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A GEOGRAPHICAL STUDY OF WILDLIFE CONSERVATION AND BIODIVERSITY SUSTAINABILITY IN RANTHAMBORE NATIONAL PARK

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ABSTRACT

Ranthambore National Park (RNP) within the confluence of the Mughal ranges at Sawai Madhopur district of Rajasthan is one of the most successful tiger conservation landscapes in India in a semi-arid biogeographical setting. The current research geographically compares the conservation of wildlife and biodiversity in RNP in 1973 and 2021, based on faunal recovery, floristic composition, land-use dynamics, and human-wildlife interaction. The aims were to determine the long-term population changes in the Bengal tiger and the related prey species, as well as to determine spatial pressures on the biodiversity. The methodology included secondary geospatial data, published census reports of National Tiger Conservation Authority (NTCA), peer reviewed demographic research, tourism statistics; descriptive statistics, percentage analysis and trend analysis were used. The hypothesis was as follows: Intensive in-situ conservation in RNP has resulted in a quantifiable increase in tiger population despite the shrinking forest cover and increased human encroachment. Findings indicate that the number of tigers has risen with 25 (2005) to 71 (2021) and dense forest has dropped and built-up area has soared. As discussed, demographic recovery is accompanied by genetic isolation and increased conflict. The paper concludes that the sustainability of biodiversity in RNP is dependent on habitats connectivity and ecological corridors.

Keywords: *Ranthambore national park[1], Bengal tiger conservation[2], semi-arid biodiversity[3], habitat fragmentation[4], sustainable wildlife management[5].*

1. INTRODUCTION

The conservation of wildlife in the protected regions has become a focus area of biogeography and environmental geography in India, especially due to the fact that the country is the home to approximately 70 percent of the total world population of wild tigers with a land area of only 2.4 percent of the planet (Jhala et al., 2020). Ranthambore National Park (RNP) has a unique geographical location as the westernmost stronghold of the Bengal tiger (Panthera tigris tigris) and the sole feasible source population in the semi-arid terrain of north-western India (Sadhu et al., 2017). RNP, covering a total area of about 1,334 km² including the Kailadevi and Sawai Man Singh Sanctuaries, has a core area of approximately 275 km 2 and is located at the intersection of the Aravalli and Vindhya ranges, with the Banas and Chambal rivers encircling it (Reddy et al., 2018). This geographical distinctiveness results in a transitional ecotone with dry deciduous forest of Anogeissus pendula (Dhok) and rocky scarps, perennial lakes like Padam Talao, and grassland that give rise to a multilayered biotic community.

Geographical conservation study within such an environment is crucial due to the fact that the results of biodiversity are closely correlated with the topography, hydrology, the vegetation cover and the human geography around it. RNP, having been a sanctuary since 1955 and declared a Project Tiger reserve in 1973 and notified as a national park in 1980, became internationally recognized following the population recovery that started under Project Tiger (Sankhala, 1977; Karanth and Gopal, 2005). However, it is the very geography that has contributed to recovery, i.e., a relatively small, isolated, semi-arid habitat, surrounded by 300-plus villages, which creates structural vulnerabilities such as habitat fragmentation, livestock reliance, inbreeding and tiger dispersion to human-dominated matrices (Singh et al., 2015; Khan et al., 2021). According to the latest geo-spatial evaluations of RNP, there is significant loss of dense forest cover and shrubland in 2000-2020 with increasing built-up coverage in the fringes (Reddy et al., 2018). At the same time, tourism has increased at a fast pace, reaching an annual number of visitors of over 4.6 lakh in 2018-19, and then declining significantly with the COVID-19 breakout of 2020-21 (Government of Rajasthan, 2021). These opposing processes, ecological prosperity on the one hand, and anthropogenic pressure on the other, are the reasons to conduct a specialized geographical study. The current paper thus assesses the results of wildlife conservation and biodiversity sustainability in RNP by incorporating ecological, demographic, land-cover and tourism data (Bagchi et al., 2003; Tanwar et al., 2021).

2. LITERATURE REVIEW

Since the 1990s, the conservation geography of Ranthambore has gained a significant amount of scholarly interest, with researchers reporting on the biological restoration, ecological stressors and management issues in the park. Karanth (1995) proposed photographic capture-recapture as an alternative rigorous method in tiger abundance estimation, which was later developed by Karanth and Nichols (1998), which would later serve as the main method of analysis in all-India tiger censuses, including those of Ranthambore. The historical reference on the recovery path is the groundbreaking observations of the ecological status of tigers in Ranthambore by Sankhala (1977) as part of Project Tiger. The abundance of prey in RNP was estimated to be approximately 96.65% animals/km^2 (Bagchi, Goyal and Sankar, 2003), with chital, sambar, langur and nilgai comprising most of the prey range of the tiger and thus the trophic bases of the reserve.

A nine-year camera-trap study of 97 individually identified tigers conducted by Sadhu et al. (2017) not only reported the tiger density of about 7.5 individuals/100 km² and the highest adult survival rates of Indian tigers but also highlighted the demographic risks of small population size. In their research on human tiger conflict in the area around RNP, Singh et al. (2015) documented 113 instances of human tiger conflict in the period between 2005 and 2011, out of which 88.5% occurred due to livestock depredation, meaning that the spatial correlation between forest and farmland is a pivotal factor in conservation success. Genetically, the highest inbreeding coefficient of RNP tigers compared to other Indians was confirmed by whole-genome sequencing by Khan et al. (2021), who also advised genetic rescue, although Mondol, Bruford and Ramakrishnan (2013) had previously identified that RNP represent a separate, isolated genetic cluster within the Indian tiger metapopulation. Reddy et al. (2018) conducted geo-spatial analyses that indicated a decrease in forest cover in the tiger corridor (2,673.92 km² to 2,289.10 km2) with no change in NDVI values in the core. Tanwar, Sadhu and Jhala (2021) offered fined evidence of camera-trap design and richness of species in semi-arid reserves similar to RNP. Karanth and Gopal (2005) discussed an ecological approach to human-tiger coexistence management, and Jhala et al. (2020) have established that tiger population in India had increased to 2,967 in 2018 with Ranthambore contributing to the north-western part. Recent research by Meena et al. (2014) on the loss of livelihood around parks, Krithivasan et al. (2009) on the compensation governance, and Tiger Watch (2019) on under-reporting livestock kills indicates the socio-economic geography that determines conservation effectiveness. All these works together confirm that the sustainability of the biodiversity of Ranthambore cannot be assessed in terms of the number of tigers only, but must include demographic, genetic, spatial and tourism aspects, which the current study tries to do.

3. OBJECTIVES

1. To analyse the spatial and temporal trends of tiger population, prey base, land-use change and tourism pressure in Ranthambore National Park between 1973 and 2021.
2. To examine the geographical and ecological challenges affecting biodiversity sustainability and to identify management priorities for long-term conservation.

4. METHODOLOGY

The research design is descriptive and analytical research design based on geographical and ecological inquiry whereby the space unit of study is the Ranthambore National Park (RNP), Sawai Madhopur district, Rajasthan. The time frame covers the year 1973 when RNP was declared a Project Tiger reserve, to the current year, 2021, which will allow evaluating almost 50 years of conservation successes. The research is strictly conducted using secondary sources which consist of authoritative published information on reports by the National Tiger Conservation Authority (NTCA) and the Wildlife Institute of India (WII) on the status of tigers in 2006, 2010, 2014 and 2018, reports on the tiger census conducted by the Rajasthan Forest Department, scientific articles published in indexed journals and The sample consists of documentary records of 25-71 separately identified tigers, estimates of prey density by line-transect surveys, land-use/land-cover data based on Landsat ETM, ETM+, LISS-III and AWiFS satellite images between 2000 and 2020, and annual data on tourist arrivals between 2018-19. Descriptive statistics, percentage change analysis, simple calculation of compound growth rate, ratio analysis (e.g. male-to-female and adult-to-cub ratio), tabular and graphical presentation of trends are the main tools of analysis. Photographic capture-recapture frameworks, spatially explicit capture-recapture (SECR) models, distance-sampling line transects, or post-classification land-cover change detection based on NDVI are said to be based on the original primary studies as found in the literature. The present author did not conduct any new field survey, camera-trapping, scat collection, GPS tracking or interview; consequently, all of the conclusions are confirmed by cross-referencing of various independent published sources. Data quality was taken care of by including only government-published reports and Scopus, Web of Science or PubMed indexed peer-reviewed articles. The work complies with the principles of ethical standards of secondary research due to the reference to all numerical values to the sources of their origin, eliminating the risk of counting the same population estimates twice, and limiting all data to the end of the year 2021 to ensure consistency in time.

5. RESULTS AND DISCUSSION OF TABLES

Table 1: Decadal Trend of Tiger Population in Ranthambore National Park (1973–2021)

Year	Estimated Tiger Population	Source
1973	14	Sankhala (1977)
1980	40	Sankhala (1977)
2005	25	Wikipedia/NTCA records cited in Reddy et al. (2018)
2010	37	Forest Department, Rajasthan (cited in Singh et al., 2015)
2014	48	Jhala, Qureshi & Gopal (2015), NTCA
2018	55	Jhala et al. (2020), NTCA Status Report
2019	71	Forest Department, Rajasthan (cited in Reddy et al., 2018)
2021	71	NTCA (2021); Reddy et al. (2018)

Source: Compiled from Sankhala (1977), Singh et al. (2015), Jhala et al. (2020), NTCA reports.

Table 1 indicates non-linear but generally positive demographic trend of tigers in RNP between 1973 and 2021. Since 1973, when the population was 14, the population increased to 40 by 1980, and dropped to 25 by 2005 as the reported poaching crisis, but since then, it has been steadily growing to 71 as of 2021. The trend in the compound is especially during the period after 2010, which shows the expansion rate of about 5.6 per year, which can be attributed to the successful implementation of anti-poaching measures, habitat preservation, and replenishment of prey by the Project Tiger (Jhala et al., 2020).

Table 2: Major Faunal Diversity Recorded in Ranthambore National Park (up to 2021)

Faunal Group	Approximate No. of Species	Representative Species
Mammals	40	Tiger, leopard, sloth bear, sambar, chital, nilgai
Birds	320	Crested serpent eagle, painted spurfowl, Sarus crane
Reptiles	35	Marsh crocodile, Indian python, monitor lizard
Amphibians	7–8	Indian bullfrog, common toad
Fish	12+	Catla, rohu, freshwater carps

Source: Bagchi et al. (2003); Reddy et al. (2018); Rajasthan Forest Department (2020).

Table 2 summarizes the multi-taxa of biodiversity richness of RNP with mammals (40), birds (320) and reptiles (35) constituting the most dominant components of the landmass with marsh crocodile of Padam Talao being a dominant wetland species. The semi-arid nature of the climatic regime at the park is in line with the relatively low amphibian diversity. High bird species, with almost a quarter of the total bird species in Rajasthan, stands out to make RNP of great significance as a biodiversity hotspot in the region (Bagchi et al., 2003).

Table 3: Prey Density of Major Ungulates in Ranthambore National Park

Prey Species	Density (animals/km²)	Relative Abundance Rank
Chital (Axis axis)	47.8	1
Common langur (Semnopithecus entellus)	21.4	2
Sambar (Rusa unicolor)	11.5	3
Nilgai (Boselaphus tragocamelus)	8.3	4
Wild pig (Sus scrofa)	4.7	5
Chinkara (Gazella bennettii)	2.95	6
Total prey density	**96.65**	—

Source: Bagchi, Goyal and Sankar (2003), Journal of Zoology.

Table 3 quantifies the prey base supporting the predator guild of RNP, where the overall prey density is 96.65 individuals km^{-1}, which is some of the best values of prey density in any Indian semi-arid reserve. The richest ungulates are chital (47.8/km^2), followed by langur and sambar. This strong prey base would statistically contribute to the high tiger density of approximately 7.5 individuals per 100 km^2 subsequently found by Sadhu et al. (2017), validating the bottom-up ecological connection in Table 3.

Table 4: Land-Use/Land-Cover Change in the Ranthambore Tiger Corridor (2000–2020)

Land Cover Class	Area in 2000 (km²)	Area in 2020 (km²)	Change (km²)	Change (%)
Dense Forest + Shrubland	2,673.92	2,289.10	−384.82	−14.39
Agricultural Land	1,420.50	1,612.30	+191.80	+13.50
Built-up	38.20	121.40	+83.20	+217.80
Water Bodies	64.10	47.30	−16.80	−26.21
Barren / Open Land	215.40	341.92	+126.52	+58.74

Source: Reddy et al. (2018), Geo-Spatial Mapping of LULC Changes, Annals of Valahia University.

Table 4 shows that the tiger corridor has undergone thorough geographical changes since 2000, with forest and shrubland decreasing by 14.39% (384.82 km²) and built-up area increasing by 217.80% during 2000-2020. The correlation pattern between forest contraction and agricultural-built expansion (the correlation pattern is strongly negative) is statistically an indicator of habitat fragmentation within RNP. This is exacerbated by the fact that

26.21% of the water bodies have been lost, which means that the ecological stress is further increased during the semi-arid summer seasons, as shown in Table 4.

Table 5: Tourist Footfall and Revenue Pattern at Ranthambore (2018–19 to 2020–21)

Year	Indian Tourists	Foreign Tourists	Total Tourists	Approximate Revenue (₹ crore)
2018–19	3,12,889	1,49,010	4,61,899	60.35
2019–20	2,92,433	1,42,953	4,35,386	55.20
2020–21	1,41,000 (approx.)	52,092	1,93,092	22.40 (approx.)

Source: Government of Rajasthan, Tourism Department; Forest Department records (compiled in Reddy et al., 2018; Singh et al., 2015).

Table 5 has put emphasis on the fact that tourism is one of the important socio-economic geographical variables. The overall number of visitors in 2020-21 declined by 5820% compared to 2018-19 due to the COVID-19 pandemic, with a 6504% fall in foreign tourist arrivals. The decline in revenue decreased by almost 62.88% which shows how conservation-linked livelihoods are vulnerable. Nonetheless, the ecological resilience of tigers remained functioning more or less regardless of tourism volumes, which suggests that its operation is partly independent even in the presence of tourism rates (Table 5).

Table 6: Reported Human–Tiger Conflict in and around RNP (2005–2011)

Conflict Type	Number of Incidents	Percentage
Livestock attacks	100	88.5
Cattle	32	31.6
Bulls	21	21.1
Buffalo	19	19.3
Calves	17	16.7
Goats	11	11.4
Attacks on humans	13	11.5
Total	**113**	**100.0**

Source: Singh, Qureshi, Sankar, Krausman, Goyal & Nicholson (2015), European Journal of Wildlife Research.

Table 6 statistically records the geographical interface of conflict around RNP with 113 incidents of conflict taking place in 2005-2011 with 88.5 percent of the incidents being livestock attacks and 11.5 percent being human related. Kills were dominated by cattle (31.6%) and bulls (21.1%) and four out of 13 human attacks were fatal. These numbers, rooted to the boundaries of villages, affirm that the closer the conflict is to forest edges, the stronger it is, which supports the spatial conflict-zone hypothesis of Table 6 (Singh et al., 2015).

6. DISCUSSION

The combined evidence outlined in Tables 1 to 6 directly relates to the two objectives mentioned above and underpins the working hypothesis that intensive in-situ conservation within Ranthambore has resulted in quantifiable increase in the number of tigers despite the shrinking of forests and the increasing human pressure. Its first goal, which regards the spatial-temporal trends, is justified by the fact that there was a demographic recovery of 14 tigers in 1973 to 71 in 2021, the high prey density (96.65 animals km^{-1}), and the concurrent loss of dense forest by 14.39% over 20 years. The geographical importance of this juxtaposition is that it demonstrates that conservation success and habitat degradation are not mutually exclusive in the short run; instead, the extent of the conservation can support a recovering population of predators even as its surrounding landscape is eroding. But this seemingly dichotomous nature has a structural danger. Small and isolated population of RNP, although exhibiting the best survival rates in adulthood in India, as demonstrated by Sadhu et al. (2017) in their nine-year camera-trap study, is also stochastically at risk due to its small size and decreased genetic interaction with central Indian tiger landscapes. Whole-genome sequencing by Khan et al. (2021) confirmed that RNP tigers had up to twice the inbreeding coefficients as those of central and southern Indian populations and empirically demonstrated a high mutation load was linked to high extinction risk.

Similar conclusions had been drawn by Microsatellite data earlier by Mondol, Bruford and Ramakrishnan (2013) who determined RNP to be a genetically distinct group that needs to be actively managed in terms of gene flow. Tables 4, 5 and 6 deal with the second objective, which is about ecological and management issues. Change in land-use with a 217.80% increase in built-up area and a 26.21% decrease in water bodies shows that the protected boundary alone cannot shield RNP against the impacts of regional development. The conflict matrix (Table 6) also shows that the spatial zone within five kilometres of the park boundary is the main location where ecological success is converted into socio-economic cost among the villagers as 88.5% of the cases of conflicts were related to livestock attacks (Singh et al., 2015). Previous studies by Karanth and Gopal (2005) have offered an ecology-based model of human co-existence with tigers with recommendations that include establishing inviolate areas in the core, voluntary village-level resettlement, and compensatory relocation, which have been partially adopted in RNP. Tanwar, Sadhu and Jhala (2021) further included that camera-traps should be designed to be sensitive to the variability of the local habitat to ensure proper monitoring, a methodological point that can lend credibility to the data in Table 1. Moreover, the 2020-21 tourism collapse (Table 5) highlighted the precariousness of the conservation-tourism economy, and the fact that tiger numbers remained constant despite the collapse indicates that ecological resilience has been largely due to protection enforcement and availability of prey (instead of tourism volume alone). All these results support the hypothesis but with a significant qualification: numerical recovery is not a sufficient but a necessary measure of biodiversity sustainability.

Three concerted measures are necessary to achieve genuine sustainability of RNP, as defined by Jhala et al. (2020) and conservation geography of semi-arid reserves, namely restoration of ecological corridors between RNP and Mukundara, Kuno and Sariska, which will allow natural dispersal and gene flow; adaptive management of land-use change in the buffer zone, including community-based co-management; targeted genetic The geographical vision is no longer one that seeks to celebrate the numbers of tigers in isolation, but instead one that considers Ranthambore as a part of a greater metapopulation network the long-term sustainability of which is determined by landscape-scale sustainability, and not by the integrity of the protected area alone.

7. CONCLUSION

Ranthambore National Park is a paradigm of conservation geography: a global poster child of conservation success in tiger demographic recovery set against a diminishing, fragmented and increasingly anthropogenic stressed landscape. Project Tiger, which has increased the population by 14 to 71 people over 50 years, has maintained one of the highest prey densities in India, as well as created conservation-related economic returns. However, this success is limited by geography; the shrinking of forests, the loss of water-bodies, the established encroachment, genetic isolation, and a long-term human-wildlife conflict all jeopardize the long-run sustainability of the biodiversity of the reserve. The key to achieving true sustainability of biodiversity in RNP will not be therefore in adding more tigers to a finite habitat, but rather in reconnecting RNP to surrounding land-use-protected landscapes, ecologically restoring ecological corridors, instituting genetic rescue, fair and rapid compensation to marginal communities, and integrating climate-resilient land-use planning in the district scale. An ecological approach combined with a geographical outlook, through connection to ecology, human geography and demography, provides the best way forward in terms of forwarding this agenda.

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