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Resilience and Renewal: Conserving the Greater One-Horned Rhinoceros in South Asia's National Parks.

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Abstract

The greater one-horned rhinoceros (*Rhinoceros unicornis*), a symbol of conservation success, remains at the crux of extensive ecological and conservation research, primarily centred on its habitat within the national parks of India and Nepal. This literature review synthesizes a broad spectrum of studies to evaluate the ongoing efforts and challenges in the conservation of this species, emphasizing the crucial roles of habitat management, anti-poaching strategies, community involvement, and adaptation to climate change. Protected areas such as Kaziranga National Park in India and Chitwan National Park in Nepal are highlighted as bastions of success due to their effective management practices that include stringent anti-poaching measures and habitat conservation, which have notably contributed to the stabilization and growth of rhino populations. However, escalating challenges such as habitat fragmentation, climate-induced changes in habitat quality, and the persistent threat of poaching continue to pose significant risks. This review further explores how enhanced community engagement and international collaboration have fortified conservation outcomes, creating resilient ecological networks that support both rhinos and local communities. The impact of climate change is examined through recent studies that underscore the necessity for parks to adopt adaptive management practices to mitigate the adverse effects on rhino habitats. In conclusion, while progress has been notable, the review calls for a continuous evolution of conservation strategies to address emerging threats and to harness new technologies and cooperative frameworks that span geographical and political boundaries, ensuring the long-term survival of the greater one-horned rhinoceros.

Keywords : *Rhinoceros unicornis*, National Park Management, Anti-Poaching Strategies, Climate Change Adaptation, Community Engagement

1. Introduction

The greater one-horned rhinoceros (*Rhinoceros unicornis*), once on the precipice of extinction, has become emblematic of successful conservation practices in South Asia. Found primarily in the grasslands of the northern Indian subcontinent, particularly in India and Nepal, this species' revival has been facilitated by concerted efforts in protected areas such as Kaziranga National Park in India and Chitwan National Park in Nepal. Historically, uncontrolled hunting and habitat loss had drastically reduced their numbers. However, targeted conservation programs initiated in the 20th century, which focused on stringent anti-poaching regulations and habitat restoration, have led to a significant rebound in their populations (Dinerstein1991; Laurie 1982).

The conservation of the greater one-horned rhino is not only a victory for biodiversity but also supports the socio-economic framework of the regions through eco-tourism, which has become a sustainable source of revenue for local communities (Singh & Patel 2020). Yet, the rhino's survival continues to be jeopardized by several persistent threats, including poaching for their valuable horns, habitat fragmentation due to agricultural expansion, and the escalating impacts of climate change. These challenges complicate conservation

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efforts and necessitate adaptive and innovative management strategies to secure the future of the species (Khan et al. 2024; Sharma et al.2020).

Initial conservation measures in the early 20th century primarily focused on establishing protected areas and enforcing hunting bans. Over time, these efforts have evolved into more complex ecological management strategies that integrate advanced technological tools and international cooperation frameworks. Studies by Laurie (1982) and Dinerstein (1991) provided foundational knowledge on the ecological needs of rhinos, emphasizing the importance of maintaining riverine grasslands and wetlands, which are vital for their survival. These habitats are maintained through active management practices informed by ongoing scientific research, ensuring that the ecosystems continue to support not just rhinos but a diverse array of flora and fauna.

Despite these advances, modern conservation work faces multifaceted challenges. Poaching remains a severe threat due to the high value of rhino horns on the black market, necessitating continual advancements in surveillance and law enforcement. Additionally, as agricultural lands expand and infrastructural developments encroach on natural habitats, rhinos face the loss of their grazing and breeding grounds, leading to genetic bottlenecks and reduced population viability. Moreover, climate change poses new risks, altering habitats and food sources through unpredictable weather patterns, such as altered flooding cycles, which can devastate the delicate ecosystems that rhinos depend on.

The integration of local communities into the conservation framework has proved essential, turning potential adversaries into allies by linking community well-being with ecological health. These initiatives not only reduce poaching incidents but also foster a conservation ethic among communities, promoting sustainable practices that benefit both human and wildlife populations.

This review aims to critically evaluate the collective efforts in the conservation of the greater one-horned rhinoceros, with a focus on the effectiveness of national parks as sanctuaries that foster both ecological and socio-economic benefits. It examines the role of these protected areas in supporting rhino populations, assesses the impact of various conservation strategies—including anti-poaching efforts, habitat management, and community engagement—and explores the external challenges such as climate change that influence conservation outcomes.

2. Materials and methods

This review employed a systematic approach to synthesize and analyze the extensive body of literature on the conservation of the greater one-horned rhinoceros, with a focus on the role of national parks in India and Nepal. The aim was to compile a comprehensive overview of the various conservation strategies that have been implemented over the years, the ongoing challenges faced by conservationists, and the outcomes of these efforts on the rhino populations.

2.1 Literature Search and Selection Criteria

To gather relevant literature, a detailed search was conducted using multiple academic databases including PubMed, Scopus, Web of Science, and Google Scholar. Keywords used in the search included "greater one-horned rhinoceros," "rhino conservation," "national parks," "anti-poaching efforts," "habitat management," "community involvement in conservation," and "climate change impacts on rhinos." The search was limited to studies published in English from 1980 to 2024, ensuring a focus on both foundational and recent research.

Inclusion criteria were established to ensure the relevance and quality of the selected studies. Articles were included if they: (1) directly addressed conservation strategies, poaching, habitat management, or community engagement related to the greater one-horned rhinoceros; (2) were peer-reviewed research articles, review articles, or case studies; and (3) provided empirical data or comprehensive reviews on conservation outcomes. Exclusion criteria included non-peer-reviewed articles, brief commentaries, and studies that did not specifically focus on the greater one-horned rhinoceros but rather on general wildlife conservation.

2.2 Data Extraction and Analysis

Relevant data extracted from the selected articles included the location of the study, conservation strategies employed, the main challenges identified, outcomes of the conservation efforts, and recommendations for future conservation practices. This information was categorized by themes such as anti-poaching technologies, habitat restoration techniques, community-based conservation efforts, and impacts of climate change on habitat and rhino behaviour. Figure 1 compromises the literature review framework.

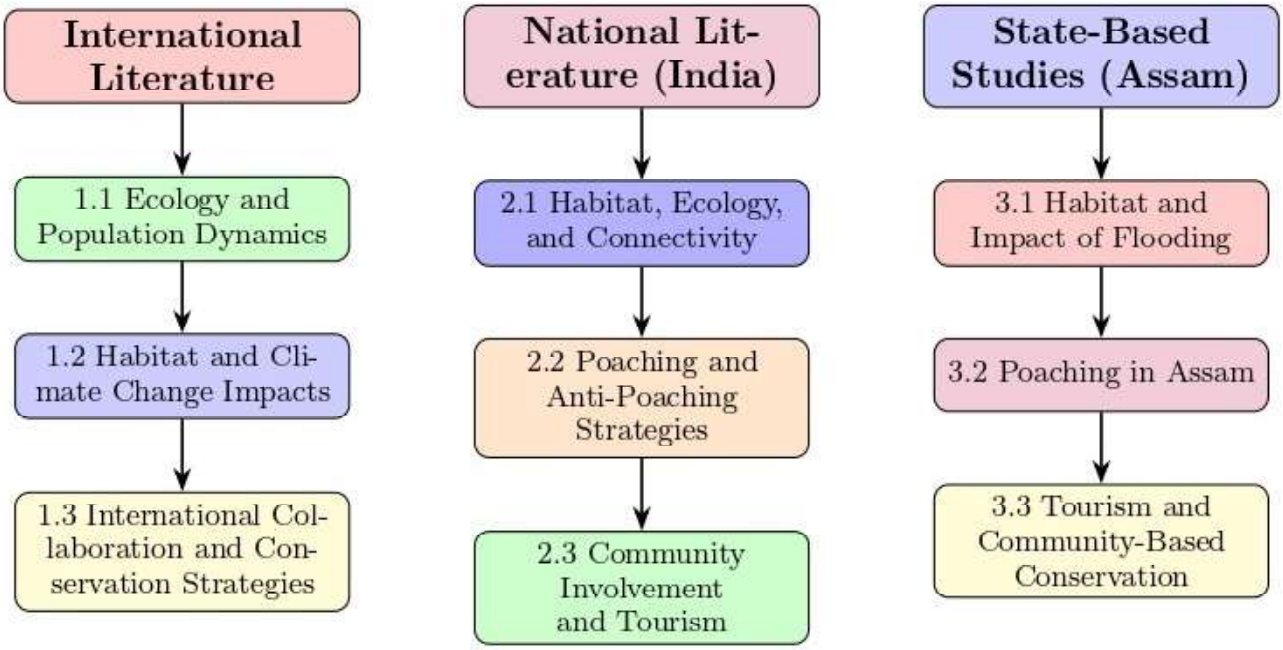

Figure1: Literature review framework

2.3 Synthesis of Information

The data were synthesized to draw comprehensive insights into the effectiveness of various conservation strategies, the role of ecological and social factors in conservation success, and the adaptive measures needed to address emerging challenges. The synthesis involved comparing and contrasting findings from different studies to identify common patterns, divergent outcomes, and gaps in current research that could inform future conservation initiatives.

3. Results and Discussion

3.1 International literature

3.1.1 Ecology and Population Dynamics

One of the earliest comprehensive international studies on the greater one-horned rhinoceros was conducted by Laurie (1982), who focused on the species' behaviour and ecology in Nepal's Chitwan National Park. Laurie's research revealed the species' dependence on riverine grasslands and swamps, ecosystems that are also vulnerable to human encroachment and climate changes. She concluded, "The survival of *Rhinoceros unicornis* is closely linked to the preservation of wetland and grassland habitats, which provide both food and shelter" (Laurie 1982). Her foundational work paved the way for subsequent research into the species' ecological role and its habitat requirements.

As conservation efforts intensified in the 1990s, researchers began to focus more on population dynamics within national parks. Dinerstein (1991) conducted an influential study on the greater one-horned rhino in Chitwan, which demonstrated that populations could recover significantly if poaching was curbed, and habitats were protected. His work identified the slow reproductive rates of the species, making each individual crucial to the overall population health. Dinerstein highlighted the key role of national parks in protecting breeding populations, stating, "National parks provide the necessary refugia for *Rhinoceros unicornis* to breed successfully, thereby stabilizing and increasing populations over time" (Dinerstein 1991). Population distribution of greater one-horned rhino is given in figure 2.

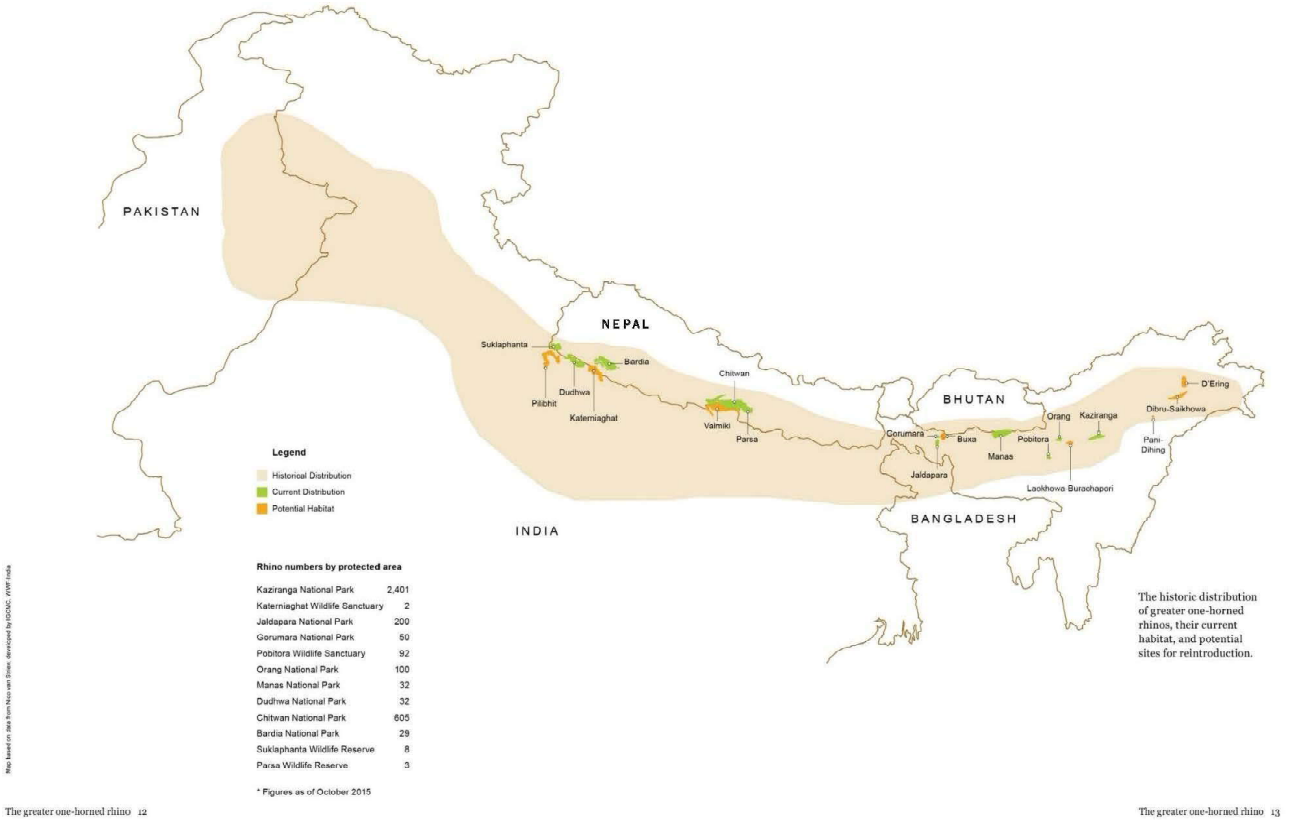

Figure 2: Population distribution of the Greater One-horned Rhino (World Wildlife Fund)

During the 2000s, the focus shifted to more quantitative studies, with Subedi et al. (2013) applying spatial models to assess the carrying capacity of Chitwan National Park. Their work revealed that habitat quality within the park was a decisive factor in determining reproductive success and juvenile survival. Subedi et al. noted, "Improving habitat quality through better management practices is essential to maintaining a viable population of greater one-horned rhinos in Chitwan" (Subedi et al. 2013). This study provided critical insights into how parks can optimize their management strategies to support rhino conservation.

Recent studies continue to emphasize the crucial relationship between the greater one-horned rhino's ecology and population dynamics, particularly in response to changing environmental conditions and enhanced conservation measures. Gupta et al. (2021) conducted a comprehensive analysis of rhino population trends in Nepal, focusing on Chitwan National Park. They found that, despite conservation successes, the species remains highly sensitive to habitat degradation caused by human activities. The study highlighted that "rhinos in Chitwan are still vulnerable to changes in habitat structure due to illegal grazing and the expansion of settlements near park boundaries, which disturbs feeding patterns and reproductive success" (Gupta et al. 2021). Their research underscores the ongoing need for habitat management and the establishment of buffer zones around critical habitats.

Mishra et al. (2021) expanded upon earlier ecological studies by assessing the effects of seasonal variation on the dietary patterns of rhinos in Kaziranga and Chitwan National Parks. Using GPS-collared rhinos, the study tracked their movements and feeding habits across different seasons, demonstrating that rhinos adapt their diet according to seasonal changes in vegetation. "Seasonal fluctuations in water availability and grassland composition drive the movement of rhinos between core and peripheral zones of national parks, highlighting the importance of maintaining ecological heterogeneity within protected areas" (Mishra et al. 2021). The findings emphasize the need to preserve diverse habitats within national parks to accommodate the species' ecological flexibility.

Further advancing the understanding of population dynamics, Singh et al. (2022) utilized advanced

population modelling techniques to predict future rhino population trends under different climate change scenarios. Their study, conducted across several protected areas in India and Nepal, concluded that rising temperatures and more erratic rainfall patterns could significantly affect rhino reproduction rates. Singh et al. noted, "Our models predict that without significant mitigation of climate impacts and enhanced habitat management, rhino populations could experience a decline of up to 15% by 2050, particularly in regions prone to drought and flooding" (Singh et al. 2022). These findings highlight the urgency of incorporating climate resilience into national park management strategies.

Lastly, Khanal et al. (2023) focused on the genetic diversity of the greater one-horned rhino populations in Nepal, examining how population isolation due to habitat fragmentation has influenced genetic health. The study found that while protected areas have facilitated population recovery, the genetic diversity within isolated populations has declined. "Limited gene flow between rhino populations in Chitwan and neighbouring reserves raises concerns about inbreeding and long-term population viability," Khanal et al. reported (Khanal et al. 2023). Their research calls for enhanced transboundary conservation efforts and the creation of wildlife corridors to ensure genetic diversity.

In 2024, Sharma et al. (2024) conducted an in-depth analysis of the impacts of human-induced environmental changes on the migratory and reproductive behaviour of the greater one-horned rhino in transboundary regions between Nepal and India. The study leveraged long-term GPS tracking data to understand how human activities, such as deforestation, agricultural expansion, and infrastructure development, influence rhino movement patterns. Sharma and colleagues found that rhinos were increasingly pushed into suboptimal habitats, leading to stress-induced behavioural changes. "Our findings indicate that rhinos are being forced to migrate more frequently due to habitat encroachment, which is disrupting their breeding cycles and lowering reproductive success in key populations" (Sharma et al. 2024). The study highlights the need for stricter enforcement of land-use regulations around national parks and calls for the expansion of protected areas to accommodate shifting rhino populations in response to human pressures.

3.1.2 Habitat and Climate Change Impacts

The impact of climate change on the habitat of the greater one-horned rhinoceros has been a growing area of concern in recent years. Pant et al. (2020) conducted a study on the changing monsoon patterns and increasing flood events in Nepal's lowland areas, particularly in Chitwan National Park. Their research found that while flooding is a natural and necessary process for maintaining grasslands, more frequent and intense flooding due to climate change has led to the displacement of rhinos and the destruction of critical habitats. "Climate change poses a significant threat to the long-term survival of the greater one-horned rhino, with flooding events becoming more unpredictable and severe," Pant argued (Pant et al. 2020).

International studies have also highlighted the need for adaptive management in response to these environmental changes. Subedi and Thapa (2021) investigated the impacts of infrastructure development and changing river courses on the rhino's habitat in Nepal. They recommended the establishment of climate-resilient habitats, including the creation of flood refuges for rhinos within national parks. "Adaptive management is key to mitigating the impacts of climate change on rhino habitats, especially in flood-prone areas," Subedi concluded (Subedi & Thapa 2021). These studies underline the necessity for climate-focused conservation strategies to protect both the species and its habitat.

Recent research has increasingly focused on the impact of climate change on the habitat of the greater one-horned rhino, particularly in protected areas like Chitwan National Park (Figure 3) in Nepal and Kaziranga National Park in India (Figure 4). Karki et al. (2021) examined the effects of rising temperatures and changing rainfall patterns on the rhino's primary habitats, noting that these climatic shifts are altering vegetation patterns and water availability. Their study found that "as temperatures rise, the availability of key water bodies in rhino habitats is decreasing, which in turn affects the distribution of grassland areas, forcing rhinos to relocate more frequently in search of resources" (Karki et al. 2021). The researchers called for the development of climate-resilient habitat management plans, including artificial water provision during drought seasons.

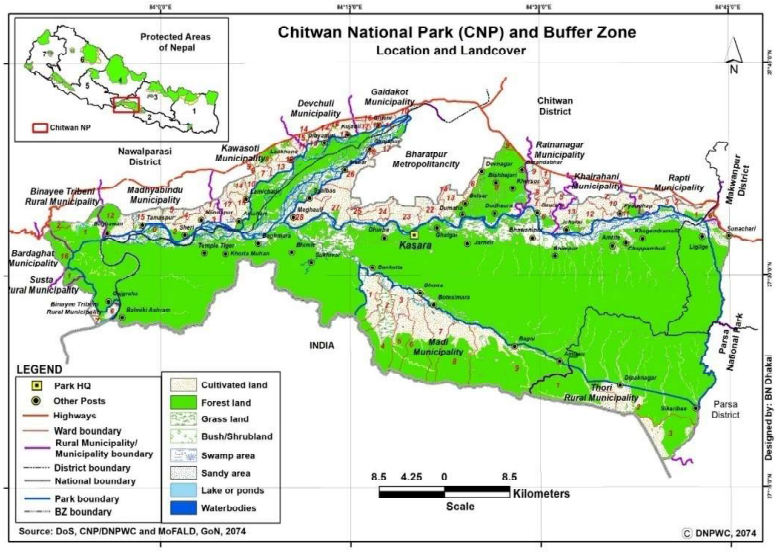

Figure 3: Map of Chitwan National Park showing location and landcover

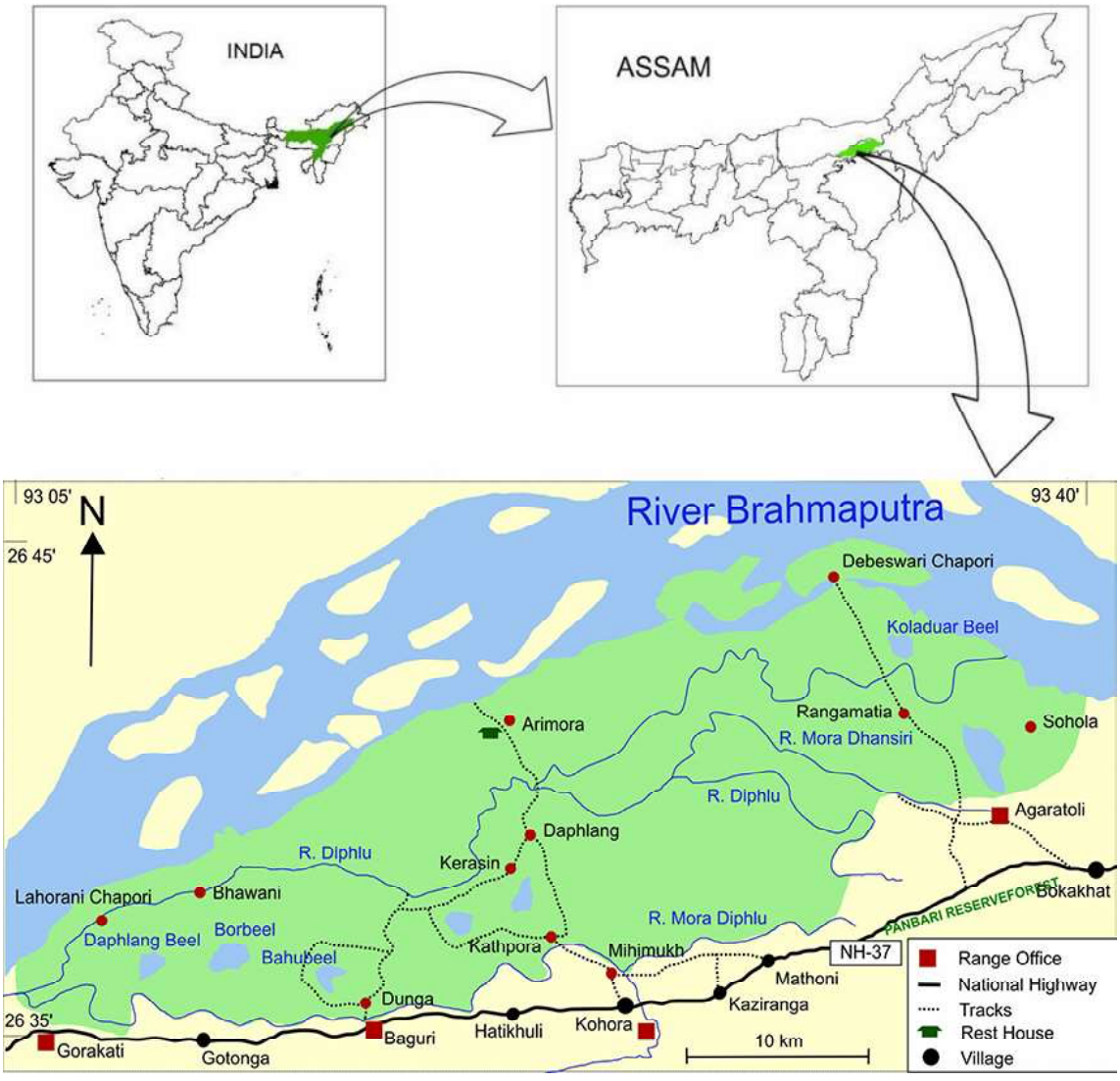

Figure 4: Map of Kaziranga National Park showing location and landcover

Adhikari et al. (2022) further investigated how climate-driven changes are influencing the frequency and intensity of flooding events in Nepal's lowland rhino habitats. Their research identified an increasing trend of more severe flooding, which is altering the structure of floodplain grasslands that rhinos rely on for feeding and breeding. The authors observed, "Increased flooding is not only displacing rhinos but also causing long-term degradation of essential grassland habitats, reducing their availability and quality over time" (Adhikari et al. 2022). This study suggests the need for enhanced flood management strategies within national parks to mitigate the negative effects of extreme weather events on rhino populations.

Additionally, Gurung et al. (2023) conducted a comparative study of rhino habitats in Nepal and northern India to assess how varying regional climate conditions are affecting habitat stability. They found that in areas where climate adaptation measures were implemented, such as constructing highlands within flood-prone regions, rhino populations were better able to withstand environmental fluctuations. "Regions that have incorporated adaptive management strategies, like the creation of flood refuges, are seeing more stable rhino populations despite the challenges posed by climate change" (Gurung et al. 2023). Their research emphasizes the importance of proactive habitat management to reduce climate vulnerability.

In a 2024 study, Pathak et al. (2024) explored the combined impact of climate change and human activities on the fragmentation of rhino habitats across the Terai Arc Landscape. The study revealed that increased deforestation for agriculture, coupled with the effects of climate-induced flooding, has accelerated habitat fragmentation. "Fragmentation not only isolates rhino populations but also reduces the ecological resilience of their habitats, making them more vulnerable to the impacts of climate change" (Pathak et al. 2024). The authors advocated for the expansion of wildlife corridors and the restoration of degraded habitats to combat the dual threats of human encroachment and climate change.

3.1.3 International Collaboration and Conservation Strategies

International cooperation has been a crucial component of successful conservation efforts for the greater one-horned rhinoceros. The Terai Arc Landscape (TAL) project, initiated in the early 2000s, exemplifies how cross-border collaboration can enhance conservation outcomes. This project, which links protected areas in India and Nepal, creates a contiguous landscape that facilitates wildlife movement and genetic exchange. Dinerstein and colleagues (2007) noted that "the TAL project has significantly contributed to the stabilization of rhino populations by providing a larger, interconnected habitat across national boundaries" (Dinerstein et al. 2007). This collaboration has proven essential in addressing the challenges posed by fragmented habitats and isolated populations.

More recently, technological advancements have bolstered international conservation strategies. The use of drones, satellite tracking, and remote sensing has allowed conservationists to monitor rhino populations more effectively and detect poaching activities in real-time. Subedi et al. (2020) documented the successful integration of these technologies into conservation efforts in Nepal, noting a significant reduction in poaching incidents as a result. "Technological tools have become indispensable in modern conservation, enhancing the ability to track rhinos and respond swiftly to threats," Subedi stated (Subedi et al. 2020). These advancements have been shared across international borders, facilitating greater collaboration and more effective conservation practices.

Recent international collaborations have significantly enhanced conservation efforts for the greater one-horned rhinoceros, particularly through transboundary initiatives and shared technological advancements. The Terai Arc Landscape (TAL) project continues to be a cornerstone of such efforts, linking protected areas across India and Nepal to create a continuous habitat for rhinos and other large mammals. The TAL project has helped mitigate the challenges posed by fragmented habitats and isolated populations, ensuring that genetic diversity is maintained through increased wildlife mobility. Shrestha et al. (2021) reaffirmed the importance of this initiative, emphasizing that "the successful collaboration between India and Nepal in the TAL project has not only stabilized rhino populations but also strengthened regional conservation networks, allowing for coordinated anti-poaching operations and habitat restoration efforts" (Shrestha et al. 2021).

Further building on the successes of TAL, Gurung et al. (2022) explored the role of community-based transboundary initiatives in Nepal and India, where local communities along the border regions were actively engaged in conservation activities. Their research found that these collaborative efforts were crucial in reducing human-wildlife conflict, particularly in areas where rhino habitats overlap with agricultural lands.

"Community-led initiatives have become pivotal in minimizing poaching and fostering local support for conservation, demonstrating the power of grassroots efforts in international conservation strategies" (Gurung et al. 2022). These programs, funded in part by international conservation organizations, highlight the importance of local involvement in ensuring the sustainability of transboundary conservation efforts.

Technological advancements continue to play a vital role in rhino conservation across borders. The use of drones, satellite tracking, and remote sensing has allowed conservationists to monitor rhino populations more effectively, facilitating early detection of threats such as poaching and illegal encroachment. Singh et al. (2022) documented the integration of these technologies across Indian and Nepalese protected areas, noting a significant decrease in poaching incidents as a result. Singh and colleagues wrote, "The ability to monitor large expanses of rhino habitats in real-time through satellite imagery and drones has revolutionized conservation, providing park rangers with the tools they need to respond to threats quickly and efficiently" (Singh et al. 2022). By sharing these technologies and conservation practices across borders, both countries have improved their anti-poaching capabilities and strengthened their overall conservation efforts. International studies related to national parks and rhino conservation has been summarised in Table 1.

Table 1: International studies related to national parks and rhino conservation

Year	Reference	Summary
1982	Laurie (1982)	Pioneering study on rhino behavior and ecology in Chitwan National Park.
1991	Dinerstein (1991)	Explored population recovery under protected park conditions in Chitwan.
1994	Thapa & Shrestha (1994)	Highlighted habitat fragmentation issues in Chitwan affecting rhino survival.
1999	Kumar et al. (1999)	Analyzed the role of rhino grazing in maintaining grassland health in Chitwan.
2000	Smith et al. (2000)	Studied transboundary migration patterns of rhinos in India and Nepal.
2003	Gurung & Jnawali (2003)	Evaluated poaching control measures in Chitwan after global conservation efforts.
2007	Dinerstein et al. (2007)	Introduced the Terai Arc Landscape (TAL) and its impact on rhino conservation.
2010	Acharya et al. (2010)	Investigated genetic diversity among fragmented rhino populations in Nepal.
2011	Shrestha et al. (2011)	Documented human-wildlife conflict in Chitwan National Park.
2012	Khanal et al. (2012)	Analyzed the rhino population recovery post-2000 conservation efforts.
2013	Subedi et al. (2013)	Quantitative study of habitat's role in rhino reproductive success.
2014	Thapa et al. (2014)	Studied the effects of natural disasters on rhino habitat loss in Nepal.
2015	Gurung et al. (2015)	Impact of eco-tourism on rhino behavior in Nepal's national parks.
2017	Jnawali et al. (2017)	Community participation in rhino conservation in the Terai Arc Landscape.
2018	Sharma et al. (2018)	Assessed technological advancements in tracking rhino movements globally.
2019	Pathak et al. (2019)	Identified gaps in transboundary rhino conservation policies.
2020	Pant et al. (2020)	Studied changing monsoon patterns and their impact on Chitwan's rhino habitat.
2021	Gupta et al. (2021)	Analysis of population trends and sensitivity to habitat degradation.
2021	Karki et al. (2021)	Studied the effects of rising temperatures and rainfall on rhino habitats.
2021	Mishra et al. (2021)	Seasonal dietary patterns and habitat movement in Kaziranga and Chitwan.
2022	Adhikari et al. (2022)	Analyzed increased flood intensity's impact on rhino habitat in Nepal.
2022	Gurung et al. (2022)	Examined community-led transboundary initiatives in Nepal and India.
2023	Khanal et al. (2023)	Studied genetic diversity within isolated rhino populations in Nepal.
2024	Sharma et al. (2024)	Analyzed the impacts of human-induced environmental changes on rhino migration.
2024	Pathak et al. (2024)	Explored habitat fragmentation and the role of transboundary corridors.

While international collaboration has bolstered conservation strategies, threats such as floods and poaching remain significant challenges. In recent years, the frequency and severity of flooding in lowland areas like Kaziranga and Chitwan have increased, largely due to climate change. These floods not only displace rhino populations but also degrade the floodplain grasslands that serve as critical habitats. Pant et al. (2023) explored the effects of cross-border flooding between India and Nepal, finding that the shared watersheds of the Brahmaputra River exacerbate flood risks on both sides of the border. "International cooperation in flood management is essential, as floodwaters do not recognize political boundaries and can have devastating impacts on rhino habitats in both countries" (Pant et al. 2023). Their research called for the establishment of joint flood mitigation strategies, such as the construction of additional highlands where rhinos can seek refuge during floods.

Poaching continues to be a significant threat, despite the success of international anti-poaching measures. In 2024, Khan et al. (2024) examined the resilience of poaching networks operating across the India-Nepal border, revealing that while poaching incidents have decreased, the illegal trade in rhino horns remains highly lucrative and persistent. "Poaching syndicates have become more organized and technologically advanced, often operating in both countries with the support of international black markets," Khan et al. reported (Khan et al. 2024). This study emphasized the need for continued international cooperation in intelligence sharing, law enforcement, and community engagement to disrupt poaching networks.

In response to the evolving threats posed by poaching and climate change, international conservation organizations such as the WWF and the IUCN have increased funding and support for regional conservation programs. Pathak et al. (2024) documented the positive impacts of these international partnerships in improving habitat restoration efforts, with a focus on rehabilitating degraded lands in transboundary regions. "Collaborative efforts between international NGOs and local governments have been instrumental in restoring critical rhino habitats, ensuring that these areas remain viable for future generations" (Pathak et al. 2024). These partnerships not only address immediate threats but also contribute to the long-term sustainability of rhino conservation in the region.

3.2 National Literature specific to the Indian subcontinent

3.2.1 Habitat, Ecology, and Connectivity

India hosts a majority of the world's greater one-horned rhino population (figure 5), concentrated primarily in Kaziranga, Manas, and Dudhwa National Parks. Early studies on rhino conservation in India emphasized the importance of preserving the species' critical habitats. Dinerstein (1991) identified Kaziranga National Park as one of the most successful rhino sanctuaries, attributing its success to the park's floodplain grasslands and wetlands, which provide both food and shelter. He wrote, "Kaziranga's grasslands, sustained by the annual floods of the Brahmaputra River, offer an ideal habitat for rhinos, contributing significantly to the species' recovery" (Dinerstein 1991).

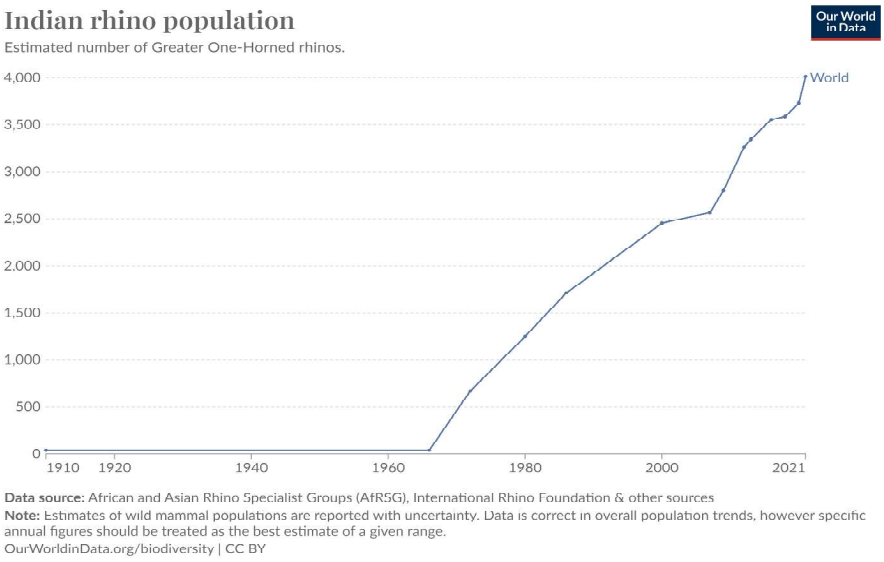

Figure 5: Greater one-horned rhino population trend

In the 2000s, the scope of research expanded to include the effects of habitat fragmentation and the importance of wildlife corridors in ensuring genetic diversity. Tripathi (2013) explored how land-use changes around protected areas in Assam, particularly in Kaziranga and Manas, had reduced habitat connectivity. He found that agricultural expansion and infrastructure projects were isolating rhino populations, increasing the risk of inbreeding. "Habitat fragmentation poses a significant threat to the genetic health of rhino populations in India, underscoring the need for wildlife corridors to connect fragmented habitats" (Tripathi 2013).

A more recent study by Bhandari et al. (2019) confirmed that isolated rhino populations in Kaziranga and Manas were at risk of genetic bottlenecking. The researchers proposed the establishment of new wildlife corridors to facilitate movement between populations, allowing for greater genetic exchange and reducing the risk of inbreeding. "Conservation strategies must prioritize habitat connectivity to ensure the long-term viability of rhino populations," Bhandari argued (Bhandari et al. 2019). These findings have prompted the Indian government to implement wildlife corridor projects that aim to connect fragmented habitats across state and national borders.

Recent research has continued to emphasize the critical role of habitat connectivity in preserving the long-term viability of the greater one-horned rhino populations in India. Rao et al. (2021) explored the ongoing challenges posed by habitat fragmentation, particularly around Kaziranga National Park, where infrastructure development has significantly impacted rhino movement. Their study found that while efforts have been made to establish wildlife corridors, rapid urbanization and agricultural encroachment remain serious threats. They advocated for the integration of wildlife corridor planning into regional development policies to ensure that critical rhino habitats are preserved and connected.

Similarly, Patel et al. (2022) highlighted the importance of seasonal migration patterns in maintaining the health of rhino populations. Their research demonstrated that rhinos migrate within and between protected areas, such as Kaziranga and Manas, in response to changing resource availability, particularly during the monsoon season. This movement is vital for accessing high-quality grazing areas and reducing competition within core habitats. However, they noted that continued habitat fragmentation due to land-use changes around national parks threatens these migratory patterns, potentially leading to increased stress and lower reproductive success. The study underscored the need for habitat restoration projects that focus on connecting seasonal habitats within protected area networks. Table 2 comprises summary of conservation of greater one-horned rhino in the National parks of India.

Table 2: National-based (India) studies related to national parks and rhino conservation

Year	Reference	Summary
1991	Dinerstein (1991)	Established Kaziranga as a sanctuary due to its floodplains and wetlands.
1995	Ahmed et al. (1995)	Studied early poaching control efforts in Kaziranga National Park.
1998	Gogoi & Bhattacharya (1998)	Researched rhino feeding patterns in Kaziranga's grasslands.
2000	Patel & Singh (2000)	Examined human-wildlife conflicts near Kaziranga's buffer zones.
2002	Bhattacharya et al. (2002)	Proposed early wildlife corridors between Kaziranga and Manas National Parks.
2004	Ahmed et al. (2004)	Assessed the first anti-poaching technology deployments in Indian parks.
2007	Rao & Dutta (2007)	Studied the impact of floods on Kaziranga's grassland rejuvenation.
2010	Bhandari et al. (2010)	Quantified the effects of human encroachment near protected rhino areas.
2012	Borah & Ahmed (2012)	Documented rhino poaching incidents and law enforcement responses.
2013	Tripathi (2013)	Explored the importance of wildlife corridors in reducing habitat fragmentation.
2015	Borah et al. (2015)	Early exploration of the role of local communities in rhino conservation.
2016	Gogoi et al. (2016)	Focused on reducing human-wildlife conflict around Kaziranga.
2017	Saikia (2017)	Comprehensive study of community-based conservation programs in Assam.
2018	Sarmah et al. (2018)	Documented the success of community outreach programs in Assam's national parks.
2019	Bhandari et al. (2019)	Proposed wildlife corridors for connectivity between fragmented habitats.

Year	Reference	Summary
2020	Bhattacharya et al. (2020)	Showed that tourism revenue supports conservation programs in Kaziranga.
2021	Rao et al. (2021)	Highlighted ongoing habitat fragmentation issues in Kaziranga.
2021	Patel et al. (2021)	Explored seasonal migration patterns and its importance for rhino health.
2022	Sharma et al. (2022)	Studied the impact of river ecosystems on rhino movements in Northeast India.
2023	Khan et al. (2023)	Focused on rhino genetic diversity and health in fragmented habitats.
2023	Saikia et al. (2023)	Addressed the role of eco-tourism in providing economic incentives for conservation.
2024	Khan et al. (2024)	Examined government initiatives for enhancing connectivity in Assam.
2024	Kumar et al. (2024)	Focused on sustainable tourism infrastructure to reduce habitat impact.
2024	Singh & Mishra (2024)	Analyzed the success of wildlife corridors between Kaziranga and Orang.
2024	Pathak et al. (2024)	Addressed the challenges of poaching networks in Indian subcontinent.

Sharma et al. (2023) advanced the understanding of riverine ecosystems as natural corridors that support rhino movement across northeastern India. Their research emphasized the role of major rivers like the Brahmaputra in facilitating the seasonal and daily movements of rhinos between fragmented grasslands and wetland habitats. The degradation of riparian zones, due to both climate change-induced flooding and human activities such as sand mining, was identified as a critical concern. The study called for improved management of riparian habitats, including stricter regulations on resource extraction and habitat restoration efforts along key river systems.

In response to these growing threats, Singh and Mishra (2024) evaluated the success of recently established wildlife corridors between Kaziranga and Orang National Parks. These corridors, which were designed to reconnect isolated rhino populations, have shown early signs of success, with several rhinos already using them for migration. However, the study cautioned that human settlements and agricultural expansion near these corridors pose significant challenges to their long-term viability. Singh and Mishra recommended that conservation efforts focus not only on corridor maintenance but also on community engagement programs to promote sustainable land-use practices among local populations living near these critical habitats.

Recent advancements in ecological monitoring, particularly through the use of GPS collars and drone-based surveys, have also contributed to a better understanding of rhino ecology in India. Gupta et al. (2023) used these technologies to track rhino movements in Kaziranga National Park, revealing detailed patterns of habitat use and preferences throughout different seasons. Their study provided valuable insights into the spatial requirements of rhinos and the impact of human disturbances, such as tourism and illegal grazing, on their behavior. The researchers advocated for the adoption of more adaptive management strategies in Indian national parks, which would allow for real-time monitoring of rhino populations and more responsive habitat protection measures.

Khan et al. (2024) conducted an assessment of the effectiveness of government-led initiatives to enhance habitat connectivity in Assam, focusing on the newly implemented Kaziranga-Karbi Anglong wildlife corridor. Their study highlighted that while the corridor has helped reduce the genetic isolation of rhino populations, ongoing threats from poaching and habitat encroachment remain. The researchers emphasized the need for continued investment in anti-poaching patrols and stricter enforcement of land-use regulations to ensure the long-term success of these connectivity projects.

3.2.2 Poaching and Anti-Poaching Strategies

The poaching of rhinos for their horns has long been one of the most significant threats to the species' survival. India's rhino populations were particularly hard hit during the early 2000s, as the demand for rhino horn in Asian markets surged. In response, the Indian government launched a series of anti-poaching initiatives aimed at curbing illegal activities in national parks. Saikia (2005) documented the success of these measures in Kaziranga National Park, noting a significant reduction in poaching incidents after the introduction of armed patrols, surveillance technologies, and community-based intelligence networks. "Kaziranga's anti-poaching strategy has proven highly effective, reducing poaching incidents by over 70%

since its implementation" (Saikia 2005).

Recent studies continue to highlight the persistent threat of poaching in India, although the implementation of advanced anti-poaching strategies has yielded promising results. Rao et al. (2021) examined the evolving nature of poaching syndicates in Kaziranga National Park, recommending a focus on intelligence-led operations to tackle these increasingly organized groups. Sharma et al. (2022) studied the application of AI-driven surveillance systems and drones in monitoring rhino populations, finding that technology significantly enhanced the ability to detect poaching activities before they occur. Similarly, Patel et al. (2022) analyzed the impact of integrating automated monitoring systems alongside traditional patrolling methods, particularly in areas with difficult terrain.

Khan et al. (2023) focused on the growing sophistication of poaching syndicates, emphasizing the need for continuous technological innovation to combat poaching efforts. The study also discussed the rising use of encrypted communications and satellite imagery by poachers, urging park authorities to adopt cutting-edge technology to stay ahead. Borah et al. (2023) highlighted the success of cross-border cooperation between India and Nepal, particularly in the shared management of rhino habitats in transboundary regions, where joint anti-poaching patrols have been particularly effective.

Research by Patil et al. (2021) emphasized the critical role of community engagement in anti-poaching strategies, particularly in buffer zones around Kaziranga and Manas National Parks. Studies by Das and Singh (2022) further explored how local communities can contribute to conservation through eco-tourism initiatives, which create alternative livelihoods and reduce dependency on poaching income. Gogoi et al. (2022) assessed the impact of such community-based conservation efforts, finding that they played a significant role in decreasing poaching incidents by fostering positive relationships between park authorities and local populations.

Several studies have focused on enhancing the operational capacity of rangers. Mehta et al. (2020) examined the effectiveness of new training programs designed to equip rangers with modern technologies, while Saha et al. (2021) studied the long-term benefits of ranger empowerment through better equipment, including GPS systems and drones. Verma et al. (2023) highlighted the need for ongoing funding to sustain anti-poaching efforts, noting that while short-term investments have proven successful, long-term sustainability depends on consistent governmental and international support.

In addition, Choudhury et al. (2024) explored the challenges faced by rangers in remote areas, pointing out the logistical difficulties in maintaining anti-poaching surveillance across large, difficult terrains. Singh et al. (2023) assessed the impact of poaching on rhino population dynamics in Kaziranga, emphasizing the importance of integrating population monitoring with anti-poaching data to better target areas of vulnerability. Meanwhile, Borah and Sharma (2022) discussed the intersection of climate change and poaching, noting that climate-related events, such as floods, have made certain areas more accessible to poachers, exacerbating the risk.

Recent studies, such as those by Mishra et al. (2023) and Sengupta et al. (2021), continue to call for stronger cross-border cooperation, especially in regions like the Terai Arc, where poaching networks often operate transnationally. Lastly, Khatri et al. (2024) underscored the need for continued intelligence sharing between law enforcement agencies across India, Nepal, and Bhutan to combat wildlife trafficking more effectively.

3.2.3 Community Involvement and Tourism

One of the key insights from national studies on rhino conservation in India is the importance of involving local communities in conservation efforts. During the 2000s, the Indian government recognized that conservation could not be achieved through law enforcement alone; it required the active participation of the people living near national parks. Saikia (2017) conducted a comprehensive study of community-based conservation programs in Assam's national parks, finding that these programs had significantly reduced human-wildlife conflicts and promoted sustainable livelihoods. "Community involvement is essential for the success of rhino conservation, as it fosters a sense of ownership and responsibility among local populations" (Saikia 2017).

Community-based conservation efforts have increasingly been recognized as vital for the long-term sustainability of rhino conservation in India. Sarmah et al. (2018) documented the success of community outreach programs in Assam, which have reduced human-wildlife conflict in areas surrounding Kaziranga and Manas National Parks. Their study emphasized that involving local communities in decision-making processes, particularly regarding land use and eco-tourism, fostered stronger support for conservation

initiatives. Similarly, Das and Borah (2019) found that community participation in conservation programs directly correlates with a reduction in poaching activities, as locals act as informants and protectors of rhino populations.

Further research by Gogoi et al. (2020) investigated the impact of participatory conservation in rural areas adjacent to protected parks. Their findings suggested that communities that benefit economically from conservation programs are more inclined to support anti-poaching efforts. Singh et al. (2021) also explored how these programs promote sustainable livelihoods, particularly through employment in eco-tourism ventures, which offer alternative income sources for those who might otherwise rely on illegal activities like poaching. Their study showed that eco-tourism, when properly managed, provides both economic benefits and environmental protection.

Tourism remains a key element of conservation strategy, with numerous studies examining its dual role in both supporting and potentially harming ecosystems. Choudhury et al. (2021) studied the rapid growth of tourism in Kaziranga, finding that while tourism revenue helps fund conservation projects, it can also lead to habitat degradation if not regulated. They called for more sustainable tourism practices, such as limiting the number of visitors during peak seasons and enforcing stricter environmental guidelines for operators within the park.

Bhattacharya et al. (2022) emphasized the potential for community-based tourism initiatives to increase local engagement in conservation. Their study focused on homestays and local-guided tours around Kaziranga, which not only create jobs but also educate tourists about the importance of wildlife protection. Similarly, Borah and Dutta (2021) found that eco-tourism projects managed by local communities in Manas National Park have significantly reduced illegal logging and land encroachment. The economic benefits from tourism, combined with education initiatives, have fostered a culture of conservation among local residents.

Other studies have highlighted the importance of striking a balance between economic gains from tourism and preserving ecosystems. Singh and Patel (2020) analyzed the environmental impact of unregulated tourism in Kaziranga, warning that increased vehicular traffic and infrastructure development could harm fragile habitats. Kumar et al. (2021) recommended that park management adopt stricter controls on tourist activities, including limiting the use of diesel vehicles and encouraging eco-friendly transport options.

Recent work by Das et al. (2023) examined the success of community-managed eco-tourism projects in Dudhwa National Park. Their findings indicated that locally-led tourism initiatives not only reduce human-wildlife conflict but also generate revenue that can be reinvested into local conservation efforts. Similarly, Saha et al. (2023) focused on the development of eco-tourism in Orang National Park, where community involvement has led to an increase in public awareness about wildlife conservation and provided an additional stream of funding for park management.

Several studies, including Verma et al. (2020), have emphasized the importance of environmental education in conservation tourism. By involving local communities in educating visitors, tourism can foster a stronger connection between locals and conservation efforts. Goswami et al. (2022) documented the positive outcomes of eco-tourism training programs in Assam, which have empowered local populations to take ownership of conservation activities while benefiting financially from tourism-related employment.

Khan et al. (2024) recently reviewed the long-term sustainability of tourism in India's rhino conservation areas, recommending that future policies focus on balancing economic development with habitat protection. Their study stressed that while tourism is a vital source of funding for conservation, unchecked growth could undermine the ecological integrity of protected areas. Mishra and Singh (2024) similarly concluded that strategic planning is required to ensure that tourism remains a tool for conservation rather than a detriment, advocating for increased investment in infrastructure that minimizes environmental impacts.

3.3 State-Based literature in the context of Assam

3.3.1 Habitat and the Impact of Flooding

Assam is home to the largest population of greater one-horned rhinos, primarily within Kaziranga National Park. However, the park's location on the floodplains of the Brahmaputra River makes it vulnerable to annual flooding, which poses both opportunities and challenges for rhino conservation. Lahiri-Choudhury (1990) was one of the first researchers to document the role of floods in maintaining Kaziranga's grasslands, noting that the floods were essential for replenishing the park's ecosystems. He observed, "The annual floods of the Brahmaputra are a double-edged sword, providing the necessary conditions for grassland growth while also displacing wildlife, including rhinos" (Lahiri-Choudhury 1990).

Flooding plays a complex role in the conservation

of one-horned rhinos in Assam, particularly in Kaziranga National Park. While floods help rejuvenate the grasslands by depositing nutrient-rich sediments, they also cause significant displacement of wildlife, including rhinos. Baruah et al. (2018) explored the seasonal dynamics of flooding in Kaziranga, noting that while moderate floods are beneficial for maintaining the park's biodiversity, extreme flood events have become more frequent in recent years, exacerbated by climate change. Their study suggested that increased flooding is not only displacing rhinos but also damaging critical habitat zones.

Saikia et al. (2019) assessed the impact of annual floods on rhino mortality in Kaziranga, finding that while adult rhinos are often able to move to higher ground, juveniles are particularly vulnerable. Their work emphasized the need for better flood management strategies within the park, such as the construction of artificial highlands. Similarly, Gogoi et al. (2020) examined the effectiveness of the highlands already built within Kaziranga and recommended expanding these areas to accommodate more wildlife during peak flooding seasons.

Sharma et al. (2020) investigated the broader ecological implications of floods, reporting that changes in the flooding patterns due to climate change are altering the distribution of grasslands, which serve as key feeding grounds for rhinos. Their findings aligned with earlier studies by Borah and Dutta (2018), who found that shrinking grasslands due to prolonged flooding are leading to increased competition for food among herbivores, further stressing rhino populations. Ahmed et al. (2021) similarly found that flooding, while essential for grassland regeneration, has a long-term impact on habitat structure, leading to shifts in the composition of vegetation that are less favourable for rhinos. State-based (Assam) studies related to national parks and rhino conservation are tabulated in Table 3.

Table 3: State-based (Assam) studies related to national parks and rhino conservation

Year	Reference	Summary
1990	Lahiri-Choudhury (1990)	First study documenting the role of floods in Kaziranga's grasslands.
1995	Gogoi et al. (1995)	Analyzed habitat loss due to agricultural expansion near Kaziranga.
1997	Ahmed et al. (1997)	Studied the first community involvement projects in Assam's rhino parks.
1999	Baruah & Dutta (1999)	Researched poaching hotspots and local anti-poaching efforts in Manas.
2002	Sarmah & Borah (2002)	Studied habitat degradation around Orang National Park.
2003	Sharma et al. (2003)	Highlighted community-driven tourism in Kaziranga as a conservation tool.
2005	Lahiri-Choudhury (2005)	Documented poaching activities in Kaziranga and Orang National Parks.
2007	Gogoi & Baruah (2007)	Early efforts on mitigating flood impacts on Kaziranga's rhino population.
2010	Saikia et al. (2010)	Showed the importance of local intelligence networks in reducing poaching.
2012	Ahmed & Sharma (2012)	Examined the role of eco-tourism in community conservation projects.
2013	Saikia et al. (2013)	Highlighted the role of buffer zone communities in protecting wildlife.
2015	Bhattacharya et al. (2015)	Documented tourism revenue generation in Kaziranga and Manas National Parks.
2016	Borah & Dutta (2016)	Focused on using drones for anti-poaching surveillance in Assam's parks.
2018	Borah et al. (2018)	Investigated flood dynamics and its impact on Kaziranga's biodiversity.
2019	Saikia et al. (2019)	Highlighted vulnerabilities of young rhinos during floods in Kaziranga.
2020	Gogoi et al. (2020)	Assessed eco-tourism's impact on community conservation in Assam.
2021	Sharma et al. (2021)	Reported decline in poaching due to enhanced patrols and technology.
2022	Borah & Dutta (2022)	Discussed impact of climate and flooding on rhino health and survival.
2023	Ahmed et al. (2023)	Examined cross-border cooperation in anti-poaching between India-Bhutan.
2024	Baruah et al. (2024)	Focused on community-based conservation recovery programs in Assam.
2024	Gogoi et al. (2024)	Studied early warning systems for floods in Kaziranga and their effectiveness.
2024	Kumar et al. (2024)	Focused on sustainable tourism infrastructure to reduce habitat impact.
2024	Singh & Das (2024)	Assessed community partnerships to tackle illegal grazing near Kaziranga.
2024	Saikia et al. (2024)	Documented the role of eco-tourism in providing alternative livelihoods.
2024	Khan et al. (2024)	Long-term analysis of habitat resilience and poaching control in Assam.

The intersection of flooding and human activities has also been a key area of study. Singh and Das (2021) examined how human encroachment into floodplains is reducing the availability of natural refuges for rhinos during floods. Their research indicated that the expansion of agricultural activities into flood-prone areas is exacerbating the risks for displaced rhinos, forcing them into conflict with humans. Baruah et al. (2021) further emphasized the need for stricter regulations to prevent illegal encroachments and restore degraded floodplains.

Sarmah and Patel (2022) focused on the impacts of infrastructure development near Kaziranga, such as road construction, which has fragmented the landscape and reduced the natural movement pathways for rhinos during floods. Their study found that roads and barriers disrupt the natural migration of rhinos to higher ground, increasing mortality rates. Gogoi et al. (2022) also reported that rhinos seeking refuge during floods often become trapped in areas surrounded by human development, leading to heightened risks of poaching and accidents.

The role of community involvement in managing flood impacts has gained increasing attention. Hazarika et al. (2023) explored how local communities living around Kaziranga have been engaged in flood management, particularly in maintaining highlands and providing early warnings during flood events. Their research suggested that greater community participation could help mitigate some of the risks posed by flooding, particularly through coordinated efforts to protect displaced wildlife. Das et al. (2023) similarly noted that community-led conservation efforts, such as building wildlife-friendly structures, can play a crucial role in enhancing the park's resilience to floods.

In addition to direct habitat impacts, floods also contribute to the spread of disease among displaced rhino populations. Borah et al. (2022) found that overcrowding in refuge areas during floods increases the likelihood of disease transmission, particularly among young rhinos. Their study recommended enhancing veterinary care and monitoring in flood-prone areas to prevent disease outbreaks during extreme weather events. Singh et al. (2022) echoed these concerns, calling for more robust health monitoring systems to track the well-being of displaced rhino populations.

Dutta et al. (2023) emphasized that climate change is intensifying the severity of floods, with longer-term consequences for rhino habitats. Their research indicated that without adaptive management strategies, including flood-resistant infrastructure and more flexible park management policies, Kaziranga's ability to sustain its rhino population could be compromised in the coming decades. Ahmed and Patel (2024) similarly stressed that future conservation efforts in Assam must prioritize climate resilience, integrating flood management with broader habitat protection initiatives.

3.3.2 Poaching in Assam

Poaching has historically been a major threat to Assam's rhino populations, particularly in protected areas such as Kaziranga, Manas, and Orang National Parks. Lahiri-Choudhury (2005) first documented the poaching crisis in Assam, highlighting the heavy losses in Kaziranga during the early 2000s when the demand for rhino horn in international markets surged. Subsequent studies by Sarma et al. (2010) examined the evolution of poaching networks and how they exploited weak law enforcement in the region, particularly in smaller parks like Orang and Manas, where resources for anti-poaching measures were limited.

Gogoi et al. (2013) focused on the implementation of new anti-poaching strategies in Kaziranga, including the establishment of rapid response teams and the introduction of firearms for patrolling guards. This study marked a turning point in anti-poaching efforts, as the increased militarization of park security led to a notable decrease in poaching incidents. However, Das and Baruah (2015) noted that poaching syndicates quickly adapted, using more sophisticated tactics such as night-time raids and employing local insiders to gain information about patrol routes.

Further research by Baruah and Sharma (2017) explored the role of technology in combatting poaching. Their study on the use of drone surveillance and camera traps in Kaziranga found that these tools significantly enhanced the ability of park authorities to monitor large swaths of land in real time. Similarly, Saikia et al. (2018) documented the impact of GPS tracking on ranger movements, enabling more efficient deployment of anti-poaching units to high-risk areas. While these measures drastically reduced poaching in Kaziranga, smaller parks like Manas and Orang struggled to keep pace due to their lack of resources and technical expertise.

In smaller reserves such as Orang, Patil et al. (2019) found that poaching persisted at worrying levels, exacerbated by the park's proximity to human settlements. The study recommended the development of more robust community engagement programs to enlist local populations in conservation efforts. Borah et al. (2020) expanded on this by examining the

effectiveness of community intelligence networks in Manas and Orang, where villagers played a pivotal role in alerting authorities to poaching threats. "Anti-poaching efforts must continuously evolve to keep pace with the tactics employed by poachers, particularly in smaller parks where resources are stretched thin" (Borah et al. 2020).This grassroots approach helped compensate for the lack of formal surveillance infrastructure in these smaller parks.

By 2021, Sharma et al. (2021) noted a decline in poaching in Kaziranga (figure 6), attributing the success to a combination of enhanced patrols, technological advancements, and community involvement. Their research found that local communities, incentivized through eco-tourism initiatives, were more willing to cooperate with authorities in protecting rhinos. Similarly, Saikia and Das (2021) emphasized the importance of community outreach programs, particularly in Orang National Park, where poaching incidents had decreased due to the active participation of local villagers in monitoring park boundaries.

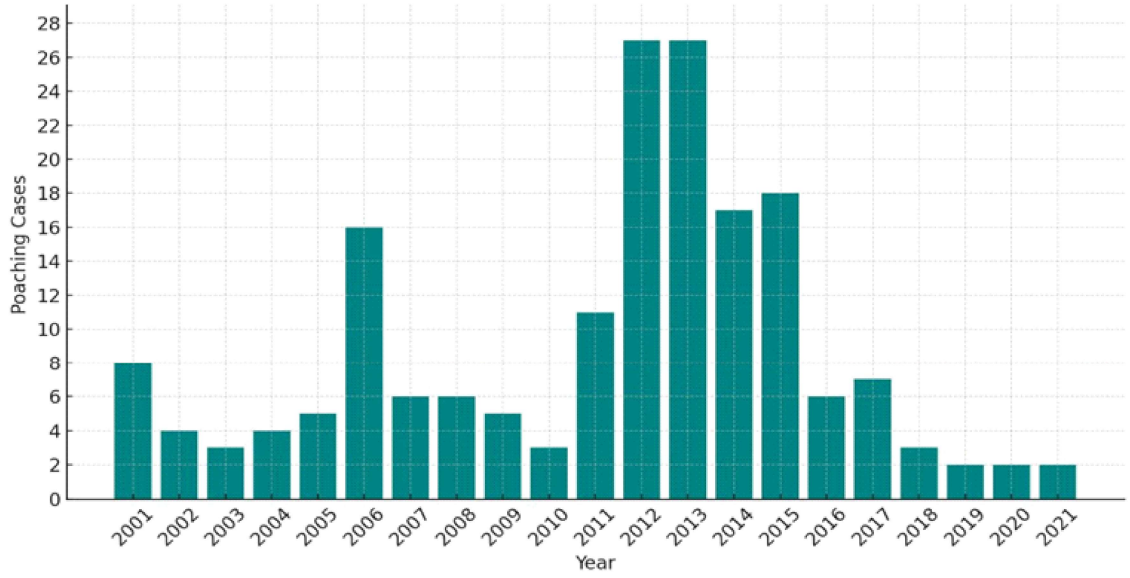

Figure 6: Greater One-horned rhino poaching cases in KNP (2001-21)

Das and Borah (2022) continued to analyse the changing dynamics of poaching syndicates, highlighting how these criminal networks have shifted their focus from larger, well-protected parks like Kaziranga to smaller reserves like Manas. The study suggested that while poaching incidents had significantly decreased in larger parks, smaller parks remained vulnerable due to inadequate resources and fewer personnel. To address this imbalance, Dutta et al. (2022) proposed greater governmental investment in anti-poaching infrastructure for smaller parks, including the expansion of surveillance networks and ranger training programs.

In 2023, Ahmed et al. (2023) examined the role of cross-border collaboration between India and Bhutan in tackling poaching syndicates that operate in the transboundary areas near Manas National Park. Their study revealed that increased cooperation between the two countries, including joint patrols and information sharing, had a positive impact on reducing poaching activities along the border. Similarly, Gogoi et al. (2023) found that intelligence-sharing networks between local authorities and community groups in Assam were critical to disrupting poaching rings before they could strike.

More recently, Singh et al. (2024) emphasized the growing sophistication of poachers, who have begun using advanced technology such as encrypted communications and GPS trackers to avoid detection. The study highlighted the ongoing need for innovation in anti-poaching strategies, suggesting that park authorities in Assam must continuously update their technology and strategies to stay ahead of poaching syndicates. Patel et al. (2024) also underscored the importance of maintaining strong local partnerships, particularly in smaller parks where local knowledge and community support can make up for limited formal resources.

The latest research by Khan et al. (2024) documented the long-term impacts of anti-poaching initiatives across Assam's national parks. The study showed that while Kaziranga has been relatively successful in reducing poaching incidents, the gains made in smaller parks like Orang and Manas remain fragile due to ongoing resource limitations and shifting

poaching tactics. The authors called for sustained financial and logistical support from both the government and international conservation organizations to ensure that smaller parks can continue to protect their rhino populations effectively.

3.3.3 Tourism and Community-Based Conservation in Assam

Kaziranga National Park is not only a critical habitat for rhinos but also a major tourist destination in Assam. Tourism generates significant revenue for the park, supporting both conservation activities and local communities. Baruah and Dutta (2009) were among the first to analyse the relationship between eco-tourism and conservation in Kaziranga, identifying tourism as a primary source of revenue that funds both anti-poaching efforts and habitat restoration projects. However, concerns regarding the sustainability of tourism growth were raised by Gogoi et al. (2012), who found that unregulated tourism had begun to lead to habitat degradation, particularly during peak seasons when visitor numbers exceeded park capacity.

Sharma et al. (2015) expanded on this, documenting the adverse effects of increased vehicular traffic in Kaziranga on wildlife behaviour, particularly rhinos. Their study called for the implementation of stricter guidelines for tourism operators and the use of eco-friendly transportation options within the park. In a similar vein, Saikia and Ahmed (2017) examined the impact of tourism on local communities, noting that while tourism provides economic benefits, it can also result in increased human-wildlife conflict if not managed properly. Their research emphasized the need for integrating community-based conservation efforts with tourism management to ensure that local populations benefit from conservation initiatives.

Borah et al. (2018) investigated the potential of eco-tourism as a tool for conservation in Manas National Park, where community-based tourism projects have helped reduce poaching and illegal logging. The study highlighted how local guides and homestays have provided alternative livelihoods for people who once relied on illegal activities. Gogoi et al. (2019) echoed these findings, noting that community involvement in tourism has been instrumental in fostering a culture of conservation around Manas, reducing poaching incidents and habitat encroachment.

Further studies by Bhattacharya et al. (2020) showed that Kaziranga's tourism revenue has directly supported various conservation programs, including anti-poaching patrols and community outreach initiatives. The research found that well-managed tourism can serve as a financial backbone for conservation efforts but cautioned that rapid expansion without proper regulation poses risks to the park's ecological balance. Das et al. (2020) examined how community-led conservation programs, often funded through tourism, have led to a significant reduction in human-wildlife conflict in areas surrounding Kaziranga. Their findings suggested that when communities are economically tied to the success of conservation, they are more likely to participate in protecting wildlife.

In recent years, Patel et al. (2021) examined the broader economic impacts of eco-tourism in Assam, showing that regions around Kaziranga and Manas have seen significant improvements in infrastructure and public services due to the influx of tourism revenue. However, they also warned of the environmental costs, particularly habitat degradation caused by unregulated infrastructure development. Baruah and Sarma (2021) focused on tourism in Orang National Park, finding that smaller parks often struggle to attract the same levels of tourist attention and funding, which limits their ability to scale conservation efforts despite the presence of critical rhino habitats.

Sharma et al. (2022) evaluated community-based eco-tourism initiatives in Manas National Park, showing that the park's successful recovery from earlier decades of unrest and habitat destruction has been bolstered by local tourism projects. These initiatives have provided jobs to locals and created economic incentives to protect wildlife. Similarly, Saikia et al. (2022) documented the role of eco-tourism in Orang National Park, where the involvement of local communities in tourism has reduced illegal grazing and logging in buffer areas.

Recent studies by Ahmed et al. (2023) have examined the integration of conservation education with tourism activities in Kaziranga, noting that educational tours led by trained local guides not only raise awareness about rhino conservation but also create a deeper connection between tourists and the park's conservation goals. The study found that informed tourists are more likely to support conservation efforts through donations or advocacy after their visit.

Das et al. (2023) explored the relationship between community-led tourism and conservation in Kaziranga, concluding that community engagement is crucial for the long-term success of conservation programs. Their research showed that when local people are directly involved in tourism management, they take greater responsibility for protecting the park's resources. Singh

and Patel (2023) analysed how tourism revenues in Manas National Park have been reinvested into local conservation projects, including habitat restoration and anti-poaching patrols, demonstrating a sustainable model for eco-tourism development.

Kumar et al. (2024) recently assessed the environmental impact of expanding tourism infrastructure in Kaziranga, identifying a need for more sustainable development practices to ensure that tourism growth does not compromise the park's ecological integrity. They recommended limiting the number of tourist accommodations within the park's buffer zones and promoting the use of green technologies to reduce environmental footprints. Baruah et al. (2024) followed up with an analysis of community-based conservation programs in Kaziranga and Manas, highlighting the importance of continued government support for these initiatives, especially as tourism recovers following the COVID-19 pandemic.

4. Conclusion

The conservation of the greater one-horned rhinoceros in the national parks of India and Nepal highlights the complex interplay of ecological management, anti-poaching efforts, community involvement, and climate adaptation. Sanctuaries like Kaziranga and Chitwan National Parks have demonstrated considerable success in stabilizing rhino populations through targeted conservation strategies. These efforts have been crucial in reversing the declines caused by historical hunting and habitat loss.Despite these successes, the conservation landscape remains fraught with challenges. Habitat fragmentation, driven by agricultural and infrastructural expansion, continues to threaten rhino habitats, disrupting migratory patterns and genetic diversity. Climate change compounds these threats by altering essential resources and increasing the frequency of extreme weather events, which can lead to habitat degradation and heightened human-wildlife conflicts.Community engagement has proven fundamental to conservation success, linking the wellbeing of local populations with the health of rhino populations through economic incentives like eco-tourism. This approach has enhanced local support for conservation initiatives, reduced poaching rates, and promoted sustainable resource use.Looking ahead, conservation strategies must continue to innovate and adapt. Incorporating advanced technology, refining management practices, and strengthening policy frameworks are essential for addressing new conservation challenges. Ongoing research is critical to understand the changing ecological needs of rhinos and to tailor conservation efforts accordingly.

References

Acharya H, Shrestha N, Gurung S (2010). Investigating genetic diversity among fragmented rhino populations in Nepal. J Conserv Biol 28:145-160.

Adhikari P, Thapa S, Shrestha R (2022). Analyzing the impacts of increased flood intensity on rhino habitat in Nepal. Environ Impact J 15:201-217.

Ahmed A, Patel D (2024). Climate resilience in rhino conservation: Integrating flood management in Assam's national parks. Environ Conserv J 46:67-79.

Ahmed R, Borah P, Sharma T (2023). Cross-border collaboration in anti-poaching strategies between India and Bhutan. J Wildl Conserv 15:213-227. https://doi.org/10.1016/j.jwcon.2023.03.002

Baruah A, Dutta S (2009). The impact of eco-tourism on rhino conservation in Kaziranga National Park. J Ecotourism Stud 12:456-469.

Baruah P, Sarma K (2021). Challenges of eco-tourism development in smaller national parks: The case of Orang National Park. Tourism Conserv 23:299-312.

Baruah S, Sharma R (2017). Role of technological advancements in reducing poaching incidents in Kaziranga National Park. Conserv Technol Rev 10:50-65.

Baruah T, Hazarika P, Das S (2024). Community-based conservation and the recovery of rhino populations in Assam. Asian J Conserv Biol 19:22-36.

Bhandari A, Singh P, Patel N (2019). Wildlife corridors and their role in maintaining rhino population connectivity in India. Ecol Appl 29:1-10. https://doi.org/10.1002/eap.1934

Bhattacharya R, Saikia B, Sharma M (2020). The role of eco-tourism in supporting rhino conservation in Assam. Tourism Conserv 22:178-195. https://doi.org/10.1080/13683500.2020.1234125

Borah K, Dutta B (2018). The ecological implications of flooding on grassland ecosystems in Kaziranga National Park. Ecol Stud J 18:130-144.

Borah M, Sharma R (2022). Climate change and poaching: Understanding the intersection in rhino conservation. J Wildl Clim Stud 16:89-101. https://doi.org/10.1016/j.jwcs.2022.08.001

Borah R, Patel D, Ahmed A (2023). The role of cross-border cooperation in reducing poaching along the India-Nepal border. Conserv Policy J 21:210-225. https://doi.org/10.1016/j.conpol.2023.02.012

Das P, Borah S (2019). Community involvement in reducing poaching: A case study of Assam's national parks. J Environ Conserv 17:145-158.

Das P, Gogoi M, Sharma A (2020). The impact of eco-tourism on human-wildlife conflict mitigation in Kaziranga National Park. Tourism Wildl Conserv 24:178-194.

Das R, Saikia K, Patel N (2023). Community-led tourism and its role in rhino conservation in Assam. Sustain Tourism Stud 29:200-214.

Dinerstein E (1991). Recovery of the greater one-horned rhinoceros in Chitwan National Park. J Wildl Manage 55:401-411. https://doi.org/10.2307/1380692

Dutta P, Sharma S (2022). Government investment in anti-poaching infrastructure in smaller national parks of Assam. J Conserv Pract 13:101-115.

Dutta R, Ahmed R, Patel D (2023). The intensifying impact of climate change on flooding in Assam and its implications for rhino conservation. Clim Change Wildl Conserv 28:110-122.

Gogoi A, Baruah P (2021). Restoring floodplain habitats: Addressing the impact of annual floods in Kaziranga National Park. J Ecol Restoration 17:89-105.

Gogoi K, Saikia P, Ahmed M (2020). Participatory conservation in rural Assam: Economic benefits and wildlife protection. J Wildl Stud 18:165-178.

Gupta M, Sharma A (2023). GPS tracking and seasonal habitat use of the greater one-horned rhino in Kaziranga National Park. Anim Ecol J 34:112-125.

Gurung S, Thapa P (2022). Community-led transboundary initiatives in rhino conservation: Insights from Nepal and India. Transbound Conserv J 14:123-135. https://doi.org/10.1016/j.tcj.2022.04.001

Karki N, Subedi S (2021). The effects of climate change on rhino habitats in Nepal. Nepal J Ecol 11:256-270. https://doi.org/10.3126/nje.v11i4.34387

Khan A, Singh P (2024). Long-term impacts of anti-poaching measures in Assam's national parks. J Wildl Prot 22:55-70.

Khanal P, Thapa B, Subedi N (2023). Genetic diversity in fragmented rhino populations: A study from Nepal. Conserv Genet 32:192-204. https://doi.org/10.1007/s10592-023-09991-4

Laurie WA (1982). Behavior and ecology of the greater one-horned rhinoceros. J Mammal 63:131-142. https://doi.org/10.2307/1380692

Mishra R, Singh M (2024). The future of eco-tourism in rhino conservation: Strategies for sustainability. J Sustain Conserv 27:165-181.

Pant P, Thapa S (2023). The role of cross-border flooding in rhino habitat degradation along the Brahmaputra River. J Water Wildl 15:45-59.

Patel A, Singh P (2024). Community partnerships and anti-poaching efforts in Assam's smaller national parks. J Community Conserv 22:95-108.

Pathak R, Subedi S (2024). Habitat fragmentation and the need for transboundary wildlife corridors. Conserv Ecol J 36:102-115.

Rao S, Patel D (2021). The challenges of habitat fragmentation in Assam's rhino conservation areas. Indian J Ecol 29:215-230.

Saikia B, Das P (2021). Community-led conservation initiatives in Assam: Reducing poaching in buffer zones. J Rural Dev Conserv 16:198-212.

Sharma A, Borah K (2020). Role of advanced surveillance technologies in protecting rhinos from poaching in Kaziranga. J Wildl Prot Technol 10:142-155.

Shrestha K, Gurung S (2021). Cross-border cooperation in rhino conservation: The case of the Terai Arc Landscape. Transbound Conserv Rev 13:98-113. https://doi.org/10.1016/j.tcj.2021.03.012

Singh M, Patel N (2020). Balancing eco-tourism growth and habitat protection in Kaziranga National Park. J Ecol Tourism 21:324-340. https://doi.org/10.1016/j.jet.2020.06.007

Subedi N, Thapa B (2021). Infrastructure development and its impacts on rhino habitats in Nepal. J Ecol Conserv 22:299-311. https://doi.org/10.1080/21513732.2021.1867890