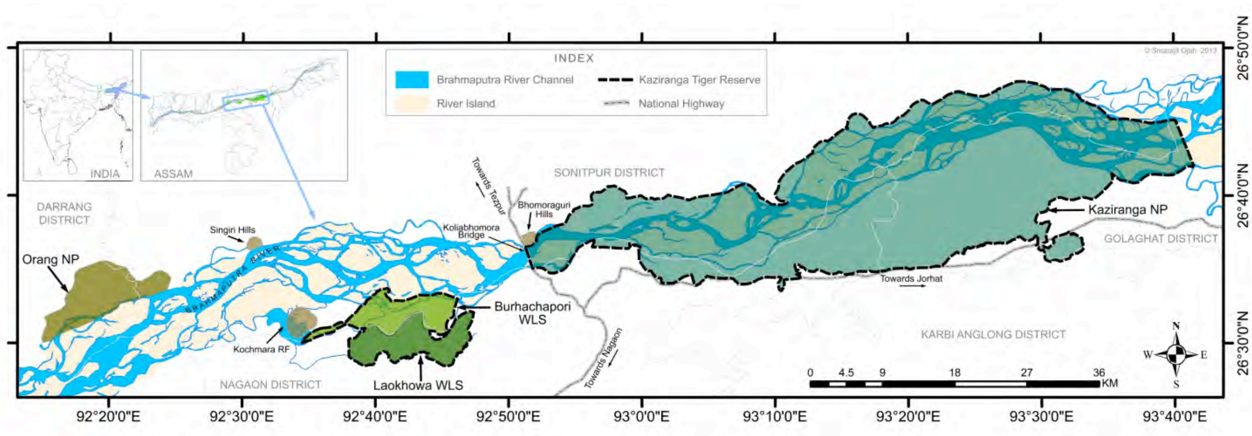


Figure 16. The Kaziranga-Laokhowa-Burhachapori-Orang Protected Area Landscape

Large mammals such as rhinos, tigers, elephants etc. frequently migrate out of Kaziranga and stray into human habitation areas near the eastern, northern and western periphery of the BWS. Such a situation demands that the wildlife be offered obstruction-free movement within the corridor to ensure that they are not blocked and thus prevent their straying into civil areas. It is important that the Kaziranga-Orang-Laokhowa-Burhachapori Brahmaputra riverine corridor is secured so as to ensure the healthy genetic exchange of wildlife. Otherwise wildlife of the adjacent protected areas would not be able to be sustained over time. Further, the islands in the region are home to many undesirable human elements, some of whom have been found to be directly associated with rhino poaching in Kaziranga and Orang National Parks.

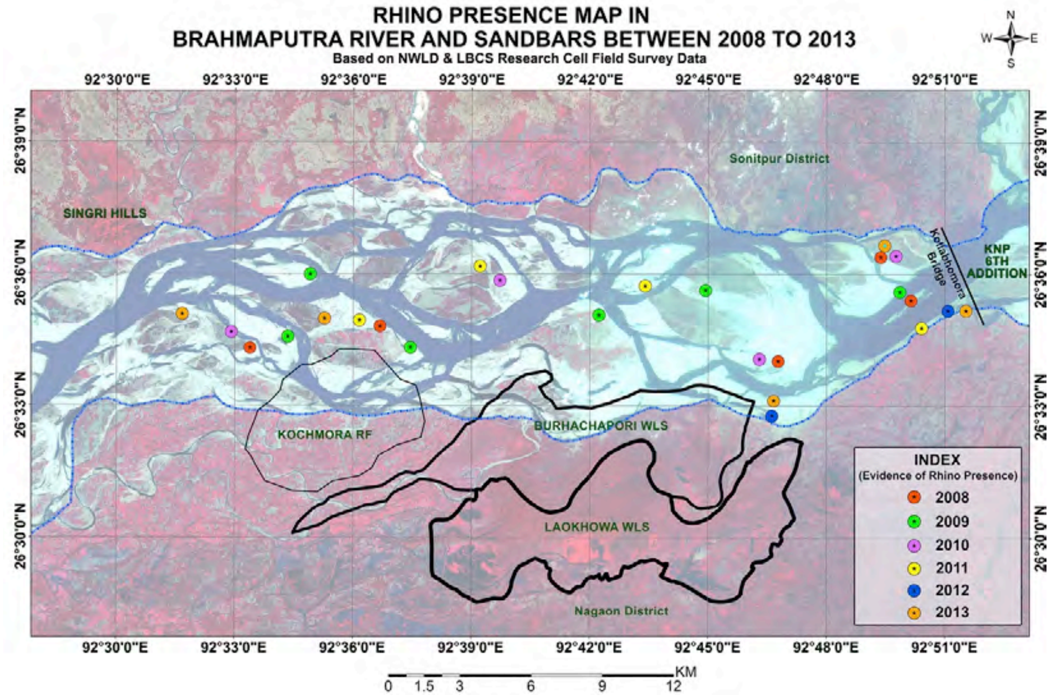


Figure 17. Map showing the presence of migrating rhinos in the River Islands within the Kaziranga-Laokhowa-Burhachapori-Orang PA Landscape (Source NWLD & Smarajit Ojah, 2014)

In 2013, a major part of the area (263.33 sq.km) comprising of a 2-km and 6-km buffer of LWS and BWS, respectively, was proposed as an Eco-Sensitive Zone (Figure 18); that proposal was discussed in a public hearing in January 2015 and the revised proposal has been submitted. Further, 90 percent of the area (250 sq.km.) was proposed as the first addition to BWS in 2014 (Figure 19).

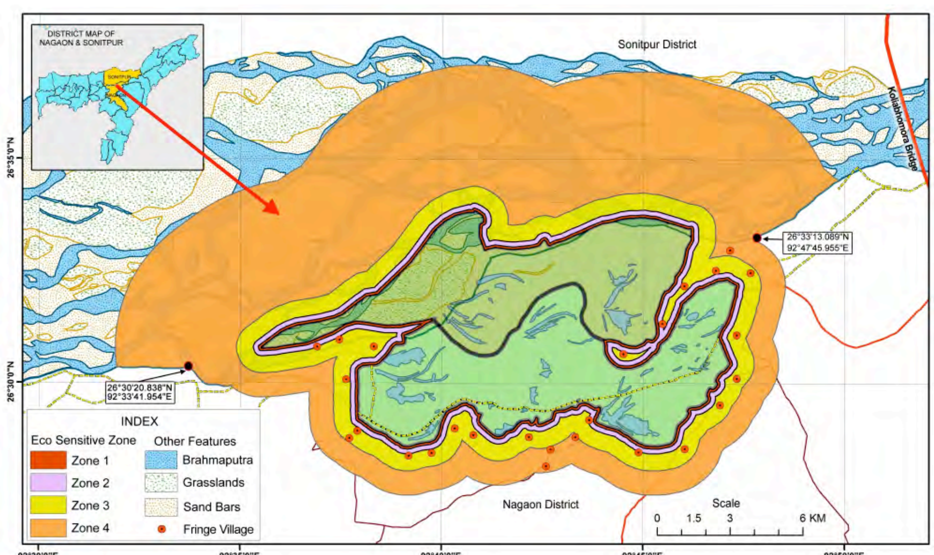


Figure 18. Proposed Eco-Sensitive Zone of Laokhowa Burhachapori Wildlife Sanctuary Complex (Source NWLD & Smarajit Ojah, 2013)

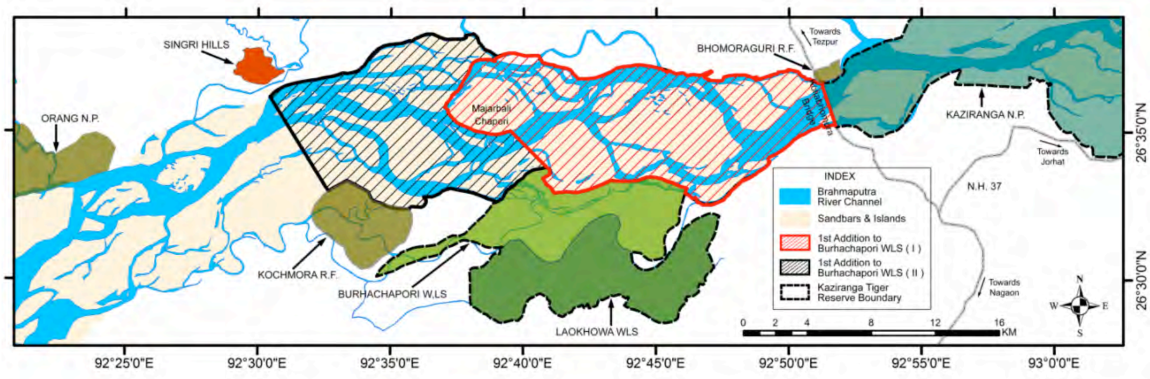


Figure 19. Proposed First Addition to Burhachapori Wildlife Sanctuary
(Source: NWLD & Smarajit Ojah, 2014)

Groundwork for Translocation of Rhinos to Laokhowa Burhachapori Wildlife Sanctuary Complex

The Assam Forest Department has adopted a three-pronged strategy for this rhino corridor:

- Controlling the biotic and anthropogenic pressures inside Laokhowa and Burhachapori Wildlife Sanctuary Complex
- Bringing the Brahmaputra River and its islands between Kaziranga and Orang National Parks under the management of the Forest Department
- Establishing a strong participatory conservation model within this landscape

Groundwork is already underway to revive the two Wildlife Sanctuaries through:

- Meetings with the Indian Rhino Vision - 2020 Program team to plan translocation of ten rhinos to Burhachapori
- Awareness meetings
- Capacity building of frontline staff
- Securing habitat from threats
- Enhancing security for the area
- Research and documentation

An important emphasis will be promoting eco-development and ecotourism in the area, which will be very important for the rhinos. Tourism has seen a revival and numbers of visitors and revenue from tourism have increased significantly over the past few years (Figure 20).

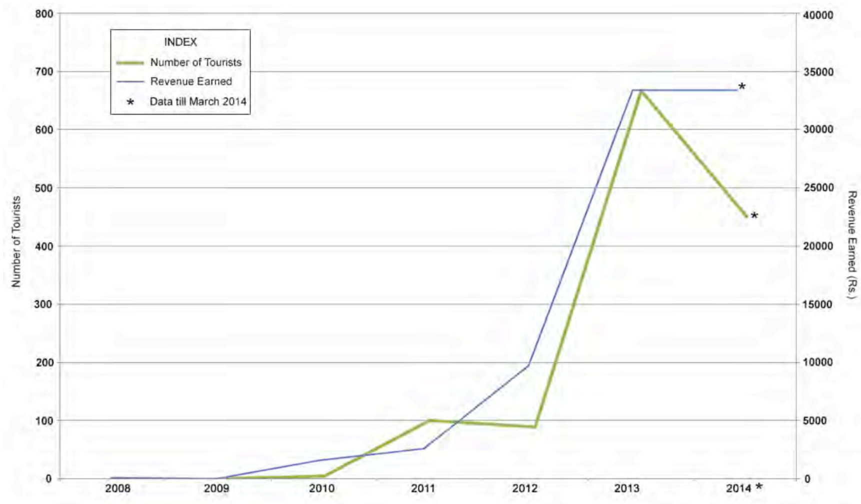


Figure 20. Trend of Tourist Inflow into Laokhowa Burhachapori Wildlife Sanctuary Complex from 2008 - 2015 (*January)

Figures 21-24. Promoting Ecotourism and Eco-Education in Laokhowa Burhachapori Wildlife Sancutaries

The two Wildlife Sanctuaries are bordered by a large number of fringe villages as well as a few forest villages. In all, there are 33 revenue villages within a 5-km 'zone of influence' of the two sanctuaries. Further, there are 7 taungiya villages and one forest village under the LWS. The sanctuary lies in a very densely populated area. The surrounding population is very poor, illiterate, and their livelihoods, to a large extent, depend on these sanctuaries. Extreme poverty and a high human population growth rate have contributed to a huge population in the fringe areas of the sanctuaries.

In LWS, 17 Education Development Centers were registered in 2009 and eight more Centers have been proposed. For BWS, 11 Education Development Centers were registered during 2009 and two more have been proposed. They are registered under the Nagaon Wildlife Division Forest Development Agency (NWLD-FDA). The chairman of the Education Development Centers is the Director of the Kaziranga Tiger Reserve.

The Nagaon Wildlife Division has undertaken a number of Entry Point Activities in the fringe and forest villages through the Education Development Centers. Already, activities such as village road repair, construction of schools, community halls, temples and mosques, providing school uniforms and reading and writing materials, organizing free health camps, providing solar mobile charging facilities along with television sets with facilities in the community halls etc., have been initiated and mostly completed. The department also is assisting the villagers to undertake commercial planting of trees like Simul (*Bombax spp*.) in the fallow and uncultivated village lands. It also is providing incentives to villagers to develop fish, pig, and poultry farms. The department has also designated certain areas along the fringes of the two sanctuaries as grazing zones where Education Development Centers members will be allowed to graze their cattle in return of depositing a nominal fee in with the Education Development Centers. The money collected will be used for developmental activities in each of the respective Education Development Centers' villages.

All the Executive Body members of the Education Development Centers are continuously trained in the process of participatory management of protected areas. As part of this effort, they were taken to Kaziranga National Park and Orang National Park on exposure visits. The Education Development Center members interacted with the Natundanga Education Development Center members of Kaziranga National Park as well as the members of Jeep Safari Association to understand the benefits of eco-tourism ventures. Moreover, a large number of school children have been taken to Kaziranga and Orang National Parks for exposure visits with the objective of creating young conservationists who value and will focus on wildlife, forest and environmental conservation.

Alternative livelihood programs have been started in the Dhania, Jhaoni, Sisuati and No. 7 Bhogamukh Education Development Centers of BWS by the Nagaon Wildlive Division. An ecotourism resort named Burhachapori Eco Resort, which caters to tourist food requirements, was opened jointly by the Nagaon Wildlive Division and the Dhania Jhaoni and Sisuati Education Development Centers for the tourism season 2014-2015. The resort also has started to market traditional artifacts, crafts, apparel, and dairy products and has created publicity materials. The

No. 7 Bhogamukh Education Development Center operates a country boat which takes tourists on river cruises and organizes river beach activities. The Education Development Center also operates one gypsy vehicle to conduct Jeep safaris in BWS.

The Nagaon Wildlife Division has constituted two 'Local Protection Squads' comprised of about 20 motivated youths who are being engaged in active patrolling duties with the frontline staff (Figures 25-26). The youths are paid a monthly stipend.

Figures 25-26. Local Protection Squad Members Education Development Center Meeting in Dhania

Other significant management initiatives with an aim to revive the two protected areas are:

- Removing cattle stations (khuttis) from inside BWS
- Increasing length of patrolling routes by construction of new roads and reviving damaged /unused roads
- Implementing scientific grassland and wetland management measures
- Conducting awareness programs in the fringe and forest villages
- Strengthening frontline staff capability by capacity building, including advanced training on use of firearms, legal procedures, mapping, wildlife monitoring, census techniques
- Enhancing security mechanism of the protected area complex by increasing the number of anti poaching camps
- Establishing an intelligence network in the fringe areas of the two protected areas, including within the adjoining Riverine landscape for pre-empting poaching attempts
- Promotion of participatory conservation model and Building upon, enhancing and extending the alternative livelihood generation activities through implementation of a strong eco development program
- Undertaking robust, authentic, scientific research and documentation activities
- Promoting eco tourism and environmental education tours in Laokhowa Burhachapori Wildlife Sanctuaries

Translocation of Rhinos to Laokhowa Burhachapori Wildlife Sanctuary Complex under IRV 2020

To understand the prevailing ecology of the Laokhowa Burhachapori WLS complex, a 1-km x 1-km grid overlay was made over the study area. Habitat parameters were identified and field data pertaining to these parameters were collected from each quadrant using relevant sampling techniques. The parameters for each grid were scored on a scale of 1-10 (low to high). In all, 15 relevant habitat parameters were considered in the analysis; the cumulative score for all the parameters for each grid was converted into percentage (100%).

The parameters were:

1. Fodder Quality
2. Fodder Availability
3. Drinking water availability
4. Wallowing space
5. Seasonal availability of water
6. Land cover distribution
7. Accessibility
8. Communication facility
9. Normal flood inundation
10. High flood inundation
11. Ungulate presence
12. Pre 1980s rhino presence
13. Soil / Bank erosion
14. Human habitation / encroachment
15. Biotic pressure

The cumulative score (100%) derived from the aggregate score (150) was then classified into four categories which was taken as indicator to arrive at the prevalent habitat scene for the complex (Results show in Table 5 and in Figure 27).

Table 5. Rhino Habitat Quality Scoring of Laokhowa Burhachapori WLS Complex

Habitat Duality	**Habitat Score**	**Total No. of Grids**
Least Suitable	<25%	79
Partially Suitable	26-50%	40
Moderately Suitable	51-75%	23
Most Suitable	> 75%	12

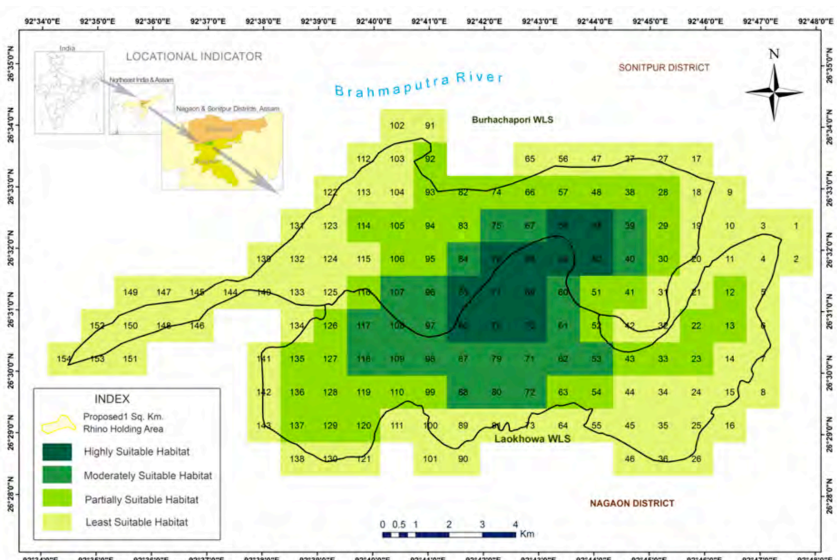


Figure 27. Rhino Habitat Suitability Mapping of Laokhowa Burhachapori Wildlife Sanctuary Complex (Source NWLD, IRV 2020 Habitat Assessment Team & Smarajit Ojah)

Based on the above findings, the construction of the Holding and Main Boma (Enclosure) was started in the Kasodhora-Koroitoli-Jhaoni region of Burhachapori Wildlife Sanctuary. The total size of the Holding Boma is 44,000 square feet while the Main Boma extends over an area of 1.50 square kilometers[1]. The Assam Forest Department will translocate a total of 10 rhinos to the Laokhowa Burhachapori Wildlife Sanctuary Complex beginning in 2015.

WEST BENGAL – Ujjwal Bhattacharya, I.F.S., Principal Chief Conservator of Forests and Wildlife and Chief Wildlife Warden, West Bengal

There are two small national parks in West Bengal that hold rhinos: Gorumara (78.45 sq. km.) and Jaldapara (216.51 sq. km.) (Figure 28). Rhinos sometimes stray outside of the protected areas, especially from Gorumara.

Threats in these two areas include: limited grasslands in the Protected Areas; presumed inbreeding depression; male-male fighting resulting in straying outside the Protected Areas; and the ever-present threat of poaching for horn.

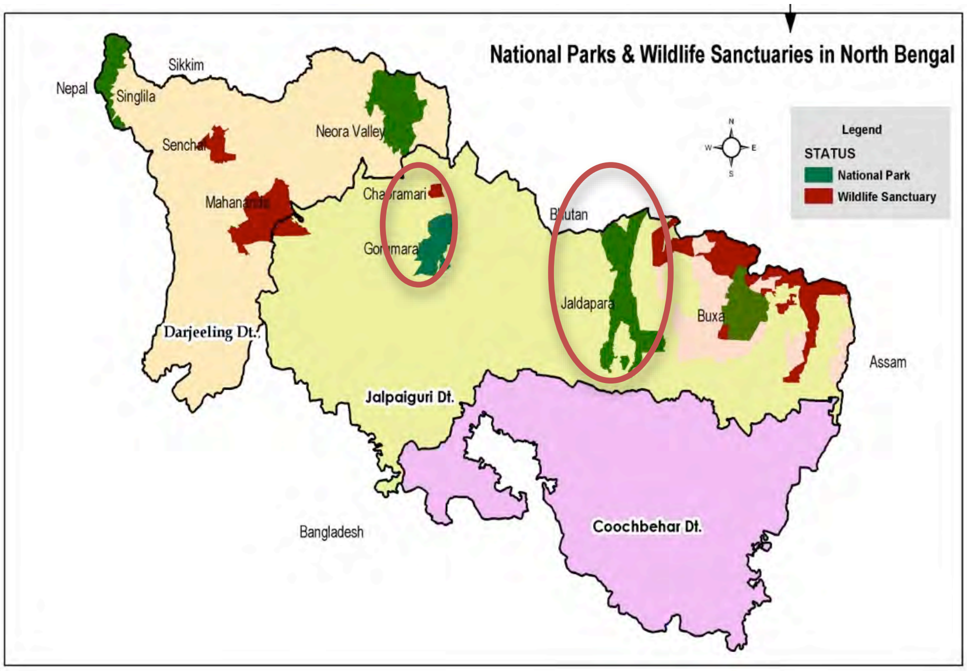


Figure 28. Gorumara and Jaldapara Wildlife Sanctuaries in West Bengal (circled in red).

[1] Details of the boma location and design are not included here due to security concerns.

JALDAPARA NATIONAL PARK

Situated in the foothills of the Eastern Himalayas in the Alipurduar district in West Bengal and on the bank of the Torsa River, the 216.51-sq.-km. Jaldapara National Park's (Figure 29) pure grassland patches of riverine forest extend over more than 30.58 sq. km. (14.11% of park), and along with Kharir-Sissoo succession covers more than 42.90 sq.km. (19.81% and with Simul-Siris succession over 22.59 sq.km. or 11.03%). Large tracts of grasslands remain in the flood plains of the Torsa River, which provides a source of water throughout the year. The Malangi area of the sanctuary is an important habitat for rhino. The Jaldapara area is highly populated and human-rhino conflict is not uncommon.

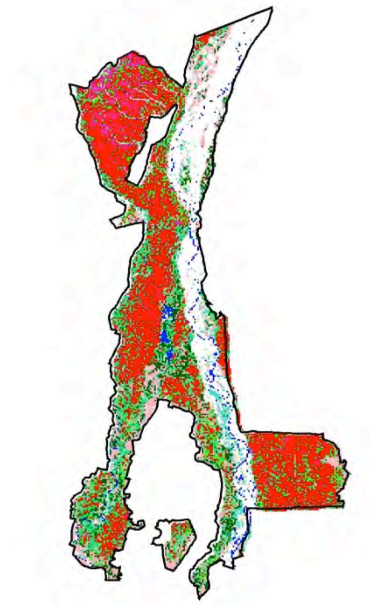


Figure 21. Map of Jaldapara National Park (legend not available)

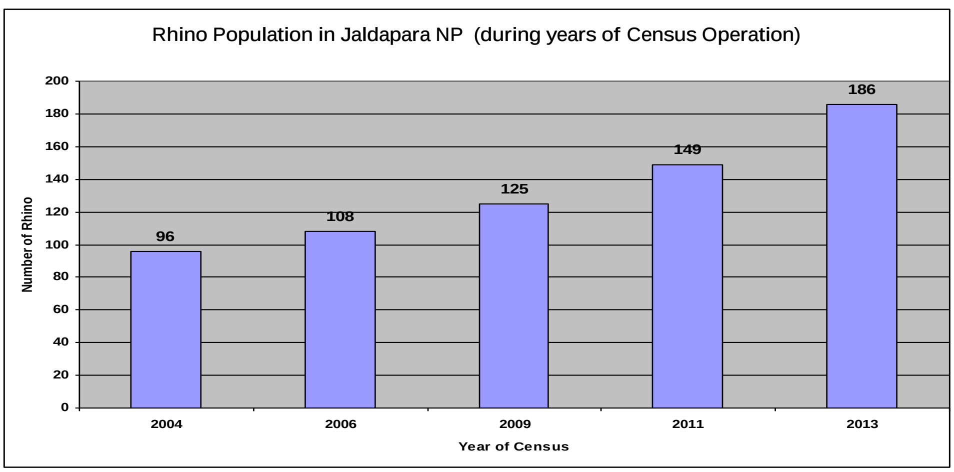


Figure 30. Population trends in Jaldapara National Park, 2004 through 2013.

The 5-year trends for Jaldapara's rhino population are shown in Figure 30. Annual mortality data are shown in Table 6; counts and birth rates are shown in Table 7.

Table 6. Mortality data, Jaldapara National Park 2005 – October 2014
*** in two natural deaths, horns were removed post-mortem**

Year (from 2005 onwards)	# rhinos poached	# Natural deaths
2005	0	3
2006	0	2
2007	0	4
2008	0	2
2009	1	4
2010	0	2
2011	0	3
2012	0	7
2013	0	8
2014 through October	1	6 *

Table 7. Number of rhinos and births in Jaldapara National Park, 2004 – 2013.

Estimation Year	# of rhinos	rhinos born
2004	96	23
2006	108	26
2009	125	28
2011	149	30
2013	186	19

GORUMARA NATIONAL PARK

Located in the Terai, Gorumara National Park (roughly 80 sq. km.) is comprised roughly of 20% riverine grassland and savannah woodland, and about 10.5 % (7.6 sq. km.) is grassland. Rhinos often stray into adjacent forest areas and villages, which presents a serious problem. The park is located in the flood plains of Jaldhaka and Murti Rivers as well as other medium and small rivers and rivulets, which, together, have created a pocket of grassland. The Murti, Indong and the Garati Rivers provide sources of water throughout the year.

Because the area inhabited by the rhinos is small, there is a great deal of male-male fighting. Population trends from 2004 through 2013 are shown in Figure 31. Table 8 shows the known mortality data for the park; Table 9 shows the annual counts and known birth rates for the park.

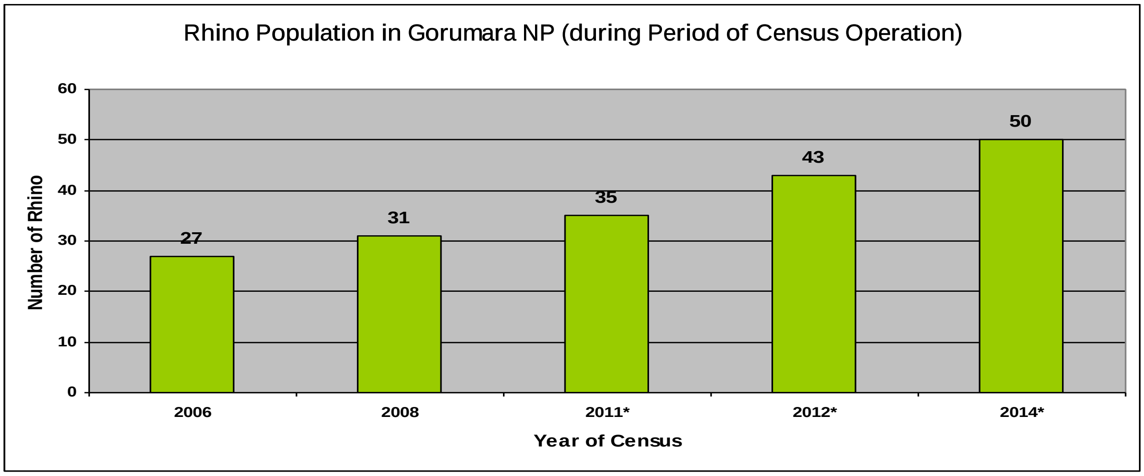


Figure 31. Rhino population trends in Gorumara National Park, 2006 – 2014.

Table 8. Mortality data, Gorumara National Park 2005 – October 2014.
**** in one natural deaths, the horn was removed post-mortem**

Year (from 2005 onwards)	# rhinos poached	# rhinos died naturally
2005	0	1
2006	0	1
2007	0	1
2008	0	1
2009	0	1
2010	0	0
2011	0	1
2012	0	0
2013	0	0
Through October 2014	1	1 **

Table 9. Number of rhinos and births in Gorumara National Park, 2004 – 2014.

Year	# of rhinos	rhinos born
2006	27	3
2008	31	08
2010	35	05
2012	43	08
2014	50	07

Conclusions for West Bengal

While poaching to-date has been nominal in both Jaldapara and Gorumara National Parks, there can be no decrease in anti-poaching efforts and it remains a critical threat. It should be noted that when Kaziranga National Park is flooded, poachers tend to shift to West Bengal parks, which is a dangerous trend. In terms of population health, inbreeding depression may be an important factor for the rhinos in these parks. There is a need to determine how to limit or somehow control infighting among males that often leads to straying outside the parks (and subsequent rhino deaths). A number of options need to be explored, including building increased tolerance among local communities for straying rhinos and/or developing straying/rescue team to deal with straying/problem rhinos.

DUDHWA NATIONAL PARK – Vino Krishan Singh, I.F.S., Deputy Director, Dudhwa Tiger Reserve

Dudhwa National Park's rhino program began in 1984, with two males and three females translocated from the outskirt of Pabitora Wildlife Sanctuary. These animals were joined by four females from Chitwan in 1985. The current rhino population in the park is 32: 10 males, 14 females, and 8 calves.

This globally important ecoregion is 68% woodland, 22% grassland, and 10% wetlands. The area includes Dudhwa National Park (660 sq. km., gazetted in 1977), Kishanpur Wildlife Sanctuary (203 sq. km.) and Katerniaghat Wildlife Division (550 sq. km.). Since 1987, Dudhwa has been one of the Project Tiger sites. Figure 32 shows a map of the park.

Figure 32. Map of Dudhwa National Park.

The rhinos are confined to a 27 sq. km. area within the park, surrounded by 24 km of five-strand solar-powered electric fence[2]. There are two base stations, Salukapur and Base Camp, which house nine patrol teams with elephants.

Table 10. Known rhino population numbers in Dudhwa National Park 2005 – 2013.

Year	Male	Female	Calf	Total
2005	7	11	3	21
2007	7	11	5	23
2009	10	15	3	28
2011	9	15	6	30
2013	10	14	8	32

The known rhino population numbers from Dudhwa are shown in Table 10; known mortality is shown in Table 11. Of the known mortality, none of the deaths are attributable to poaching.

[2] Details of the rhino area location are not included here due to security concerns

Table 11. Known rhino mortality in Dudhwa National Park 2008 – 2013.

Year (from 2005 onwards)	# rhinos poached	# rhinos died naturally	# rhinos born
2008-09	0	0	3
2009-10	0	0	1
2010-11	0	0	3
2011-12	0	1	3
2012-13	0	4	4

Perceived threats to rhinos in Dudhwa include inbreeding, intra-specific conflict due to crowding, proximity to semi-porous international borders, and potential conflicts with humans if rhinos are released into open forest. The potential for poaching events also must be considered.

At the 1999 IUCN/SSC AsRSG meeting in Kaziranga National Park, it was recommended that there should be at least ten wild rhino populations in India with a minimum of 100 rhinos in each site. Feasibility studies have been carried out and the Bhadi area was recommended as a second site for rhinos in Dudhwa National Park. The area is 14 sq. km., and is comprised of 70% grassland and 30% woodland. The fencing for the area has been completed and the park is awaiting its new rhino population.

Park guards are using rhino-identification-based monitoring. Each guard has a guidebook with four photos of each rhino in the park; notes are entered on subsequent pages. SMART patrolling has been implemented to track where patrols are going. SMART results are posted in each office each month and patrols adjusted accordingly.

PLENARY DISCUSSION - THE MOST IMPORTANT ISSUES FACING THE REALIZATION OF IRV 2020

Workshop participants discussed the most important challenges facing the successful realization of IRV 2020. Each participant put his or her 'issues' on a large post-it note and in turn presented his or her ideas to the group. A smaller group then themed the issues, which fell under the following categories.

Habitat
Identification of habitat
Invasive species, e.g., Mimosa
The "blind spot" Karbi Anglong
Corridors
Loss of habitat (natural and anthropogenic), difficult to maintain large population and options to translocate rhinos for better genetic diversity
Re-assessment of habitat/site
Finding new homes for the rhinos of West Bengal

Community
Multi-stakeholder participation
Community participation
Community Perception
Reviving community-based wildlife protection measures

Research
Lack of appropriate (robust) methods to monitor demographic trends
Getting new bloodlines for rhinos of Jaldapara and Gorumara National Parks (West Bengal)
In Dudhwa National Park, new blood needs to be translocated in to achieve our vision

Management
Translocation deadlock
Lack of frontline staff for monitoring
Dedicated team to work scientifically and systematically on rhinos is lacking
Vision for rhino conservation needed for Dudhwa for the future of rhinos

Information, Education and Communication

Funding
Funding needs and availability
Funding for patrolling needed
Funds for extension of areas using private lands around protected areas needed
Inadequate funds for rhino conservation especially from government sources
Insufficient protection of IRV 202 investment in Manas makes it very difficult to raise funds for IRV 2020 from international donors

Security
Security threat for translocated rhinos in Manas NP
Protection needs to be in place before translocations
Staff motivation important
Inability to procure immobilization drugs/logistics in timely way for translocations
Poaching and threat to habitat and connectivity
Coordinated efforts to counter poaching with a regional strategic plan lacking
Counter-poaching measures (not anti-poaching measures)
Intelligence sharing needed among agencies and stakeholders
Protection of rhinos from poaching
Encroachment of habitat
Slow speed of translocations

After this discussion, Dr. Phil Miller of the IUCN Conservation Breeding Specialist Group gave an overview of Population Viability Analysis and worked with the group to build population models.

Population Viability Analysis Introduction – Dr. Phil Miller, IUCN Conservation Breeding Specialist Group

Population viability analysis (PVA)[3] can be an extremely useful tool for investigating current and future demographic dynamics of greater one-horned rhino (GOHR) populations distributed across the state of Assam in northeastern India (refer to Figure 1 in this document). The need for and consequences of alternative management strategies can be modeled to suggest which practices may be the most effective in managing GOHR populations. *Vortex*, a simulation software package written for PVA (Lacy et al. 2014), was used here as a tool to study the

[3] A Population Viability Reference by Lacy and Miller is attached as Appendix II to this document.

interaction of a number of GOHR life history and population parameters, and to test the effects of selected management scenarios on long-term population viability. Specifically, our analysis focuses primarily on the efficacy of translocation of rhinos from a large source population in Kaziranga National Park to other areas within the state of Assam.

The *Vortex* package is a simulation of the effects of a number of different natural and human-mediated forces – some, by definition, acting unpredictably from year to year – on the health and integrity of wildlife populations. *Vortex* models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or random variables that follow specified distributions. The package simulates a population by recreating the essential series of events that describe the typical life cycles of sexually reproducing organisms.

PVA methodologies such as the *Vortex* system are not intended to give absolute and accurate "answers" for what the future will bring for a given wildlife species or population. This limitation arises simply from two fundamental facts about the natural world: it is inherently unpredictable in its detailed behavior; and we will never fully understand its precise mechanics. Consequently, many researchers have cautioned against the exclusive use of absolute results from a PVA in order to promote specific management actions for threatened populations (e.g., Ludwig 1999; Beissinger and McCullough 2002; Reed et al. 2002; Ellner et al. 2002; Lotts et al. 2004). Instead, the true value of an analysis of this type lies in the assembly and critical analysis of the available information on the species and its ecology, and in the ability to compare the quantitative metrics of population performance that emerge from a suite of simulations, with each simulation representing a specific scenario and its inherent assumptions about the available data and a proposed method of population and/or landscape management. Interpretation of this type of output depends strongly upon our knowledge of pronghorn biology, the environmental conditions affecting the species, and possible future changes in these conditions.

The *Vortex* system for conducting population viability analysis is a flexible and accessible tool that can be adapted to a wide variety of species types and life histories as the situation warrants. The program has been used around the world in both teaching and research applications and is a trusted method for assisting in the definition of practical wildlife management methodologies. For a more detailed explanation of *Vortex* and its use in population viability analysis, refer to Lacy et al. (2015).

Primary Questions for PVA Modeling

The experts who attended the "Indian Rhino Vision 2020 Population Modeling Workshop" identified a set of primary questions for which PVA model construction and implementation could be useful in addressing:

1. Can we build a simulation model of GOHR demography that is reasonably realistic, and that can help us evaluate alternative management strategies for selected GOHR populations in Assam?
2. How demographically robust are the Kaziranga National Park and Pobitora Wildlife Sanctuary GOHR populations? Can these populations be used as a source of animals for translocation to other areas of Assam without compromising their own long-term viability?
3. How many animals should be translocated from Kaziranga National Park to create a viable GOHR population in Manas National Park?
4. Is the rate of poaching currently observed in Manas National Park considered unsustainable in the long-term, even with translocation efforts planned for the future?
5. What level of translocation effort is required to generate a long-term viable GOHR population in the Burachapori Wildlife Sanctuary?

Note that the analyses described below do not consider the GOHR population in Assam's Rajiv Gandhi Orang National Park, or the rhino populations found outside of Assam, such as West Bengal's Jaldapara and Gorumara National Parks or Dudhwa National Park in Uttar Pradesh. It is hoped that any future analyses conducted on these populations can use the information contained in this report as a reference.

Baseline Input Parameters for Population Viability Simulation Models

All simulations described in this report were conducted using *Vortex* version 10.0.7.9 (January 2015). Each simulation was repeated 1000 times to generate statistics on mean population performance, extinction risk, etc., with population projections of 30 years.

Timestep for all simulations: Since rhino reproductive ecology is easily described on an annual basis, we have chosen the timestep for our simulations as one year. Projections of population abundance will therefore be presented annually.

Breeding system: Rhino are known to display a polygynous breeding system, where a single male may mate with multiple females during a given year. This is simulated in *Vortex* by allowing adult males to be sampled multiple times as mates for available females.

Age of first offspring: *Vortex* considers the age of first reproduction as the age when a female rhino gives birth to their first calf, and not simply the onset of sexual maturity. As described in an earlier analysis of GOHR demography (Molur et al. 1995), we assumed that wild females produce their first calf at eight years of age, while males begin producing offspring at ten years of age.

Maximum age of reproduction: In its simplest form, *Vortex* assumes that animals can reproduce at their normal rate throughout their adult life. We assume here that GOHR adults may live up to 50 years in the wild. Many animals will not reach this age through natural mortality or, in the specific case of GOHR in Assam, because of the risk of poaching.

Reproductive events per year: Adult GOHR females will reproduce only once per breeding event.

Offspring sex ratio: Without detailed wild population data to the contrary, we assume a 50:50 sex ratio across all calves produced in a given year.

% Adult females breeding: This variable defines the average proportion of females that produce a calf in a given year. Once again, we follow the analyses of Molur et al. (1995) to assume that the interbirth interval for any given female is approximately three years. Therefore, we set the mean probability of reproducing for the average adult GOHR female at 0.30.

Density dependent reproduction: *Vortex* can model density dependence with an equation that specifies the proportion of adult females that reproduce as a function of the total population size. In addition to including a more typical reduction in breeding in high-density populations, the user can also model an Allee effect: a decrease in the proportion of females that bread at low population density due, for example, to difficulty in finding mates that are widely dispersed across the landscape.

The equation that *Vortex* uses to model density dependence is:

$$P(N) = \left(P(0) - \left[\left(P(0) - P(K)\right)\left(\frac{N}{K}\right)^B\right]\right)\frac{N}{N+A}$$

in which $P(N)$ is the percent of females that breed when the population size is N, $P(K)$ is the percent that breed when the population is at carrying capacity, and $P(0)$ is the percent breeding when the population is close to zero (in the absence of any Allee effect). The exponent B can be any positive number and determines the shape of the curve relating the percent breeding to population size, as the population becomes large. If $B = 1$, the percent breeding changes linearly with population size. If $B = 2$, $P(N)$ is a quadratic function of N. The parameter A defines the magnitude of the Allee effect.

We do not have specific data on the nature and intensity of density-dependent reproduction in the greater one-horned rhino in Assam. In the absence of these data, we adopted a simpler ceiling form of density dependence through the specification of a habitat carrying capacity for each population site. See below for more information on this aspect of the model.

Environmental variation (EV) in % breeding: Annual environmental variation in female reproductive success is modeled in *Vortex* by specifying a standard deviation (SD) for the proportion of adult females that successfully produce offspring in a given year. In the absence of specific data on this parameter, we assume that the variation is equal to 10%, thereby producing a full statistical distribution of female breeding rates between 10% - 50% (mean ± 2SD). This may be a slight overestimate of the true annual variability in reproductive rate, but was considered by workshop participants to be a reasonable value for the scenarios evaluated in this analysis.

Distribution of litter size: As the production of twins has not been observed in GOHR females, we assume that all successful reproductive events result in the birth of a single calf.

Mate monopolization: In many species, some adult males may be socially restricted from breeding despite being physiologically capable. This can be modeled in *Vortex* by specifying a portion of the total pool of adult males that may be considered "available" for breeding each year. We assume here that all GOHR males are both physiologically and socially capable of breeding after they survive to ten years of age. Since we are not tracking the genetic structure of individual populations, or the potential demographic consequences of that genetic structure (see below), the degree of mate monopolization among GOHR males is not a sensitive factor in our models.

Mortality rates: *Vortex* defines mortality as the annual rate of age-specific death from year x to $x + 1$; in the language of life-table analysis, this is equivalent to $q(x)$. We assume that our

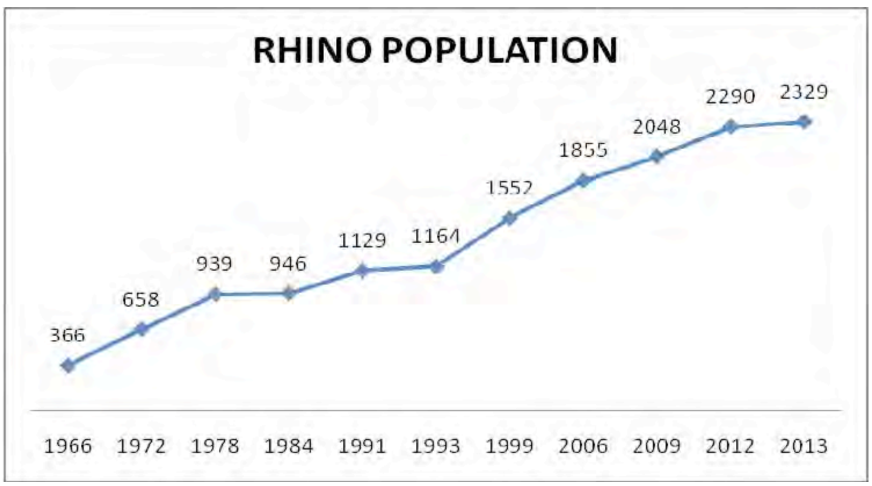


Figure 33. Census estimates of greater one-horned rhino abundance in Kaziranga National Park from 1966 to 2013. Figure from Govt. of Assam (2014).

model, intended to reflect the current GOHR populations in Assam, will include all sources of mortality – with the exception of poaching (see below) – in the specification of age-specific mortality rates.

We began our analysis of population-specific mortality by considering the GOHR population in Kaziranga National Park. Govt. of Assam (2014) present data on both population abundance trends in Kaziranga NP (Figure 33) and mortality events (Figure 34) over the past 4 -5 decades of rhino monitoring in the Park. If we exclude those years (1988, 1998, 2004, 2008 and 2012) where seasonal flooding resulted in higher rates of mortality, we can estimate an average long-term natural mortality rate by comparing the number of natural deaths to the population abundance estimates across years (with interpolation between census points where necessary). Data on natural mortality was taken from Yadava (2014). Using these data, we estimated an annual average adult mortality rate of approximately 3%, with adult males being given a slightly higher rate (3.3%) than females (2.8%), consistent with a slight female bias in adult abundance. We estimate an annual environmental variability in adult mortality of 0.5%, calculated directly from annual mortality rate estimates discussed above and assuming all observed inter-annual variability is driven by environmental factors and not due to observer measurement error (perhaps an optimistic assumption).

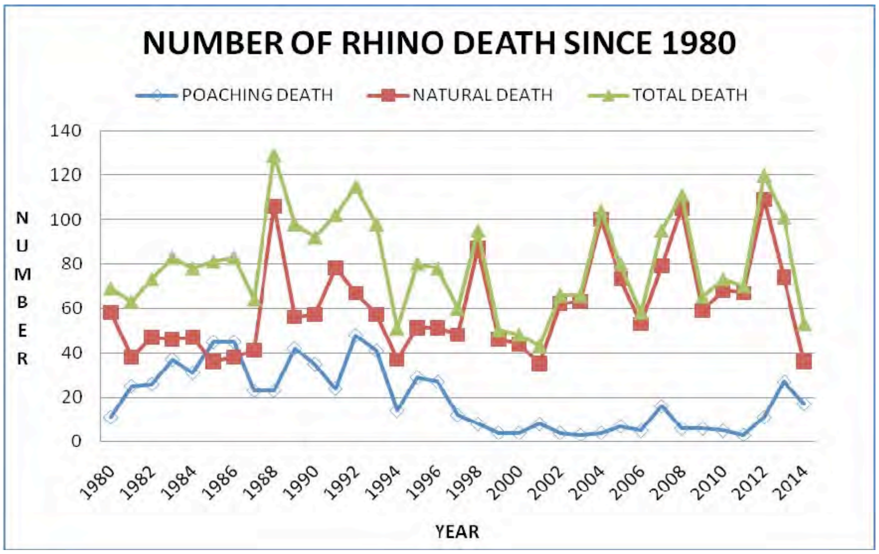


Figure 34. Estimated numbers of death from natural causes and from poaching in Kaziranga National Park during the period 1980 - 2013. Figure from Govt. of Assam (2014).

Mortality rates for calves and subadults were adapted from those reported in Molur et al. (1995) in an iterative process to create a Kaziranga population that, with the addition of periodic flood-induced mortality and annual removal of animals through poaching (see below), increased in abundance at an annual rate of approximately 3%. This rate is calculated using abundance estimates over the period 1996 – 2013, when more aggressive anti-poaching efforts began and the rate of population growth increased relative to the period 1980 – 1993 when poaching rates were high.

A similar type of population trend analysis revealed that the Pobitora population has been increasing at a rate of approximately 2.0 – 2.5% per year during the period in which census estimates were obtained (1987 – 2012) (Govt. of Assam 2014). These data also reveal higher proportional rate of poaching-based mortality in this population compared to the Kaziranga population. Taken together, these data were used in an iterative fashion within *Vortex* to derive a mortality schedule for Pobitora that was consistent with the growth rate discussed above. Overall, this meant reducing natural mortality rates to values that are lower than those for Kaziranga; this may or may not realistically reflect habitat quality and/or availability on the ground in these two protected areas.

Finally, where data are not available, we assume that the Manas and Burachapori populations (recognizing that Burachapori currently does not have rhinos, but will be receiving animals very shortly as part of the planned translocation program) will have natural mortality rates that are identical to those estimated for the Kaziranga population.

We assume that environmental variability for reproduction and survival are correlated, meaning that environmental conditions that influence one demographic process in any given year – favorably or otherwise – will also impact the other process in a proportional fashion.

Poaching-based mortality: Govt. of Assam (2014) also present data on recent rates of GOHR poaching in the Kaziranga, Pobitora, and Manas populations. For Kaziranga, over the period 1996 – 2013 when anti-poaching efforts were increased, the overall average rate of poaching was about nine animals per year. However, this rate has increased over the past 2-3 years to more than 15 animals per year. We therefore increased the long-term rate of poaching in the Kaziranga population to approximately 12 animals per year.

Through a similar analysis, we set the mean poaching rate for Pobitora at approximately two animals per year, and for Manas to be approximately four animals per year. This rate for Manas is based on the worrisome observation of a large increase in poaching risk over the past couple of years.

Poaching was implemented as a semi-random process in *Vortex* by specifying functions in the software's Harvest module. We assume that adults are poached preferentially due their larger horn size, although this may not be completely accurate as precise determination of the age of poached animals is not always possible. We assumed that, on average, 7±2 males and 5±2 females are poached annually from the Kaziranga population. This is simulated in *Vortex* by specifying these rates as

#males = 7+(2*NRAND)
#females = 5+(2*NRAND)

where NRAND is the random normal deviate (mean 0, standard deviation 1.0). With this formulation, annual female poaching deaths would range from 1 to 9 and males from 3 to 11 (mean±2SD).

For Pobitora and Manas, we assume that the number of poached animals would be equal across males and females over a period of many years, although the actual number and gender of poached animals would vary from year to year. The simulated rates of poaching for both these populations and for Burachapori in selected translocation scenarios were varied in multiple scenarios to evaluate the impact of higher or lower rates of loss on long-term population viability.

Inbreeding depression: *Vortex* includes the ability to model the detrimental effects of inbreeding, most directly through reduced survival of offspring through their first year. Specific data on inbreeding depression in either captive or wild GOHR populations were not available for this analysis. Furthermore, since the generation length for rhino species is rather long in relation to the length of our projections (see below), we did not include population genetics in our consideration of population viability in the context of the questions we address in this analysis.

Catastrophes: Catastrophes are singular environmental events that are outside the bounds of normal environmental variation affecting reproduction and/or survival. Natural catastrophes can be floods, droughts, disease, or similar events. These events are modeled in *Vortex* by assigning an annual probability of occurrence and a pair of severity factors describing their impact on mortality (across all age-sex classes) and the proportion of females successfully breeding in a given year. These factors range from 0.0 (maximum or absolute effect) to 1.0 (no effect), and in its most basic implementation in *Vortex*, are imposed during the single year of the catastrophe, after which time the demographic rates rebound to their baseline values.

Monsoon season floods along the Brahmaputra River contribute to GOHR mortality in Kaziranga National Park. Periodically, the floods are of such severity that a substantial number of additional rhinos die as they fail to seek shelter from the rising waters. Data from 1980 to today (Figure 3) suggest that these severe flooding events may take place every 5 – 7 years. We therefore adopted a mean annual probability of occurrence of 0.16 for this event, equating to one major event approximately every six years. Govt. of Assam (2014) give the number of rhino that died during those years known to include severe flooding events; analysis of these data shows that rhino survival in flood years declines from the typical 97% to approximately 95%, yielding a flood catastrophe severity of (0.945)/(0.967) = 0.975. We assume that these flooding events do not impact annual rates of reproduction[4].

Initial population size: *Vortex* operates on a pre-breeding census model; therefore, all models are initialized with animals at least one year of age, i.e., including those youngest individuals that were born the previous breeding cycle and have survived to just before one year of age. All simulated populations were initialized with the latest census estimates given by the literature and by workshop participants. The size of the Kaziranga population (N_0 = 2350) was based on the most recent 2013 census estimate of 2329 and accounting for some modest growth in the population since that census. The size of the Manas (N_0 = 30) and Pobitora (N_0 = 92) populations were based on Govt. of Assam (2014), with specific age distribution info for Manas provided by S. Ghosh from Manas National Park. Since specific age-sex information on the starting populations for Kaziranga and Pobitora were not available, these models were initialized according to a stable age distribution, governed by the reproductive and mortality rates described above.

Carrying capacity: How close is a given subpopulation to its maximum, long-term equilibrium abundance – is there an opportunity for the population to grow to a larger size? This is simulated through specifying a given habitat's population carrying capacity, K. The carrying

[4] The impact of floods in Pobitora is also similar in the sense that the same years were also critical, however the death rates were lower. In the last 10 years, three rhino calves were recorded to have died from floods in Pobitora.

capacity for a given habitat defines an upper limit for the population size, above which additional mortality is imposed randomly across all age classes in order to return the population at the end of a specific timestep to the value set for K.

Yadava (2014) suggests that the Kaziranga population is near its long-term ecological carrying capacity in the boundaries of the National Park. Similarly, workshop participants working in the Pobitora Wildlife Sanctuary indicate that this population is currently very near its carrying capacity. The carrying capacity for Manas is thought to be approximately 100 individuals, and the now empty Burachapori Wildlife Sanctuary is considered large enough to sustain about 80 in the long-term. A summary of these current population abundance and carrying capacity estimates is presented in the table below.

Population	**N_0**	**K**
Kaziranga National Park	2,350	2,700
Manas National Park	30	100
Pobitora Wildlife Sanctuary	92	95
Burachapori Wildlife Sanctuary	0	80

A summary of the population-specific demographic input data for the full set of analyses is presented in Table 12.

Translocation Scenario Design

All scenarios featuring movement of rhinos from the Kaziranga or Pobitora source populations to the Manas or Burhachapori-Laokhowa target populations were implemented using the Translocation module in *Vortex*. Individuals of the desired age and gender were harvested from the source population for a designated period of time, and these same animals are then supplemented to the target population in the same year (model timestep). We assume that additional mortality resulting from the translocation, and that animals translocated to their new habitat will breed and survive at the same rates as in their original habitat. Scenarios were designed to investigate the impact of the number of animals moved, the number of years translocation was to continue, and the impact of poaching on both source and target populations.

Table 12. Summary of population-specific demographic parameters used as input to *Vortex* simulation models as part of the GOHR PVA.

Parameter	Kaziranga National Park	Pobitora Wildlife Sanctuary	Manas National Park	Burachapori – Laokhowa Wildlife Sanctuaries
Breeding Age (♀/ ♂)	8 / 10	8 / 10	8 / 10	8 / 10
Maximum Age	50	50	50	50
Offspring per Year	1	1	1	1
Sex Ratio at Birth (%♂)	50	50	50	50
Density Dependent Breeding?	No	No	No	No
% ♀♀ Breeding Annually (SD)	30 (10)	30 (10)	30 (10)	30 (10)
Annual Mortality (%±SD) (♀/ ♂) Age 0 – 1	10±7 / 10±7	6±2 / 8±2	10±7 / 10±7	10±7 / 10±7
Annual Mortality (%±SD) (♀/ ♂) Age 1 – 2	8±5 / 9±5	5±2 / 8±5	8±5 / 9±5	8±5 / 9±5
Annual Mortality (%±SD) (♀/ ♂) Age 2 – 3	6±5 / 9±5	4±2 / 7±5	6±5 / 9±5	6±5 / 9±5
Annual Mortality (%±SD) (♀/ ♂) Age 3 – 5	5±2 / 9±2	4±2 / 7±5	5±2 / 9±2	5±2 / 9±2
Annual Mortality (%±SD) (♀/ ♂) Age 5 – 6	5±2 / 8±2	3±2 / 7±2	5±2 / 8±2	5±2 / 8±2
Annual Mortality (%±SD) (♀/ ♂) Age 6 – 7	5±2 / 7±2	3±2 / 7±2	5±2 / 7±2	5±2 / 7±2
Annual Mortality (%±SD) (♀/ ♂) Age 7 – 8	4±2 / 6±2	3±2 / 6±2	4±2 / 6±2	4±2 / 6±2
Annual Mortality (%±SD) (♀/ ♂) Age 8-10	2.8±0.5 / 5±2	1.5±0.4 / 5±2	2.8±0.5 / 5±2	2.8±0.5 / 5±2
Annual Mortality (%±SD) (♀/ ♂) Age 10+	2.8±0.5 / 3.3±0.5	1.5±0.4 / 2.5±0.5	2.8±0.5 / 3.3±0.5	2.8±0.5 / 3.3±0.5
Poaching Rate (Mean±SD) (♀/ ♂)	5±2 / 7±2	1±1 / 1±1	2±1 / 2±1	1±1 / 1±1
Drought (Flood) Freq / Severity (Survival)	0.16 / 0.975	3 calves died during floods during last 10 years		
% ♂♂ in Breeding Pool	100	100	100	100
Initial Population Size	2350	92	30	0
Carrying Capacity	2700	95	100	80

Results from Simulation Models

Baseline Model Retrospective Analysis

Using the input data described in the preceding section, a model of the Kaziranga population was created with the initial population size corresponding to the interpolated abundance estimate for 1996 derived from the census data from Govt. of Assam (2014). The model trajectory tracked the actual change in rhino population abundance quite well from simulation year 0 (1996) to year 14 (2010) (Figure 35). After that point, the simulated population growth rate declined somewhat as the population began to approach the carrying capacity of 2700 individuals. This slight departure from the true population trajectory may suggest that the carrying capacity is too low, but the overall impact of this feature of the model is relatively small. Overall, the model predicts a population growth rate of 0.030, which compares quite favorably with the census-based growth estimate of 0.031 over the same period. Therefore, we consider this Kaziranga model to be sufficiently realistic to use as a baseline for additional models studying the suitability of this population as a source for translocation to the Manas and Burachapori populations.

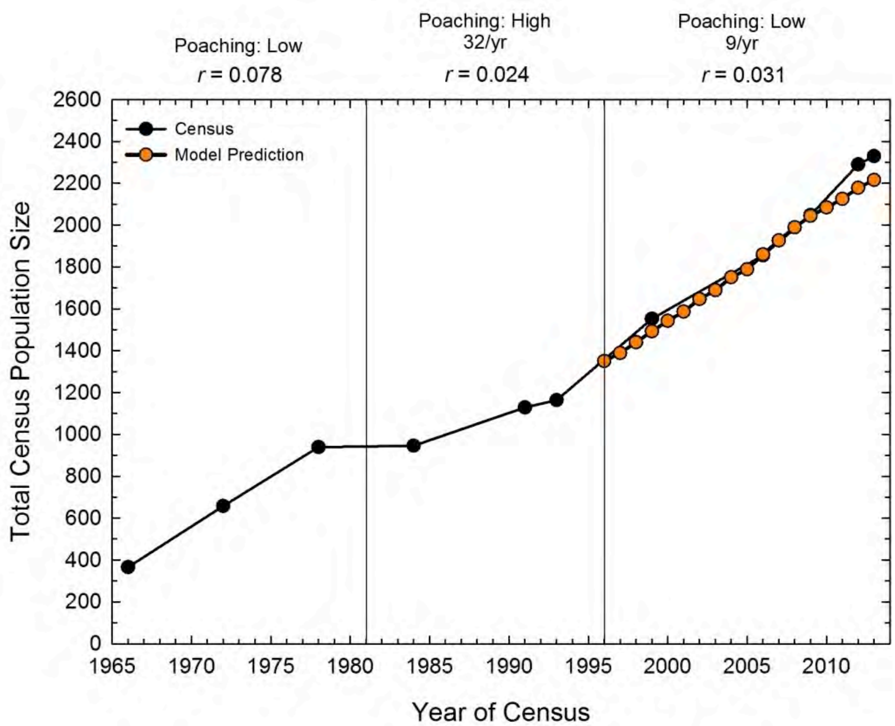


Figure 35. Retrospective analysis of the Kaziranga greater one-horned rhino population model. Actual census data (black circles) compared to demographic model projection (orange circles). Census data taken from Govt. of Assam (2014).

A similar analysis for the Pobitora population (Figure 36) demonstrates that our model generates a very close approximation to the actual population trajectory derived from the census data over the period 1987 – 2012. In the same fashion, we can therefore consider this model to be sufficiently realistic to use it as a tool to investigate the viability of Pobitora as a source of animals for translocation to other habitats.

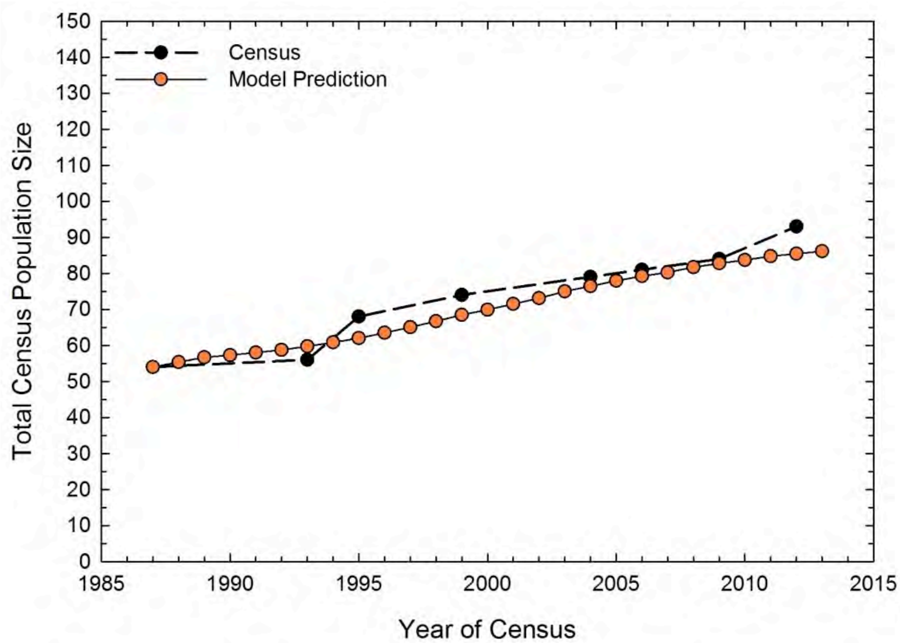


Figure 36. Retrospective analysis of the Pobitora greater one-horned rhino population model. Actual census data (black circles) compared to demographic model projection (orange circles). Census data taken from Govt. of Assam (2014).

Feasibility Analysis: Kaziranga and Pobitora as Source Populations for Translocation

We created a new series of scenarios based on the Kaziranga baseline model, with the addition of a systematic removal of adult male and female rhinos each year from the population to simulate use of these animals for translocation projects. As an example, we removed (harvested) a total of 10 animals in one scenario, with this group of animals composed of three males aged 1, 3, and 5 years old (all of pre-breeding age), and seven females – four adults of randomly-selected age, and one animal each aged 1, 3, and 5 years old. This collection of animals simulates the composition of recent translocations to Manas National Park, including the translocation of mothers with young calves that may be as young as one year of age (although movement of animals this young may be a rare occurrence). We then created additional harvest scenarios with 20 through 60 animals removed each year, with ages and gender of these animals in the same proportion as in the original scenario with 10 animals removed.

As can be seen in Figure 37[5], the simulated Kaziranga population maintains a positive population growth rate as long as no more than 30 – 40 animals are removed each year. When the rate of annual removal exceeds this threshold, the mean population trajectory decreases steadily. When the maximum number harvested annually reaches sixty individuals, the long-term growth rate declines to -0.001 over the time period of the simulation (note that the rate of decline is greater in the later stages of the simulation). Under the conditions and assumptions of this analysis, the maximum sustainable removal rate of individuals appears to be approximately 35-40 individuals per year. This is, of course, a removal rate that is very unlikely to be realized in actual practice. Furthermore, it follows from this analysis that larger numbers of individuals could be removed for shorter periods of time without significantly compromising the viability of the Kaziranga population. Similarly, the removal of individuals with longer intervening intervals, such as every other year or every three years, is expected to have a smaller impact on long-term population growth. Taken together, this analysis suggests that the levels of harvest currently proposed for translocation projects in Burachapori Wildlife Sanctuary (and, to a lesser extent, Manas NP) are well within the thresholds that define long-term viability of the Kaziranga source population.

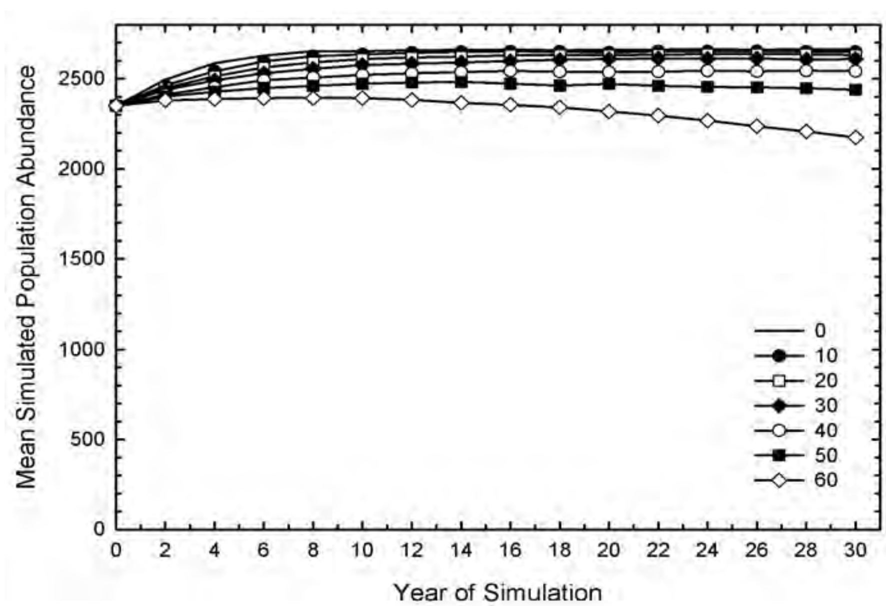


Figure 37. Simulated Kaziranga GOHR population, with harvest of animals at increasing intensity (multiples of 10 animals) to simulate removal of animals for translocation. Numbers in the graph legend refer to the number of animals removed annually. See accompanying text for more information on model structure and interpretation.

[5] In this and all figures to follow that show mean simulated population abundance, the parameter that is plotted is the average population size across all iterations in a given scenario – even those that go extinct. This metric then captures the combined impact of population decline and extinction risk into a single value. For more information on this parameter, refer to Lacy et al. (2015).

In contrast, a similar analysis (Figure 38) suggests that removing animals from the Pobitora Wildlife Sanctuary population leads to a significantly greater risk of population decline if that source population experiences even moderate poaching pressure. Removing just three animals (1 male, 2 females) each year for a 10-year period leads to a reduction in total population size from the current number of 92 animals to 78 animals. Following this harvest period, the population is able to recover over the next two decades to just less than 90 animals. Removing a larger number of individuals will, of course, reduce the source population even further, with the potential risk of destabilizing the population and introducing a risk of extinction. For example, removing six individuals (4 females, 2 males) for 10 years leads to a reduction in population size to 35 animals, with much lower population growth rates following this harvest period and a risk of population extinction approaching 50% after 30 years (data not shown).

If poaching pressure is removed from the Pobitora population, this same level of harvest for translocation does not appreciably affect longer-term demographic dynamics, with the population remaining at or very near the habitat carrying capacity for the duration of the simulation. Taken together, these results suggest that Pobitora can be used as a source of animals for translocation programs, but the number of animals available for harvest is limited due to the habitat carrying capacity and the underlying population growth rate observed in the recent past. These results assume that future levels of poaching will not increase beyond today's rates; if mortality due to poaching increases in the coming years, the suitability of this population to provide animals for translocation programs may be severely limited.

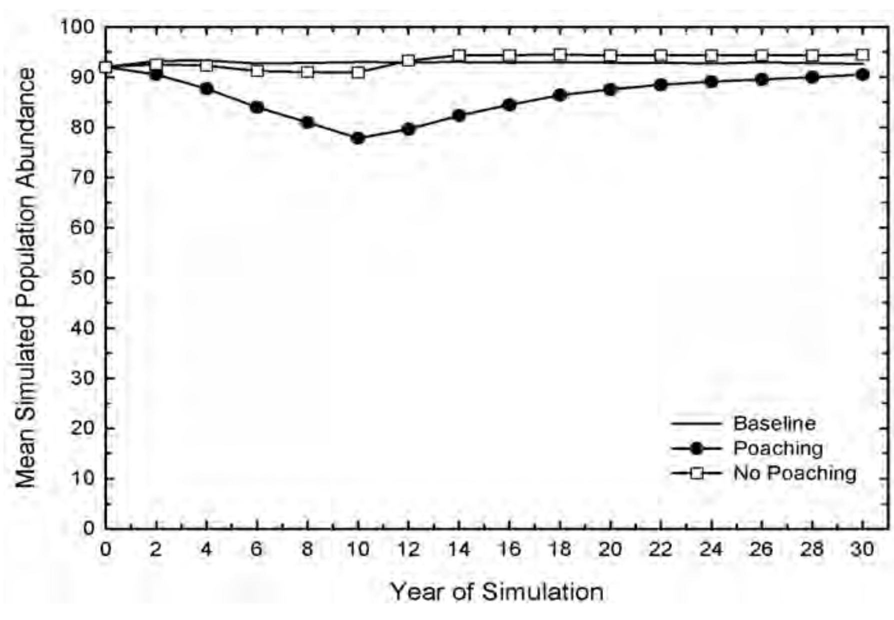


Figure 38. Simulated Pobitora population of GOHR, with harvest of 3 animals (2 female, 1 male) per year for 10 years to simulate removal of animals for translocation. Poaching scenario involves random removal of 1±1 adult male and 1±1 adult female for the duration of the scenario. Unlabeled line is the baseline scenario, no removal for translocation. See accompanying text for more information on model structure and interpretation.

Translocation Analysis: Manas National Park

We evaluated the future of the Manas NP GOHR population under three different translocation scenarios: no further translocation of rhinos from Kaziranga NP; translocation of 10 animals from Kaziranga NP (three males aged 1, 3, and 5 years old and seven females – four adults of randomly-selected age, and one animal each aged 1, 3, and 5 years old) for years 1 and 2 of the simulation; and translocation of 20 animals from Kaziranga NP, composed of double the number of animals in the translocate-10 scenario. Additionally, we imposed poaching rates in Manas at high (2±1 male, 2±1 female), medium (1±1 male, 1±1 female), or occasional (0±1 male, 0±1 female) intensity. While the translocation process lasted only two years, the poaching was assumed to continue at a constant rate for the entire 30-year simulation.

The results of these analyses are shown in Figure 39. Under relatively high rates of poaching, as have been seen in the past couple of years (top panel), even aggressive translocation efforts where a large number of animals are translocated from Kaziranga over a 2-year period does not lead to a viable Manas population. The rates of poaching are simply too high if maintained over a long period, driving the population into a sharp decline to eventual extinction with approximately 20 – 30 years. When poaching rates are reduced by about 50% of their current numbers (middle panel), the addition of 20 animals for each of the first two years of the simulation leads to a Manas population that can remain stable over the next 30 years, although there is a 5% risk that even this level of translocation will not be successful and the population would become extinct. A more modest effort of 10 animals per year is not enough to overcome the impact of poaching, resulting in an extinction risk of approximately 50% and a general decline in population abundance. If poaching rates are reduced further to approximately one animal poached per year (bottom panel), the translocation efforts can yield robust population growth and negligible risk of extinction.

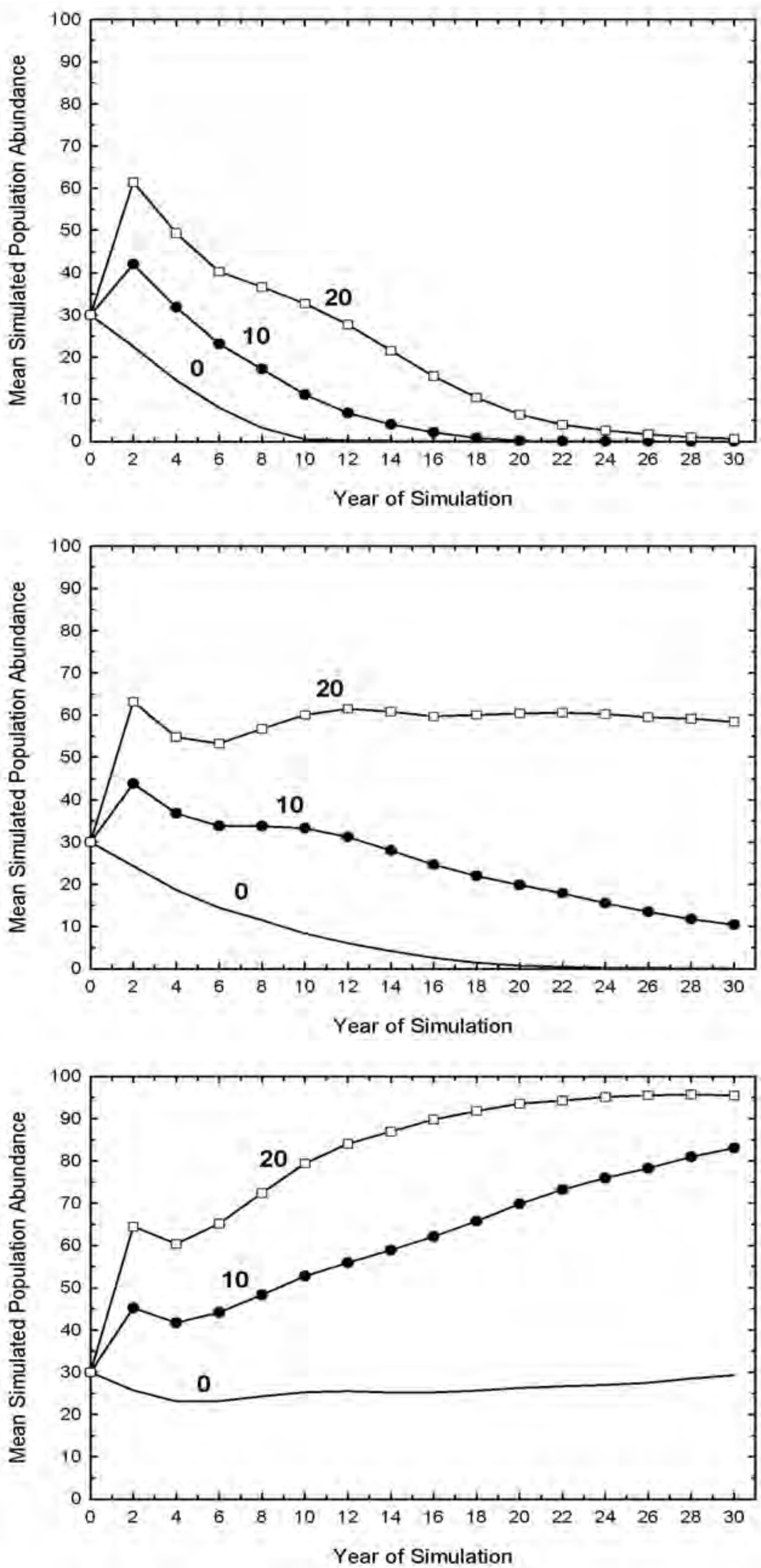


Figure 39. Mean abundance trajectories for a simulated Manas NP population of greater one-horned rhino with translocation of animals from Kaziranga NP and with removal of Manas animals through poaching. Poaching rates in Manas NP are assumed to be high (2±1 male, 2±1 female: top panel), medium (1±1 male, 1±1 female: middle panel), or occasional (0±1 male, 0±1 female: bottom panel). Within each panel, trajectories correspond to the strength of translocation: 0 animals (no symbols), 10 animals per year for years 1-2 of the simulation (closed circles), or 20 animals per year (open squares). See accompanying text for more information on model structure and interpretation.

Given the results in the bottom panel of Figure 39, we may ask ourselves if translocation is required to increase GHOR abundance in Manas NP if poaching is eliminated. An analysis was conducted to address this question, where translocation was not included and poaching rates were either reduced by 50% of the baseline value or eliminated completely. The results of these scenarios (Figure 40) suggest that, if poaching pressure can be eliminated from the Manas population and if we assume that the Manas population can grow at a rate comparable to that for the Kaziranga population ($r \approx 0.03$), this population could increase on its own. This predicted population growth can only take place after the subadult males currently in the population mature to adulthood in approximately 3-4 years[6]. These simulated trajectories demonstrate the considerable sensitivity of small populations of rhino to even low levels of additional mortality through poaching.

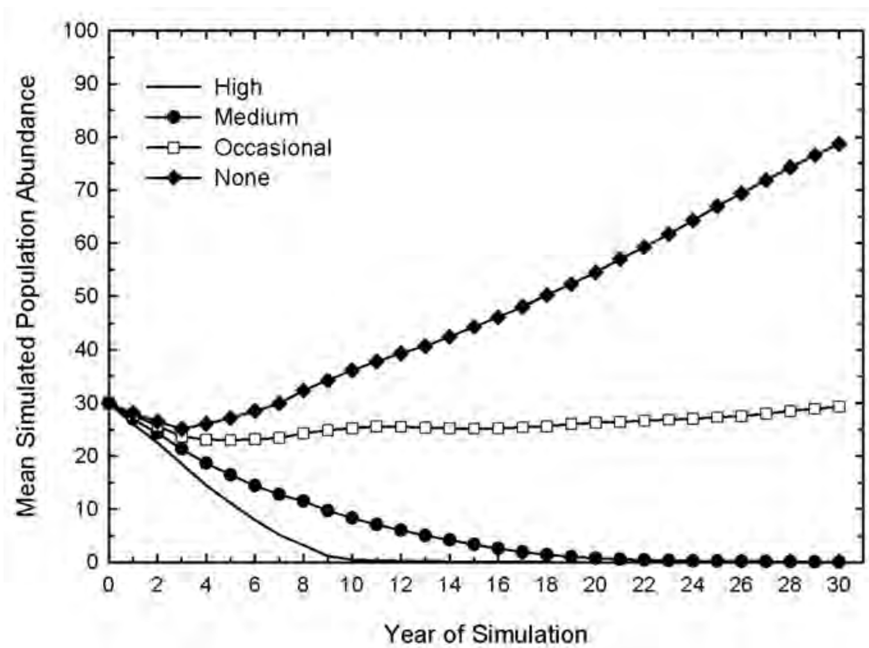


Figure 40. Mean abundance trajectories for a simulated Manas NP population of greater one-horned rhino without translocation of animals from Kaziranga NP and with variable rates of poaching: random removal of 2±1 adults of each sex (bottom blue line), 1±1 adults of each sex (middle red line), or no poaching (top green line). See accompanying text for more information on model structure and interpretation.

[6] The oldest male in the population at present is perhaps around 7-8 years old.

Translocation Analysis: Burachapori Wildlife Sanctuary

Our translocation scenarios that were intended to evaluate the conditions necessary to create a viable GOHR population included the following features:

- Translocation of 6 (3♀, 3♂), 9 (6♀, 3♂), or 15 (9♀, 6♂) adult animals from Kaziranga NP;
- Translocation in either years (1, 2, 3) or years (1, 3, 5);
- Poaching in Burachapori was either absent or beginning in year 1 and maintained at high (2±1 adults each gender), medium (1±1 adults each gender), or occasional (0±1 adults each gender) levels throughout the simulation.

We created a total of 24 scenarios featuring various combinations of the above factors. Once again, we assume that the GOHR population that is created in Burachapori through translocation will be able, in the absence of poaching, to show a mean population growth rate that is comparable to that seen in the Kaziranga population over the past 15-20 years.

Figure 41 shows the results of those scenarios featuring translocation of rhinos from Kaziranga to Burachapori in years 1, 2, and 3. When a relatively low level of translocation effort is employed (top panel), a population can be established successfully in Burachapori only if poaching is eliminated as a threat to mortality. Even occasional poaching of approximately one animal per year puts that population at risk, with only a 40% chance of success in population establishment. If the poaching rate is any higher, the population cannot grow after the initial translocation period and it will become extinct if poaching rates are not reduced.

If more extensive translocation efforts are employed, with 9 animals added in each of the first three years of the simulated project (middle panel), occasional poaching of rhino from Burachapori can be tolerated and the population can increase in abundance following the translocation. Our models indicate a 1% chance that the population will not survive after the initial translocation, but if it does survive the simulated trajectory shows robust population growth.

Occasional poaching of rhino from Burachapori can also be tolerated under the most intensive translocation efforts that we simulated (bottom panel), with no observed risk of population extinction over the course of the simulation. However, even with this maximum level of effort, sustained poaching of just 2-3 animals per year is not sustainable over the period of our simulation; this level of poaching reduces the probability of successful population establishment to just 80%.

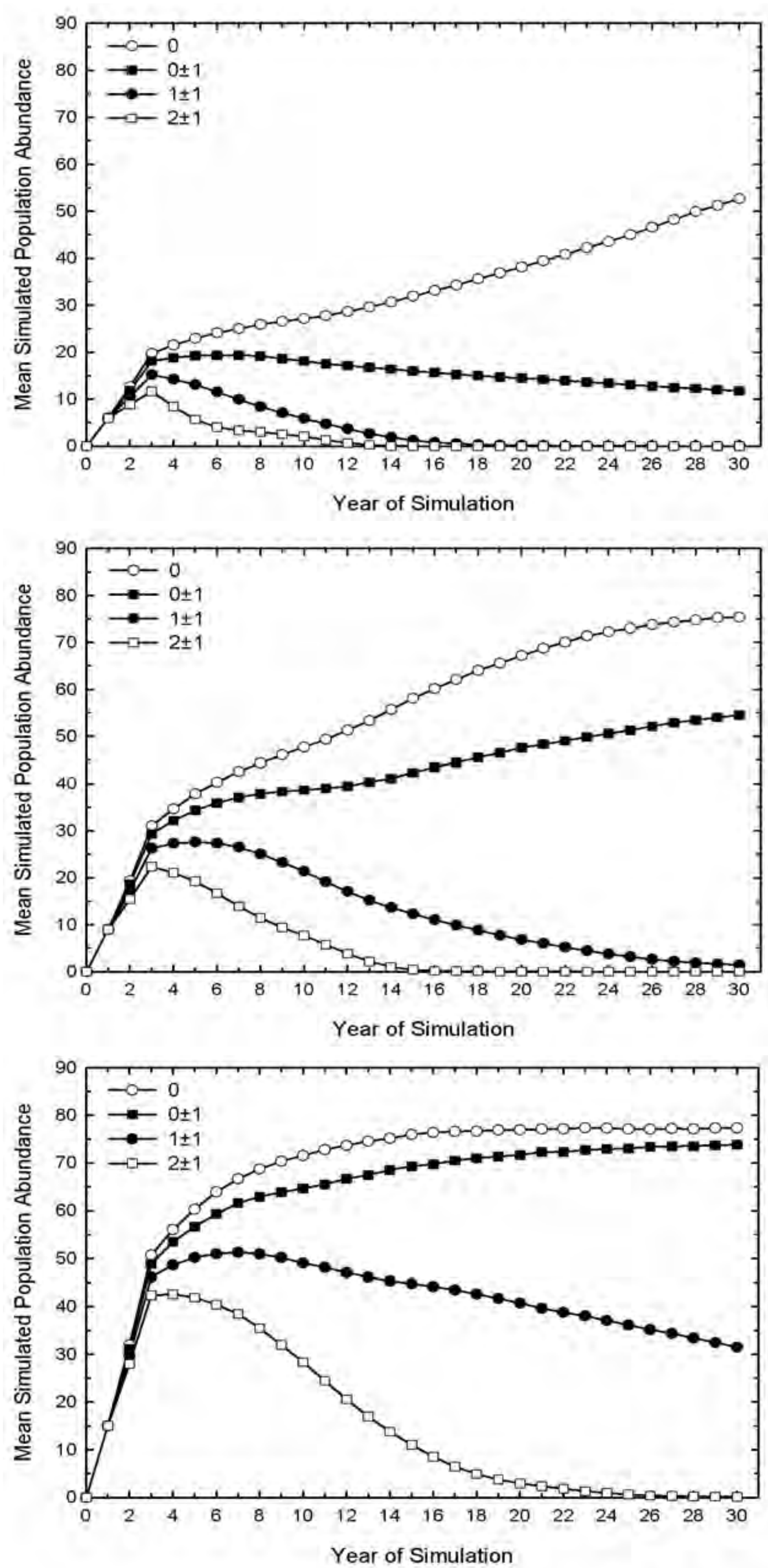


Figure 41. Mean abundance trajectories for a simulated Burachapori Wildlife Sanctuary population of greater one-horned rhino with translocation of animals from Kaziranga NP in years 1, 2 and 3. Top panel: 6 animals (3 female, 3 male) added each year. Middle panel: 9 animals (6 female, 3 male) added each year. Bottom panel: 15 animals (9 female, 6 male) added each year. Within each panel, the graph legend indicates the number of animals of each gender that are removed by poaching each year of the simulation. See accompanying text for more information on model structure and interpretation.

A very similar picture emerges when the translocation effort is modified to add animals every other year over the first five years of the simulation (Figure 42). Although it takes a few years longer to complete the translocation process, the population abundance trajectories and final population size estimates for these scenarios are very close to those in the previous analysis where animals are added to Burachapori in successive years. As the rate of poaching increases, the slower introduction of animals in this second set of analyses does lead to slightly higher probabilities of population failure as the additional mortality leads to greater levels of population instability. Nevertheless, as seen in the first set of Burachapori translocation scenarios, the probability of successfully establishing a rhino population in the Wildlife Sanctuary is high when poaching is limited to only occasional removals. The additional annual removal of just a single animal above this threshold can lead to significant risk of population extinction following the translocation effort.

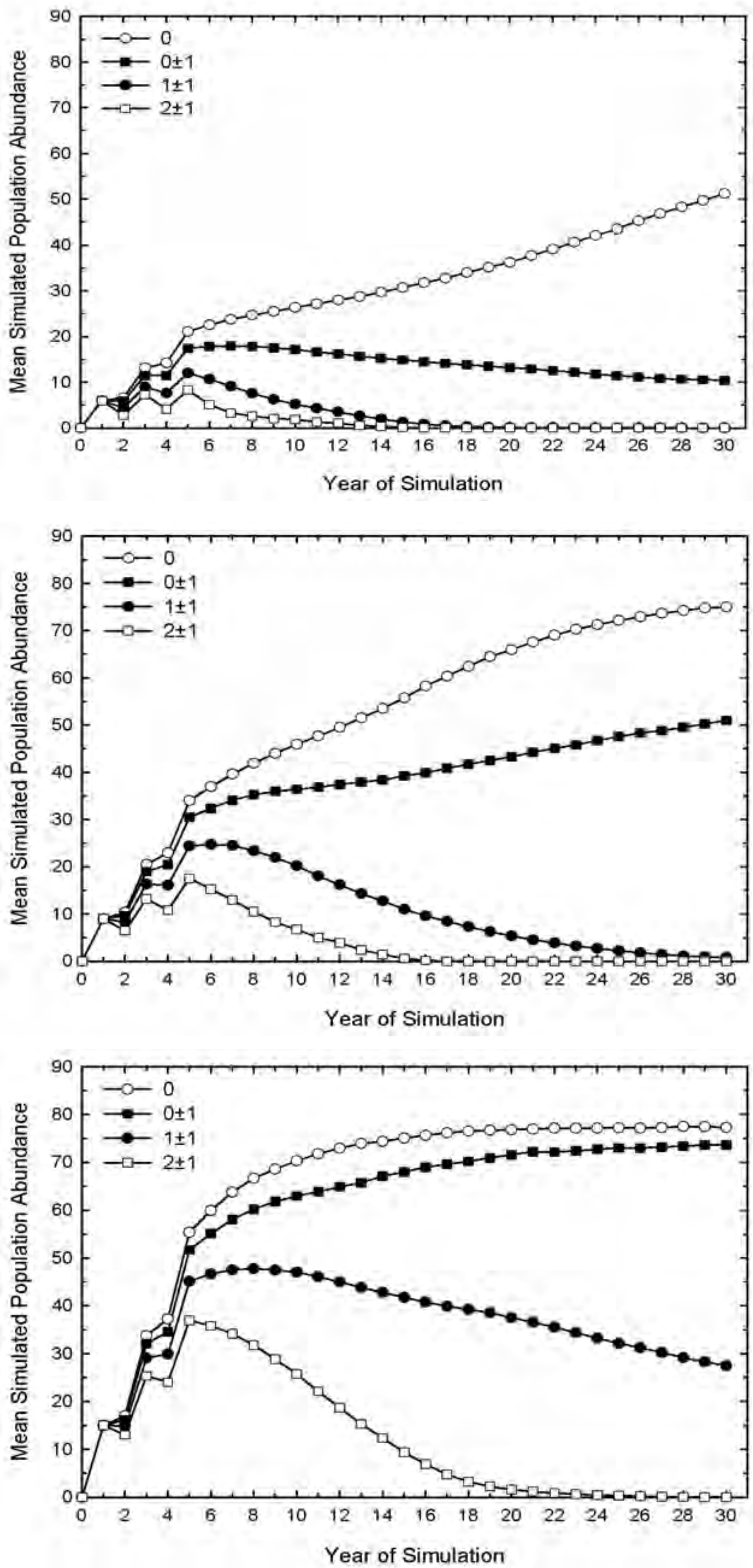


Figure 42. Mean abundance trajectories for a simulated Burachapori Wildlife Sanctuary population of greater one-horned rhino with translocation of animals from Kaziranga NP in years 1, 3 and 5. Top panel: 6 animals (3 female, 3 male) added each year. Middle panel: 9 animals (6 female, 3 male) added each year. Bottom panel: 15 animals (9 female, 6 male) added each year. Within each panel, the graph legend indicates the number of animals of each gender that are removed by poaching each year of the simulation. See accompanying text for more information on model structure and interpretation.

Conclusions

We may conclude our analysis of greater one-horned rhino population viability in Assam by returning to the original set of questions that provided the foundation for our study.

- *Can we build a simulation model of GOHR demography that is reasonably realistic, and that can help us evaluate alternative management strategies for selected GOHR populations in Assam?*

  Our retrospective demographic analysis of both the Kaziranga and Pobitora rhino populations indicates that we are indeed capable of building such models. It is important to remember, however, that population abundance trajectories are influenced by a host of factors, which may or may not be realistically portrayed in our models. As a result, it remains crucial to treat these models and the insight they provide as preliminary and subject to continued revision and refinement.

- *How demographically robust are the Kaziranga National Park and Pobitora Wildlife Sanctuary GOHR populations? Can these populations be used as a source of animals for translocation to other areas of Assam without compromising their own long-term viability?*

  Based on the models constructed and discussed in this report, it appears that the Kaziranga NP rhino population is sufficiently large to tolerate removal of as many as 40 animals a year over a period of 2 – 3 decades. Since this population is currently estimated to be approximately 2350 individuals, and the estimated annual growth rate in the population is approximately 3%, this estimate of a sustainable harvest for the purposes of translocation is logical. This conclusion, however, is critically dependent on the underlying demographics of the source population. If ecological conditions decline in the Park, or if poaching pressure increases, the long-term stability of the rhino population may be in jeopardy – and its utility as a source population for translocations could be compromised. Careful monitoring of population abundance and poaching rates in the Park is an extremely important component of a successful rhino population management approach.

  The Pobitora population is considerably smaller than its counterpart in Kaziranga. Additionally, while the absolute number of animals removed from there is lower than at Kaziranga, it represents a larger proportion of the total population. Consequently, the Pobitora population is considerably more sensitive to the removal of animals for use in translocation projects. Our models suggest that only 2 – 3 animals should be eligible for removal, and over a short period of time in order to minimize the overall impact of the removal on long-term population viability. Given the comparative stability of the Kaziranga population, it appears feasible to rely on the Kaziranga population for the large majority of animals destined for translocation projects, with perhaps occasional use of Pobitora animals to increase the genetic diversity of translocation stock (or perhaps even Orang animals for the same reason, although the analysis of this population is not part of the current study). The issue of genetic diversity has not been addressed in this study, and may not be of primary importance in the short term when trying to establish a new rhino population.

- *How many animals should be translocated from Kaziranga National Park to create a viable GOHR population in Manas National Park?*
- *Is the rate of poaching currently observed in Manas National Park considered unsustainable in the long-term, even with translocation efforts planned for the future?*

It appears that the first question is an explicit function of the underlying poaching pressure affecting GOHR within the Park. If we assume that the habitat within the Park is suitable to support rhino population growth of approximately 3% per year, our models suggest that the introduction of additional rhino into Manas NP would likely not be necessary if poaching were to be eliminated over the long-term. As this condition may be unlikely to achieve in the near future, some translocation effort would almost certainly be required to substantially increase the Manas rhino population over the next 1 – 2 decades. This translocation effort can be successful only if poaching pressure is reduced to a minimal level, i.e., less than one animal poached every year. Until the current intensity of poaching is reduced through some form of local management, the introduction of additional animals from a source such as Kaziranga will likely be considered an unwise use of a precious resource.

- *What level of translocation effort is required to generate a long-term viable GOHR population in the Burachapori Wildlife Sanctuary?*

As with the discussion of rhino population viability in Manas NP, the issue of designing an optimal translocation strategy for the Burachapori Wildlife Sanctuary site is closely linked to the predicted poaching pressure that is to be expected. If poaching can be largely eliminated as a threat to this emerging population, the translocation of just 6 – 9 adult individuals (3 – 6 females) each year for just three years may be sufficient to create the demographic conditions necessary for sustained positive population growth. If at least nine animals can be moved into the new habitat annually, and if poaching can be largely eliminated, it may be possible for that population to grow strongly and reach an abundance close to the habitat carrying capacity over a period of approximately 30 years. As stated previously, this optimistic prediction is critically dependent on minimizing the rate of loss of animals through poaching. Our simulations suggest that an increase of just 1 – 2 animals lost per year to poachers greatly increases the probability of failure of the type of translocation program evaluated in this study.

Throughout this report, as graphically demonstrated in the results of our simulation models, we emphasize the critical impact that even relatively low rates of animal loss due to poaching can have on the long-term viability of small populations of greater one-horned rhino population in Assam – and likely elsewhere throughout the species' range in India and Nepal. The work described here is by no means exhaustive; rhino populations in Assam (Rajiv Gandhi Orang NP) and elsewhere in India (Jaldapara and Gorumara NPs in West Bengal, and Dudhwa NP in Uttar Pradesh) were not explicitly considered in this analysis. We hope that the analyses and associated discussions presented here will motivate others in these areas to conduct similar analyses for their own populations, and perhaps interpret the results in the broader context of range wide conservation needs for the species.

MIND MAP

As models were being developed, participants also worked to identify the various factors affecting rhino poaching in Manas National Park, which is at a crisis point. Participants created a Mind Map (Figure 43) to as a tool to generate, visualize, structure, and classify ideas, and to aid in understanding how the various factors affecting poaching are related. After the mind-map was created, participants voted by placing sticky dots on the factor(s) that they believed most affected rhino poaching in Manas National Park.

Discussion of Mind Map

The group agreed that the insurgency issues are the primary factor affecting poaching in the Manas National Park. The group also agreed that the effect of the insurgents on poaching was not within the manageable interests of this group, and that dealing with the insurgents is the responsibility of the government. <u>Participants recommended that the government make a decision to remove insurgents from Manas and implement counter-insurgency measures</u>.

It is unclear whether there is a mandate in place for the army to assist with anti-poaching efforts in Manas, if there is a mandate, it is not currently being carried out. It is important to note that park staff are not trained to deal with insurgents, and are lacking in confidence. Because of poaching pressures, they have had to change from park guards to soldiers in order to deal with the problem.

<u>Potential solutions identified included</u>:

- Joint patrolling with paramilitary. That said, there are also problems inherent in coordinating between the park and the paramilitary hierarchies. New types of capacity building, for example involving tactical and intelligence training, would be useful, with the paramilitary involved.
- Staff rotation and new recruits would also help to alleviate the inertia and poor morale within the park.

The High-level Task Force for Manas has been in place for some time but is not yet fully functional and the local government is probably failing because the responsibility for law and order in the area has not been transferred to the Bodo Territorial Council from the Government of Assam.

Politically, the government, specifically the Chief Minister of Assam, the Forest Minister and the Bodo Territorial Council need to be engaged. <u>The group recommended the following steps and tasked the following individuals to take responsibility</u>:

1. Present the population modeling scenarios generated at this workshop to the Chief Secretary of the Bodo Territorial Council, the Chief Minister of Assam and the Forest Minister of Assam. Responsible: Bibhab Talukdar, Amit Sharma, Kaushik Barua
2. Convene serious discussions with a full explanation of the local, national and international ramifications of the failure of IRV 2020 rhino translocations with the Bodo Territorial Council and the Forest Minister. Responsible: Bibhab Talukdar, Amit Sharma, Kaushik Barua
3. Letter of concern about the poaching situation in Manas should be written to the Indian Prime Minister, the Chief Minister, and the Forest Minister from groups such as the Asian Rhino Specialist Group, the International Rhino Foundation, WWF, the IUCN Species Survival Commission, and the World Heritage Commission. Responsible: Susie Ellis and Barney Long
4. National and international media attention should be drawn to the issue of poaching in Manas. Responsible: Anupam Sharma, Barney Long, Susie Ellis

Other promising solutions/ideas identified are:

1. Develop a program similar to Project Tiger for rhinos.
2. Develop a mechanism that will assist in understanding the trade dynamics for GOHR populations.

Figure 43. Mind map identifying factors affecting rhino poaching in Manas National Park

Lessons Learned from Manas Translocations

The group also discussed observations and lessons learned to-date from the Manas translocat These include:

- It is not difficult to reintroduce rhinos safely.
- Rhinos are excellent swimmers and terrain negotiators.
- Rhinos can have a home range of more than 100 sq. km.
- Rhinos will stray even from good habitat. The reason is unknown.
- An excellent team has been developed for rhino translocation and rescue.
- Apart from Manas, there are few places large enough for rhino conservation, really on Kaziranga, Orang, Burachapori and Dudhwa.
- Rhinos are an umbrella species that leads to progress in protected areas.
- Good security existed and was anticipated to improve but things changed quickly in M National park. We need to think about and be prepared for what to do if things don't well or if unforeseen crises arise, particularly those disasters that might be predictable
- Procurement of immobilization drugs has been less than optimal; procuring stocks of immobilization drugs need to be negotiated well in advance of translocations and procedures needs to be simplified.
- We need to have movement and site strategies.

Other Areas

A general problem for all populations is that most have reached carrying capacity and there ar other grasslands for rhinos. There seems to be no solution; Nepal may have room for a few numbers but at some point their populations will also reach saturation.

In contrast to Manas National Park, Gorumara National Park has had no poaching. Participant attributed this to human management - people do not enter the park. Additionally, regular ecotourism funds go to villages, which allows the park to gain the confidence and trust of fring villagers. There is pressure within the population, especially among males, but these pressure not related to anthropogenic factors. Rhinos are straying every other day from Gorumara. Ke track of straying rhinos is becoming increasingly difficult, e.g., four of them will not come back is problematic as West Bengal has the highest population density of humans in India and the potential for human-rhino conflict is very high.

For Dudhwa, there was a discussion as to whether the pens should be opened up or left as is. consensus was that there should be a way to create connectivity between the populations (th current Dudhwa population and the one that will be set up soon).

Research Needs

There are a number of research needs. For example, there are genetic considerations to cons with respect to managing the populations and with implications for translocations.

Research Needs identified included:

- demographic research such as line transects and genetic capture-mark-recapture. On method would be to divide areas into blocks for counting and matching rhino photos.

- standardize census methodology across rhino-bearing areas. (In areas that have tigers this could be linked to Project Tiger.)
- demographic research such as line transects and genetic capture-mark-recapture.
- standardized post-mortem exams and protocols for non-poaching deaths
- disease surveillance
- habitat and food preferences of rhinos (WII has just finished a study on Chitwan)
- estimating the real carrying capacity of rhino-bearing areas
- anthropological and social studies of communities
- relationship between ecotourism and poaching levels
- habitat utilization

Other Needs

All participants felt strongly that India needs to develop Standard Operating Procedures for translocations and reintroductions, taking into account the translocation guidelines developed by the IUCN African Rhino and Reintroduction Specialist Groups. Another need is to develop a DNA database such as RHODIS for GOHRs.

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Appendix II.   Population Viability Analysis and Simulation Modeling Reference

Population Viability Analysis and Simulation Modeling

Philip S. Miller, Conservation Breeding Specialist Group (IUCN / SSC)
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Introduction

Thousands of species and populations of animals and plants around the world are threatened with extinction within the coming decades. For the vast majority of these groups of organisms, this threat is the direct result of human activity. The particular types of activity, and the ways in which they impact wildlife populations, are often complex in both cause and consequence; as a result, the techniques we must use to analyze their effects often seem to be complex as well. But scientists in the field of conservation biology have developed extremely useful tools for this purpose that have dramatically improved our ability to conserve the planet's biodiversity.

Conservation biologists involved in recovery planning for a given threatened species usually try to develop a detailed understanding of the processes that put the species at risk, and will then identify the most effective methods to reduce that risk through active management of the species itself and/or the habitat in which it lives. In order to design such a program, we must engage in some sort of predictive process: we must gather information on the detailed characteristics of proposed alternative management strategies and somehow predict how the threatened species will respond in the future. A strategy that is predicted to reduce the risk by the greatest amount – and typically does so with the least amount of financial and/or sociological burden – is chosen as a central feature of the recovery plan.

But how does one predict the future? Is it realistically possible to perform such a feat in our fast-paced world of incredibly rapid and often unpredictable technological, cultural, and biological growth? How are such predictions best used in wildlife conservation? The answers to these questions emerge from an understanding of what has been called "the flagship industry" of conservation biology: Population Viability Analysis, or PVA. And most methods for conducting PVA are merely extensions of tools we all use in our everyday lives.

The Basics of PVA

To appreciate the science and application of PVA to wildlife conservation, we first must learn a little bit about population biology. Biologists will usually describe the performance of a population by describing its demography, or simply the numerical depiction of the rates of birth and death in a group of animals or plants from one year to the next. Simply speaking, if the birth rate exceeds the death rate, a population is expected to increase in size over time. If the reverse is true, our population will decline. The overall rate of population growth is therefore a rather good descriptor of its relative security: positive population growth suggests some level of demographic health, while negative growth indicates that some external process is interfering with the normal population function and pushing it into an unstable state.

This relatively simple picture is, however, made a lot more complicated by an inescapable fact: wildlife population demographic rates fluctuate unpredictably over time. So if we observe that 50% of our total population of adult females produces offspring in a given year, it is almost certain that more or less than 50% of our adult females will reproduce in the following year. And the same can be said for most all other demographic rates: survival of offspring and adults, the numbers of offspring born, and the offspring sex ratio will almost always change from one year to the next in a way that usually defies precise prediction. These variable rates then conspire to make a population's growth rate also change unpredictably from year to year. When wildlife populations are very large – if we consider seemingly endless herds of wildebeest on the savannahs of Africa, for example – this random annual fluctuation in population growth is of little to no consequence for the future health and stability of the population. However, theoretical and practical study of population biology has taught us that populations that are already small in size, often defined in terms of tens to a few hundred individuals, are affected by these fluctuations to a much greater extent – and the long-term impact of these fluctuations is always negative. Therefore, a wildlife population that has been reduced in numbers will become even smaller through this fundamental principle of wildlife biology. Furthermore, our understanding of this process provides an important backdrop to considerations of the impact of human activities that may, on the surface, appear relatively benign to larger and more stable wildlife populations. This self-reinforcing feedback loop, first coined the "extinction vortex" in the mid-1980's, is the cornerstone principle underlying our understanding of the dynamics of wildlife population extinction.

Once wildlife biologists have gone out into the field and collected data on a population's demography and used these data to calculate its current rate of growth (and how this rate may change over time), we now have at our disposal an extremely valuable source of information that can be used to predict the *future* rates of population growth or decline under conditions that may not be so favorable to the wildlife population of interest. For example, consider a population of primates living in a section of largely undisturbed Amazon rain forest that is now opened up to development by logging interests. If this development is to go ahead as planned, what will be the impact of this activity on the animals themselves, and the trees on which they depend for food and shelter? And what kinds of alternative development strategies might reduce the risk of primate population decline and extinction? To try to answer this question, we need two additional sets of information: 1) a comprehensive description of the proposed forest development plan (how will it occur, where will it be most intense, for what period of time, etc.) and 2) a detailed understanding of how the proposed activity will impact the primate population's demography (which animals will be most affected, how strongly will they be affected, will animals die outright more frequently or simply fail to reproduce as often, etc.). With this information in hand, we have a vital component in place to begin our PVA.

Next, we need a predictive tool – a sort of crystal ball, if you will, that helps us look into the future. After intensive study over nearly three decades, conservation biologists have settled on the use of computer simulation models as their preferred PVA tool. In general, models are simply any simplified representation of a real system. We use models in all aspects of our lives; for example, road maps are in fact relatively simple (and hopefully very accurate!) 2-dimensional representations of complex 3-dimensional landscapes we use almost every day to get us where we need to go. In addition to making predictions about the future, models are very helpful for us to: (1) extract important trends from complex processes, (2) allow comparisons among different types of systems, and (3) facilitate analysis of processes acting on a system.

Recent advances in computer technology have allowed us to create very complex models of the demographic processes that define wildlife population growth. But at their core, these models attempt to replicate simple biological functions shared by most all wildlife species: individuals are born, some grow to adulthood, most of those that survive mate with individuals of the opposite sex and then give birth to one or more offspring, and they die from any of a wide variety of causes. Each species may have its own special set of circumstances – sea turtles may live to be 150 years old and lay 600 eggs in a single event, while a chimpanzee may give birth to just a single offspring every 4-5 years until the age of 45 – but the fundamental biology is the same. These essential elements of a species' biology can be incorporated into a computer program, and when combined with the basic rules for living and the general characteristics of the population's surrounding habitat, a model is created that can project the demographic behavior of our real observed population for a specified period of time into the future. What's more, these models can explicitly incorporate random fluctuations in rates of birth and death discussed earlier. As a result, the models can be much more realistic in their treatment of the forces that influence population dynamics, and in particular how human activities can interact with these intrinsic forces to put otherwise relatively stable wildlife populations at risk.

Many different software packages exist for the purposes of conducting a PVA. Perhaps the most widely-used of these packages is *VORTEX*, developed by the IUCN Conservation Breeding Specialist Group (CBSG) for use in both applied and educational environments. *VORTEX* has been used by CBSG and other conservation biologists for more than 15 years and has proved to be a very useful tool for helping make more informed decisions in the field of wildlife population management.

The *VORTEX* Population Viability Analysis Model

For the analyses presented here, the *VORTEX* computer software (Lacy 1993a) for population viability analysis was used. *VORTEX* models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. *VORTEX* also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

Density dependence in mortality is modeled by specifying a carrying capacity of the habitat. When the population size exceeds the carrying capacity, additional morality is imposed across all age classes to bring the population back down to the carrying capacity. The carrying capacity can be specified to change linearly over time, to model losses or gains in the amount or quality of habitat. Density dependence in reproduction is modeled by specifying the proportion of adult females breeding each year as a function of the population size.

VORTEX models loss of genetic variation in populations, by simulating the transmission of alleles from parents to offspring at a hypothetical genetic locus. Each animal at the start of the simulation is assigned two unique alleles at the locus. During the simulation, *VORTEX* monitors how many of the original alleles remain within the population, and the average heterozygosity and gene diversity (or "expected heterozygosity") relative to the starting levels. *VORTEX* also monitors the inbreeding coefficients of each animal, and can reduce the juvenile survival of inbred animals to model the effects of inbreeding depression.

VORTEX is an *individual-based* model. That is, *VORTEX* creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime. *VORTEX* keeps track of the sex, age, and parentage of each animal. Demographic events (birth, sex determination, mating, dispersal, and death) are modeled by determining for each animal in each year of the simulation whether any of the events occur. Events occur according to the

specified age and sex-specific probabilities. Demographic stochasticity is therefore a consequence of the uncertainty regarding whether each demographic event occurs for any given animal.

VORTEX requires a lot of population-specific data. For example, the user must specify the amount of annual variation in each demographic rate caused by fluctuations in the environment. In addition, the frequency of each type of catastrophe (drought, flood, epidemic disease) and the effects of the catastrophes on survival and reproduction must be specified. Rates of migration (dispersal) between each pair of local populations must be specified. Because *VORTEX* requires specification of many biological parameters, it is not necessarily a good model for the examination of population dynamics that would result from some generalized life history. It is most usefully applied to the analysis of a specific population in a specific environment.

Further information on *VORTEX* is available in Lacy (2000) and Miller and Lacy (2003).

Results reported for each scenario include:

Deterministic r -- The deterministic population growth rate, a projection of the mean rate of growth of the population expected from the average birth and death rates. Impacts of harvest, inbreeding, and density dependence are not considered in the calculation. When r

= 0, a population with no growth is expected; r < 0 indicates population decline; r > 0 indicates long-term population growth. The value of r is approximately the rate of growth or decline per year.

The deterministic growth rate is the average population growth expected if the population is so large as to be unaffected by stochastic, random processes. The deterministic growth rate will correctly predict future population growth if: the population is presently at a stable age distribution; birth and death rates remain constant over time and space (i.e., not only do the probabilities remain constant, but the actual number of births and deaths each year match the expected values); there is no inbreeding depression; there is never a limitation of mates preventing some females from breeding; and there is no density dependence in birth or death rates, such as a Allee effects or a habitat "carrying capacity" limiting population growth. Because some or all of these assumptions are usually violated, the average population growth of real populations (and stochastically simulated ones) will usually be less than the deterministic growth rate.

Stochastic r -- The mean rate of stochastic population growth or decline demonstrated by the simulated populations, averaged across years and iterations, for all those simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity. Usually, this stochastic r will be less than the deterministic r predicted from birth and death rates. The stochastic r from the simulations will be close to the deterministic r if the population growth is steady and robust. The stochastic r will be notably less than the deterministic r if the population is subjected to large fluctuations due to environmental variation, catastrophes, or the genetic and demographic instabilities inherent in small populations.

P(E) -- the probability of population extinction, determined by the proportion of, for example, 500 iterations within that given scenario that have gone extinct in the simulations. "Extinction" is defined in the *Vortex* model as the lack of either sex.
N -- mean population size, averaged across those simulated populations that are not extinct.

SD(N) -- variation across simulated populations (expressed as the standard deviation) in the size of the population at each time interval. SDs greater than about half the size of mean N often indicate highly unstable population sizes, with some simulated populations very near extinction. When SD(N) is large relative to N, and especially when SD(N) increases over the years of the simulation, then the population is vulnerable to large random fluctuations and may go extinct even if the mean population growth rate is positive. SD(N) will be small and often declining relative to N when the population is either growing steadily toward the carrying capacity or declining rapidly (and deterministically) toward extinction. SD(N) will also decline considerably when the population size approaches and is limited by the carrying capacity.

H -- the gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity (Lacy 1993), with a 10% decline in gene diversity typically causing about 15% decline in survival of captive mammals (Ralls et al. 1988). Impacts of inbreeding on wild populations are less well known, but may be more severe than those observed in captive populations (Jiménez et al. 1994). Adaptive response to natural selection is also expected to be proportional to gene diversity. Long-term conservation programs often set a goal of retaining 90% of initial gene diversity (Soulé et al. 1986). Reduction to 75% of gene diversity would be equivalent to one generation of full-sibling or parent-offspring inbreeding.

Strengths and Limitations of the PVA Approach

When considering the applicability of PVA to a specific issue, it is vitally important to understand those tasks to which PVA is well-suited as well as to understand what the technique is not well-designed to deliver. With this enhanced understanding will also come a more informed public that is better prepared to critically evaluate the results of a PVA and how they are applied to the practical conservation measures proposed for a given species or population.

The dynamics of population extinction are often quite complicated, with numerous processes impact the dynamics in complex and interacting ways. Moreover, we have already come to appreciate the ways in which demographic rates fluctuate unpredictably in wildlife populations, and the data needed to provide estimates of these rates and their annual variability are themselves often uncertain, i.e., subject to observational bias or simple lack of detailed study over relatively longer periods of time. As a result, the elegant mental models or the detailed mathematical equations of even the most gifted conservation biologist are inadequate for capturing the detailed nuances of interacting factors that determine the fate of a wildlife population threatened by human activity. In contrast, simulation models can include as many factors that influence population dynamics as the modeler and the end-user of the model wish to assess. Detailed interactions between processes can also be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes.

PVA models have also been shown to stimulate meaningful discussion among field biologists in the subjects of species biology, methods of data collection and analysis, and the assumptions that underlie the analysis of these data in preparation for their use in model construction. By making the models and their underlying data, algorithms and assumptions explicit to all who learn from them, these discussions become a critical component in the social process of achieving a shared understanding of a threatened species' current status and the biological justification for identifying a particular management strategy as the most effective for species conservation. This additional benefit is most easily recognized when PVA is used in an interactive workshop-type setting, such as the Population and Habitat Viability Assessment (PHVA) workshop designed and implemented by CBSG.

Perhaps the greatest strength of the PVA approach to conservation decision-making is related to what many of its detractors see as its greatest weakness. Because of the inherent uncertainty now known to exist in the long-term demography of wildlife populations (particularly those that are small in size), and because of the difficulties in obtaining precise estimates of demographic rates through extended periods of time collecting data in the field, accurate predictions of the future performance of a threatened wildlife population are effectively impossible to make. Even the most respected PVA practitioner must honestly admit that an accurate prediction of the number of mountain gorillas that will roam the forests on the slopes of the eastern Africa's Virunga Volcanoes in the year 2075, or the number of polar bears that will swim the warming waters above the Arctic Circle when our great-grandchildren grow old, is beyond their reach. But this type of difficulty, recognized across diverse fields of study from climatology to gambling, is nothing new: in fact, the Nobel Prize-winning physicist Niels Bohr once said "Prediction is very difficult, especially when it's about the future." Instead of lamenting this inevitable quirk of the physical world as a fatal flaw in the practice of PVA, we must embrace it and instead use our very cloudy crystal ball for another purpose: to make **relative**, rather than **absolute**, predictions of wildlife population viability in the face of human pressure.

The process of generating relative predictions using the PVA approach is often referred to as sensitivity analysis. In this manner, we can make much more robust predictions about the relative response of a simulated wildlife population to alternate perturbations to its demography. For example, a PVA practitioner may not be able to make accurate predictions about how many individuals of a given species may persist in 50 years in the presence of intense human hunting pressure, but that practitioner can speak with considerably greater confidence about the relative merits of a male-biased hunting strategy compared to the much more severe demographic impact typically imposed by a hunting strategy that prefers females. This type of comparative approach was used very effectively in a PVA for highly threatened populations of tree kangaroos (*Dendrolagus* sp.) living in Papua New Guinea, where adult females are hunted preferentially over their male counterparts. Comparative models showing the strong impacts of such a hunting strategy were part of an important process of conservation planning that led, within a few short weeks after a participatory workshop including a number of local hunters (Bonaccorso et al., 1998), to the signing of a long-term hunting moratorium for the most critically endangered species in the country, the tenkile or Scott's tree kangaroo (*Dendrolagus scottae*).

PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models often underestimate the threats facing the population, or the total risk these threats collectively impose on the population of interest. To address this limitation, conservation biologists must try to engage a diverse body of experts with knowledge spanning many different fields in an attempt to broaden our understanding of the consequences of interaction between humans and wildlife.

Additionally, models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data and model results periodically, with changes made to the conservation programs as needed (see Lacy and Miller (2002), Nyhus et al. (2002) and Westley and Miller (2003) for more details).

Finally, it is also important to understand that a PVA model by itself does not define the goals of conservation planning of a given species. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used.

Further Reading

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