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Protecting the Greater One-Horned Rhinoceros: The Role of Workforce Capacity, Legal Enforcement, and Patrolling in Protected Areas

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Abstract

This study examines the relationship between anti-poaching management strategies and wild greater one-horned rhinoceros population outcomes in Assam, India. Drawing on archival data from the Assam Forest Department, the study assesses whether key anti-poaching measures, including frontline staffing levels, personnel salary expenditures, poacher arrests, and patrolling efforts, are associated with changes in wild rhino populations. The findings reveal that frontline staffing levels and salary expenditures are significantly associated with rhinoceros population recovery, suggesting that investments in human resources may strengthen deterrence, field monitoring, and habitat protection. Legal enforcement, measured by the number of poachers arrested, also demonstrates a statistically significant association with rhinoceros population outcomes, highlighting the importance of effective law enforcement in anti-poaching strategies. In contrast, patrolling effort alone was not a statistically significant predictor of rhinoceros population changes, suggesting that patrol effectiveness may depend on complementary measures, such as adequate staffing, consistent law enforcement, and systematic monitoring. Overall, the findings highlight the importance of institutional capacity and coordinated enforcement strategies in rhinoceros conservation. The study offers practical policy implications for prioritizing investments in frontline personnel, strengthening enforcement capacity, and improving monitoring systems to support long-term rhinoceros population recovery.

Keywords: anti-poaching, rhinoceros population, workforce capacity, legal enforcement, patrolling, protected areas, national park

1. Introduction

The greater one-horned rhino (*Rhinoceros unicornis* Linnaeus, 1758) is a megaherbivore classified as Vulnerable (Ellis & Talukdar, 2019), with an estimated 4,075 mature individuals remaining in the wild (Save the Rhino, 2026). The species faces multiple threats, including habitat loss (A. Medhi & Saha, 2014; Sarma et al., 2009), human–wildlife conflict (S. Medhi & Saikia, 2025), poaching (Gogoi & Gogoi, 2022; United Nations Office on Drugs and Crime, 2022), and climate change (D. K. Dutta et al., 2021; Hira, 2022; Thukral et al., 2025). In the late 1800s and early 1900s, the decline in alluvial plains grasslands for agricultural development led to an increase in sport hunting for wild rhinos. Wild rhinos are illegally hunted mainly for their horns, and occasionally for their tails and nails to be used in Traditional Asian Medicine (Ellis & Talukdar, 2019). In Taiwanese, Vietnamese, and Chinese markets, Asian rhino horn is traditionally referred to as “fire horn,” whereas African rhino horn is known as “water horn.” These distinctions reflect cultural associations and the perceived status associated with rhino horn in these markets (Ellis & Talukdar, 2019; Gogoi & Gogoi, 2022). Rhino horn has also commanded exceptionally high prices on illegal markets, with reported values ranging from US$97,000 to US$400,000 per kilogram (Dang Vu & Nielsen, 2018; Haas & Ferreira, 2016).

Two major strongholds of greater one-horned rhino populations occur in the floodplains of Chitwan National Park in Nepal and Kaziranga National Park in India (Subedi et al., 2017). India and Nepal have been major sources of illegally harvested rhino horn, with China identified as a destination market and Myanmar serving as a transit route for smuggling (United Nations Office of Drug and Crime, 2022). According to the Asian Rhino

Specialist Group, cross-border trafficking through Myanmar has become a primary route for moving rhino horn from Assam to Kachin State in Myanmar, Yunnan Province in China, and other Southeast Asian countries, including Vietnam (Gogoi & Gogoi, 2022). This trafficking has contributed to significant declines in several important wild rhino populations, particularly in Chitwan and Bardia National Parks in Nepal and Manas National Park and Laokhowa Wildlife Sanctuary in India. Nevertheless, government-led conservation policies and targeted protection measures in India and Nepal have contributed to the preservation of remaining greater one-horned rhinoceros populations. These efforts have been associated with declining poaching incidents across several protected areas, although Laokhowa Wildlife Sanctuary in India has been identified as a notable exception (Ellis & Talukdar, 2019).

Illegal wildlife trafficking remains a significant threat to the conservation of the greater one-horned rhinoceros. According to the Asian Rhino Specialist Group, cross-border trafficking routes extend from Assam, India, through Kachin State in Myanmar to Yunnan Province in China and other Southeast Asian markets, including Vietnam (Gogoi & Gogoi, 2022). Poaching and illegal wildlife trade have contributed to substantial declines in several important rhinoceros populations, particularly those in Chitwan and Bardiya National Parks in Nepal and Manas National Park and Laokhowa Wildlife Sanctuary in India. In response, local governments in India and Nepal have implemented conservation policies and anti-poaching measures to protect remaining rhinoceros populations. These efforts have contributed to reductions in poaching across several protected areas, although Laokhowa Wildlife Sanctuary in India remains a notable exception (Ellis & Talukdar, 2019).

Although greater one-horned rhino populations have shown increasing trends in India and Nepal (Ellis & Talukdar, 2019), global rhino horn seizures have also increased, highlighting the continued challenges posed by illegal trade (United Nations Office on Drugs and Crime, 2022). Rhino horns seizures make up 11.8% of the total seizures between 2014 to 2018, and there were 10 live rhinos and 970.5 kg of rhino horns were illegally seized in 2019 (United Nations Office of Drug and Crime, 2022). Between 2010 to 2020, 83 incidents of rhino horns estimated to be approximately 63 kg was seized and 43 suspects were arrested between 2018 to 2021 by the law enforcement authorities in India alone (CITES CoP19, 75, 2021). These seizures could have a devastating impact on wild rhino populations, and could cause broader crisis in biodiversity loss (Jhala et al., 2021; Subedi et al., 2017).

This study evaluates the effectiveness of long-term anti-poaching management practices by examining the relationships between workforce capacity, legal enforcement, patrolling effort, and wild greater one-horned rhino population outcomes in Assam, India. Workforce capacity reflects sustained institutional investment in frontline personnel, including staffing levels and salary expenditures, which support rhino protection, habitat monitoring, and community engagement (World Wildlife Fund for Nature, 2018; WWF-India, 2021). Legal enforcement captures the implementation of wildlife protection laws, including Sections 428 and 429 of the Indian Penal Code of 1860 and Section 51 of the Wildlife Protection Act of 1972, which establish legal penalties for offenses involving wildlife (Chandewar, 2024; WWF-India, 2021). Patrolling efforts refers to systematic field-based enforcement and monitoring activities aimed at detecting illegal activities, identifying poaching hotspots, documenting wildlife distribution and habitat use (Hoppe-Dominik et al., 2011; Hotte et al., 2016; Jachmann, 2008; Lotter & Clark, 2014; Moreto & Matusiak, 2017). Those three dimensions are operationalized using administrative indicators, including the number of frontline personnel, salary expenditures, poacher arrests, and patrolling effort. By examining these measures over time, the study assesses whether sustained investments in institutional capacity, legal enforcement, and field monitoring are associated with long-term changes in rhinoceros populations across Assam's national parks.

2. Poaching Vulnerability and Conservation Enforcement in Assam

Wild rhinos are particularly vulnerable to external threats, such as poaching, due to their slow life cycle (H. Y. Jhala et al., 2021; Subedi et al., 2017). Their reproduction and biology predisposes them to longevity estimates of 30 to 45 years, lengthy gestation length of approximately 16 months, longer median inter-calve interval of approximately 2.8 years, and higher age of sexual maturity estimates of 5 to 7 years for females and 8 to 10 years for males (Ellis & Talukdar, 2019; Laurie, 1982). Laurie (1982) also notes that some males are lost to male-to-male competition during mating.

The vulnerability of wild rhinoceros populations to poaching varies considerably depending on population size, poaching intensity, and the demographic characteristics of individuals targeted. Jhala et al. (2021) found that small populations of fewer than 10 individuals and medium-sized populations of 20 to 30 individuals were particularly vulnerable to poaching and unable to sustain continued losses. Even larger populations exceeding 50 individuals could withstand only low levels of poaching for a limited period before experiencing population

collapse. Moreover, sustained low-level poaching may pose a greater long-term extinction risk than intense but intermittent poaching events. Similarly, Subedi et al. (2017) demonstrated that persistent poaching at moderate levels can substantially increase the probability of rhinoceros population extinction. However, Jhala et al. (2021) suggested that populations of approximately 100 individuals may remain viable over the long term under low levels of poaching while maintaining high genetic heterozygosity, even without immigration from other populations. Beyond population size and poaching intensity, the demographic composition of poaching losses also influences population viability. Although poachers frequently target male rhinoceroses because of their larger horns, Subedi et al. (2017) found that the loss of reproductive females poses a greater threat to population persistence than the loss of males. Specifically, annual poaching losses exceeding 6 females and 12 males may result in negative population growth and heightened extinction risk, particularly when accompanied by declining habitat quality (Subedi et al., 2017).

Assam is recognized for its rich biodiversity and contains several national parks and UNESCO-designated protected areas (Government of Assam—Environment and Forest, 2025). Despite these conservation efforts, wildlife poaching remains a significant challenge. Assam's porous international border with Myanmar and its state border with Nagaland may facilitate opportunistic poaching and the movement of wildlife products (Gogoi & Gogoi, 2022; Talukdar, 2003). Gogoi and Gogoi (2022) report that poachers maintain clandestine camps in Dimapur, Nagaland, and along the riverbanks of the Brahmaputra River. The authors also indicate that river routes are widely used for travel and communication, potentially facilitating covert poaching activities. In Assam, the management of protected areas and the implementation of anti-poaching measures involve the Office of the Principal Chief Conservator of Forests (PCCF), the Head of Forest Force (HoFF), and the State Board for Wildlife. These institutions play roles in overseeing biodiversity conservation and supporting wildlife protection initiatives, including anti-poaching operations, within the framework of the Assam Project on Forest and Biodiversity Conservation (2018).

3. Data and Methods

Assam is in northeastern India, south of the eastern Himalayas, and encompasses the Brahmaputra and Barak River valleys. The state is recognized for its rich biodiversity, diverse flora and fauna, and extensive network of protected areas. Kaziranga, Manas, and Orang National Parks support important wild rhino populations and vary considerably in size, ranging from approximately 78.80 to 500 km² (Government of Assam—Environment and Forest, 2025).

Kaziranga, Manas, and Orang protected areas were first created under the British government. Kaziranga National Park was created as a reserve forest in 1905 under Lord Curzon, the Viceroy of India. Similarly, Manas National Parks were created as wildlife sanctuary in 1928, and Orang National Park was created as a game reserve in 1915 (Government of Assam--Environment and Forest, 2025; National Tiger Conservation Authority, 2025; Saikia, 2011). After independence, these protected areas became national parks and assigned special designations under the new Indian government--Table 1 summaries the park designations (Government of Assam--Environment and Forest, 2025; National Tiger Conservation Authority, 2025). In the mid to late-1980s, data collection on conservation actions such as workforce capacity, legal enforcement, patrolling efforts, and wildlife census gathering was formalized in terms of mandatory actions and record-keeping. This study heavily relies on administrative records logged by forest officers in the national parks and verified by the Principal Chief Conservator of Forests and Head of Forest Force (PCCF/HoFF), Assam. The dataset used records that include: (1) annual workforce numbers, (2) annual workforce salary expenditures, (3) the number of poachers arrested per year, (4) average kilometers patrolled per year, and (5) rhino census data covering the period from 1985 to 2020.

Table 1. Study sites and conservation designation timeline

Protected Area	National Park Size (sq. km)	National Park Designation	UNESCO Designation	Tiger Reserve Notification	Biosphere Reserve Notification	Megafauna
Kaziranga National Park	430	1974	1985	2007	NA	Rhino (*Rhinoceros unicornis)*
Manas National Park	500	1973	1985	2008	1989	
Rajiv Gandhi Orang National Park	78.80	1999	NA	2016	NA	

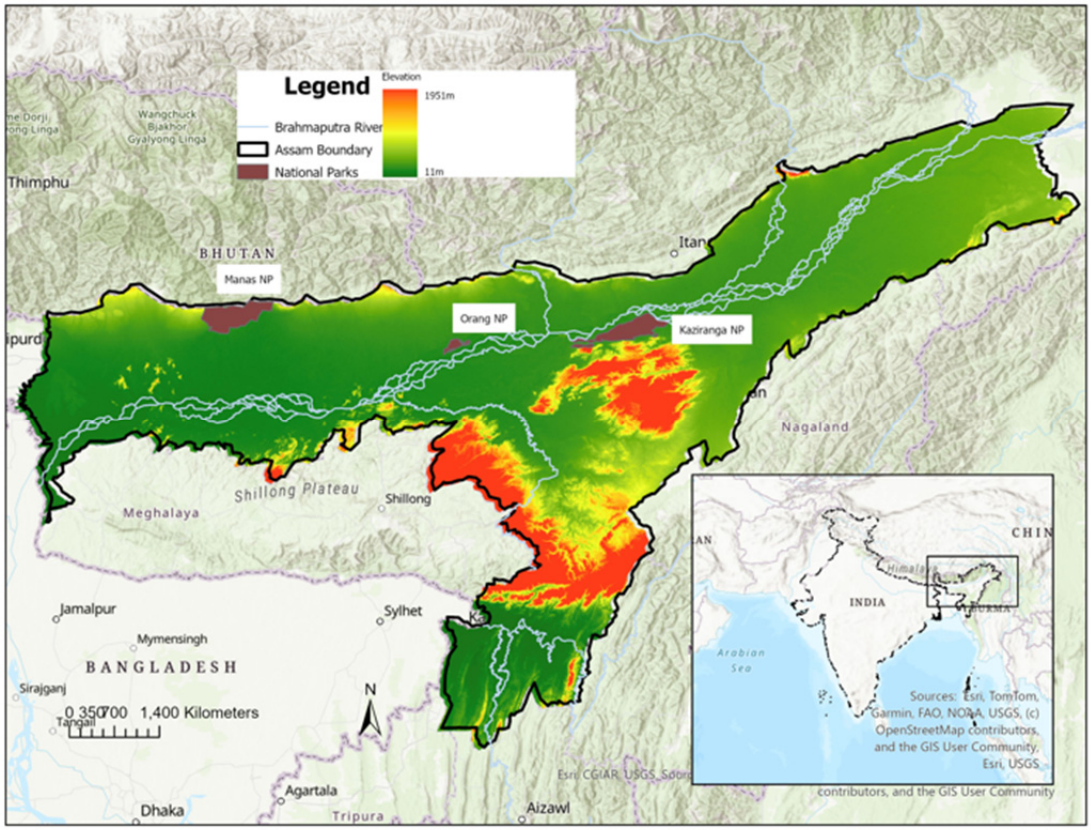


Figure 1. Locations of National Parks with Wild Greater One-Horned Rhinoceros Populations in Assam, India

For the empirical analysis, we developed a set of variables to examine the effects of workforce capacity, legal enforcement, and patrolling efforts on rhino population outcomes. These variables are defined as follows.

Table 2. Description of variables used in the analysis

Dimensions	Variables	Description
Dependent	Rhino population density	We calculated rhino population density by dividing the estimated number of rhinos by the area of each national park (km²). The resulting density values were then natural log-transformed for analysis.
Independent	Legal enforcement	Legal enforcement was measured as the annual number of poachers arrested in each national park. During the study period, India's wildlife protection framework included the Wildlife (Protection) Act of 1972 and relevant provisions of the Indian Penal Code of 1860. These laws established penalties for wildlife-related offenses, including fines and imprisonment, and provided a legal basis for enforcement against illegal hunting. Annual arrest counts were neither normalized by national park area nor natural log-transformed because the recorded values were predominantly zero and exhibited little variation.
	Patrolling efforts	Patrolling effort was measured as the average number of kilometers patrolled on foot per year. Patrolling is an important wildlife protection strategy intended to deter poaching and support wildlife law enforcement. In Assam's national parks, frontline forest staff conduct patrols during both daytime and nighttime. Although patrolling methods include boats, jeeps, elephant-back patrols, and foot patrols, this study focused exclusively on foot-patrolling distance in the regression models. Annual foot-patrolling distance was neither normalized by national park area nor natural log-transformed because the analysis focused on absolute patrolling effort rather than the proportion of each park's area covered by patrols. Differences in park area were accounted for in the regression models.
	Workforce capacity	• *Workforce Numbers:* Frontline staffing included Forest Guards, Game Watchers, Foresters I and II, and Ranger Officers I and II. We calculated frontline staff density by dividing the number of frontline staff by the area of each national park (km²). The resulting values were then natural log-transformed to account for differences in park size and standardize workforce measures relative to the area of each park. • *Workforce Salary:* Because salaries were uniform across frontline staff within each year, we estimated total annual frontline staff salary for each national park using a standardized calculation. First, we calculated the midpoint of the reported salary range for frontline staff. We then converted this amount from Indian rupees to U.S. dollars using the corresponding annual exchange rate. Next, we multiplied the midpoint salary in U.S. dollars by the number of frontline staff in each national park for each year to estimate total frontline staff salary. This measure was therefore proportional to the number of frontline staff employed. Finally, we applied a natural logarithmic transformation to the estimated total salary to reduce skewness in the data.
Control	Biosphere reserve	The reserve plays a critical role in protecting endangered species, maintaining ecological corridors, and supporting transboundary wildlife conservation with Bhutan. It also contributes to rhino reintroduction programs and habitat restoration
	UNESCO world heritage site (UNESCO)	Areas with outstanding natural beauty, geological formations, ecological processes, or habitats for endangered species
	Time	To account for year-specific variation across the study period from 1985 to 2020.

4. Results

To evaluate the conservation outcomes of long-term anti-poaching management practices, we examined the associations between workforce capacity, legal enforcement, patrolling effort, and changes in wild greater one-horned rhino populations. We used ordinary least squares (OLS) regression models implemented in R (R Core Team, 2022) to assess these relationships. Outliers were retained because observed population fluctuations may represent ecologically meaningful variation associated with environmental change, poaching pressure, or market demand. Missing values in rhino population density were addressed using group mean imputation (Tay, 2021). We assessed multicollinearity using the variance inflation factor (VIF), applying a threshold of 4; all models had VIF values below this threshold. We evaluated heteroscedasticity using the Breusch–Pagan test and found no evidence of heteroscedasticity in the models. Table 3 presents descriptive statistics for the variables included in the analysis, and Table 4 summarizes the results of the rhino population regression models.

Model 1 serves as the baseline specification and includes all control variables. In Models 2 through 5, the biosphere reserve and UNESCO designation variables were excluded to address multicollinearity concerns. In Models 6 and 7, the UNESCO variable was excluded, while in Model 8, the biosphere reserve variable was excluded for the same reason. Additionally, in Models 6 through 8, workforce capacity was disaggregated into two separate measures, workforce size and salary expenditures, to address multicollinearity. A model simultaneously including UNESCO designation, workforce salary expenditures, legal enforcement, and patrolling effort was not estimated because of multicollinearity concerns. Across the estimated models, UNESCO designation, biosphere reserve status, workforce size, salary expenditures, and legal enforcement were statistically significant predictors of rhinoceros population outcomes ($p < .001$). Time and patrolling effort were also statistically significant predictors, although at a slightly lower significance level ($p < .01$). These findings highlight the associations between institutional protection measures, workforce capacity, law enforcement, and long-term rhinoceros population outcomes.

Table 3. Descriptive statistics for variables used in the analysis

Variable	Number of Observations	Mean	SD	Max	Min
Legal enforcement	108	16.676	22.130	113.000	0.000
Rhino population	108	8.278	3.371	10.000	0.000
Patrolling	108	-0.254	0.848	0.749	-2.699
Workforce number	108	-0.201	0.136	0.075	-0.354
Workforce salary	108	-5.729	0.565	-4.611	-6.397

Table 4. Regression analysis of rhino population density

	Dependent variable:							
	Rhino Population Density (Log Transformed)							
	Control	Control + Workforce Capacity	Control + Workforce Capacity + Legal Enforcement	Control + Workforce Capacity + Patrolling Efforts	Control + Workforce Capacity + Legal Enforcement + Patrolling Efforts	Control + Workforce Numbers + Legal Enforcement + Patrolling Efforts	Control + Workforce Numbers + Legal Enforcement + Patrolling Efforts	Control + Workforce Salary + Legal Enforcement + Patrolling Efforts
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
UNESCO	0.633***						-1.432***	
	(0.055)						(0.105)	
Biosphere Reserve	-1.951***					-1.514***		-1.919***
	(0.055)					(0.062)		(0.070)
Time	-0.002	0.002	-0.003	0.003	-0.001	-0.002	-0.011**	-0.004
	(0.002)	(0.004)	(0.003)	(0.004)	(0.004)	(0.002)	(0.004)	(0.002)
Workforce Salary		1.349***	1.326***	1.392***	1.388***			-0.455***
		(0.088)	(0.082)	(0.105)	(0.097)			(0.056)
Workforce Numbers		7.459***	6.531***	7.591***	6.704***	1.625***	5.802***	
		(0.362)	(0.400)	(0.405)	(0.426)	(0.217)	(0.401)	
Legal Enforcement			0.009***		0.009***	0.003	0.008***	0.001
			(0.002)		(0.002)	(0.001)	(0.002)	(0.001)
Patrolling Efforts				-0.010	-0.015	-0.026**	-0.003	-0.023**
				(0.014)	(0.013)	(0.008)	(0.013)	(0.008)
Constant	3.239	4.815	14.151*	3.095	11.858	5.611	24.399**	5.265
	(4.291)	(7.063)	(6.905)	(7.452)	(7.171)	(4.761)	(7.256)	(4.629)
Observations	108	108	108	108	108	108	108	108
R^2	0.928	0.805	0.834	0.806	0.837	0.929	0.827	0.933
Adjusted R^2	0.926	0.800	0.828	0.799	0.829	0.925	0.818	0.930
Residual Std. Error	0.231 (df = 104)	0.379 (df = 104)	0.352 (df = 103)	0.380 (df = 103)	0.351 (df = 102)	0.232 (df = 102)	0.362 (df = 102)	0.225 (df = 102)
F Statistic	444.495*** (df = 3; 104)	143.421*** (df = 3; 104)	129.727*** (df = 4; 103)	107.231*** (df = 4; 103)	104.403*** (df = 5; 102)	266.398*** (df = 5; 102)	97.303*** (df = 5; 102)	283.362*** (df = 5; 102)

Note: *p<0.05, **p< 0.01, ***p<0.001

5. Discussion

The empirical results indicate that workforce capacity, measured by the number of frontline staff and total workforce salary, is significantly associated with wild rhino population outcomes. A sustained investment in

forest personnel can strengthen rhino protection by increasing field presence, improving habitat and population monitoring, and deterring illegal hunting. This finding is supported by Acharya et al. (2020), who found that increased forest staff presence may reduce rhino poaching and support population recovery. Similarly, Moore et al. (2018) found that increasing the number of rangers substantially reduced the likelihood of poaching-related threats in areas where such threats were present.

Furthermore, these findings indicate that workforce capacity serves as a direct conservation intervention, rather than merely an administrative resource. The presence forest staff can increase surveillance, discourage poachers, support rapid response to threats, and improve monitoring of rhino populations and habitats. However, consequences of insufficient workforce capacity in terms of salary support may be illustrated by Manas National Park, where the Assam Forest Department's withdrawal during the civil conflict from the mid-1980s to 2003 contributed to the local extinction of the greater one-horned rhino (A. Dutta, 2020). The conflict increased the availability of arms within the park, intensifying commercial rhino poaching, bushmeat hunting, and local encroachment, all of which undermined rhino conservation outcomes even in protected areas that are designated as UNESCO World Heritage Sites and Biosphere Reserve (Dudley et al., 2002; Sahoo et al., 2013).

Our analysis indicates that legal enforcement, measured by the number of poachers arrested, is predictive of wild rhino population outcomes. This finding suggests that enforcement actions may contribute to rhino protection by increasing the risks and consequences associated with poaching. Although rhino poaching has declined in recent years (Ellis & Talukdar, 2019), it has not been fully eliminated in Assam (Gogoi & Gogoi, 2022). For example, in Kaziranga National Park, reported cases show that poaching incidents declined from 89 rhinos poached and 22 poachers arrested during 2015–2016 to 12 rhinos poached and one poacher arrested during 2019–2020 (Gogoi & Gogoi, 2022). This decline suggests that legal enforcement, when combined with broader anti-poaching management, can strengthen deterrence and improve rhino protection outcomes.

India's legal framework provides an important institutional basis for these enforcement actions. During the study period, the Indian Penal Code of 1860 and the Wildlife (Protection) Act of 1972 provided the legal framework for penalizing wildlife-related offenses, including through fines and imprisonment. Such legal provisions support the prosecution of offenders and may help deter illegal hunting. Evidence from other contexts in India also suggests that stronger enforcement, including more frequent prosecutions, may be associated with measurable reductions in poaching incidents (Chandewar, 2024). However, legal enforcement alone may not be sufficient. Sustained rhino protection also requires investments in enforcement infrastructure, including anti-poaching camps, trained personnel, and stakeholder engagement with local communities (Gogoi & Gogoi, 2022; S. Medhi & Saikia, 2025). These findings indicate that legal enforcement is most effective when embedded within a broader conservation strategy that combines prosecution, field presence, and community-based support for rhino protection.

The empirical results further indicate that patrolling effort is a statistically significant predictor of wild rhinoceros population outcomes. However, this association does not necessarily imply that increased patrolling alone is sufficient to enhance rhinoceros protection. Rather, the effectiveness of patrol activities may depend on their strategic deployment, systematic monitoring, and coordination with broader law enforcement measures. In Assam's national parks, frontline forest personnel conduct foot patrols during both daytime and nighttime, typically in pairs and equipped with firearms, radios, compasses, and protective gear (Gogoi & Gogoi, 2022; WWF-India, 2021). Despite these efforts, Vigne and Martin (1994) observed that poachers were rarely apprehended within national parks, raising questions about the effectiveness of conventional foot patrols in detecting and preventing illegal activities.

The negative predictive effect of foot patrolling may also reflect the methods used in rhino poaching. While homemade traps such as snares are used in parts of South Asia, they are more commonly associated with small mammal poaching rather than rhino poaching in Assam (Gogoi & Gogoi, 2022; Sethi, 2022; Wong & Lemieux, 2021). In Assam, the primary methods of rhino poaching include shooting, pit poaching, electrocution, and poisoning (Gogoi & Gogoi, 2022). These methods may be difficult to detect through routine patrol presence alone, particularly when patrols are not guided by spatial intelligence on poaching risk.

For patrolling to achieve stronger conservation outcomes, patrol efforts should prioritize identifying poaching hotspots and concentrating enforcement resources in these high-risk areas (Hotte et al., 2016; Moreto & Matusiak, 2017). Expanding the use of GIS-based monitoring systems, such as M-STrIPES in every protected area, could improve the effectiveness of patrols by recording the location of poaching incidents, identifying recurring threat patterns, and supporting more targeted deployment of frontline staff (WCS Thailand, 2022). Therefore, while patrolling remains an important anti-poaching action, its contribution to rhino population

protection may depend less on the total distance covered by foot patrol, and more on the strategic use of spatial monitoring, intelligence-led enforcement with coordination from legal enforcement and workforce capacity.

The findings from Assam highlight the importance of workforce capacity, legal enforcement, and patrolling efforts in supporting greater one-horned rhino conservation. Rather than relying only on broad conservation strategies, effective rhino protection depends on sustained institutional capacity, adequate frontline personnel, and the consistent implementation of wildlife protection laws. These elements help translate conservation policy into practice by strengthening field-level protection, improving monitoring, and increasing accountability for poaching-related offenses. For rhino conservation more broadly, the Assam case suggests that long-term population recovery requires not only protected-area designation and policy commitments, but also the human and institutional capacity needed to implement conservation actions on the ground.

6. Conclusion

This study examined how workforce capacity, legal enforcement, and patrolling efforts are associated with greater one-horned rhino population outcomes across national parks in Assam, India. The findings indicate that conservation outcomes are closely associated with institutional and enforcement capacity, particularly frontline staffing, salary support, and legal enforcement. These results suggest that sustained investment in personnel and enforcement infrastructure is important for translating wildlife protection policies into effective conservation practice.

The analysis also suggests that patrolling effectiveness should not be assessed solely by the distance covered. Rather, its contribution appears to depend on how strategically patrols are deployed and how effectively they are integrated with adequate staffing, monitoring systems, spatial intelligence, and legal enforcement. This points to the importance of a coordinated anti-poaching strategy in which field presence, enforcement authority, and monitoring capacity reinforce one another.

More broadly, the findings underscore that long-term rhino conservation depends not only on formal protected-area designation and wildlife protection laws, but also on the institutional capacity to implement those protections on the ground. Adequately supported frontline personnel, consistent enforcement, and targeted monitoring of poaching risks are therefore central components of effective conservation management. The Assam case provides practical insights for strengthening greater one-horned rhino conservation and may also inform anti-poaching strategies for other threatened wildlife populations facing similar enforcement and institutional challenges.

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