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Beyond parks as monoliths: Spatially differentiating park-people relationships in the Tadoba Andhari Tiger Reserve in India

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ABSTRACT

Parks represent spatially and socially heterogeneous conservation units, yet are often assessed and managed using spatially homogeneous approaches. This paper represents an effort to focus on the larger social–ecological landscapes within which protected areas are embedded, to understand why conservation succeeds and fails in different parts of the landscape. In a wildlife sanctuary in the central plains of India (Tadoba Andhari Tiger Reserve), we address: (i) how people living within and immediately outside a park differentially impact its resources and (ii) how the park differentially impacts communities living within. Using forest plots, satellite imagery and interviews, we evaluate park conservation by assessing plant diversity, land cover change, forest fragmentation, and attitudes of local communities towards conservation. We find that interior villages have a negative impact on regeneration, but there is a decline in tree species diversity, and increased forest cover change and fragmentation at the park periphery. Interior villages suffer greatly from crop and livestock depredations by wildlife and consider park rules to be unfairly devised. Yet, they affirm the importance of the park for conservation, and are willing to work with park authorities for stricter protection. Park authorities largely focus on resettlement of interior villages, when they should also pay attention to protecting the peripheral areas of the park from severe degradation by surrounding villages. In summary, we find that different parts of the park landscape face different conservation challenges. Taking into account spatial variations in the factors influencing conservation can greatly benefit the management of protected areas.

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1. Introduction

For well over a century, protected areas have been a cornerstone of conservation efforts around the globe. Rapidly expanding in recent decades, protected parks now exist in almost all parts of the world, covering over 13% of the world's land area (Jenkins and Joppa, 2009). Yet in many parts of the developing world, where there are high population densities, parks coexist with people in tightly coupled, fractious and uneasy relationships (Nagendra 2008). The conflicts between parks and people have been studied for decades, with conservation agencies and social scientists often taking contentious positions on the need for conservation versus human rights (Terborgh et al., 2002; Chapin, 2004). Some participants in this debate make vigorous claims that participatory approaches to conservation have been ineffective, urging a return to strict protection strategies – others point to successful cases of community conservation and urge the need to closely involve local communities as agents of conservation (Persha et al., 2010).

In recent years, many scholars have conducted in depth examinations of large datasets to seek answers to whether parks or community protected areas are effective (DeFries et al., in press; Naughton-Treves et al., 2005; Nepstad et al., 2005; Hayes, 2006; Nagendra, 2008, 2009; Persha et al., 2010). The answers indicate that many government and community protected areas are effective, while others are degrading despite protection. Both strict protection and participatory conservation appear valid and workable approaches to conservation in some contexts, while failing in other situations. The causes for these varying outcomes have been examined in a number of studies. Nagendra (2007) identifies the nature of the institutional regime, the presence of monitoring, and the size of the user group as critical to the success of forest management in

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Nepal. In a global analysis, Walker (2009) finds that parks succeed when monitoring is low cost while the benefits of catching rule breakers are high, and when there is a strong likelihood of catching rule breakers. Bray et al. (2008) find that in Guatemala, distance to human settlements and the length of previous settlement was a significant explanatory of deforestation, while in Mexico the distance to previous deforestation was a critical factor. Agrawal and Chhatre (2006) find that biophysical factors such as slope and elevation play a critical role in shaping outcomes of forest change in Indian forests, cautioning that an overly great focus on institutions can obscure the fact that biophysical locations play a critical role in impacting forest management. These studies take an important step forward, by acknowledging that the factors impacting conservation outcomes are likely to be location specific.

Following Ostrom and Nagendra (2006), who ask to "move(s) the debate beyond the internal and external boundaries of protected areas… (to) understand when and why protection, recovery, and clearing occur in these larger landscapes", we build on this body of previous work on protected areas, by further exploring heterogeneity in forest outcomes within different parts of a protected area-embedded landscape. We study forest change in a central Indian park, the Tadoba Andhari Tiger Reserve (TATR), where one of us has been working extensively with park authorities and local communities for over a decade, to examine the specific trajectories of forest change in different areas of the park. We evaluate a range of aspects that include plant diversity, land cover change, forest fragmentation, and peoples' attitudes to conservation.

Our goal is to assess how the factors influencing conservation can differ markedly in different parts of the same landscape, thus establishing the usefulness of spatial approaches that move beyond treating parks as homogeneous monolithic units, and paying attention to the diversity of drivers and outcomes of forest management within a park-embedded landscape.

Through this process, we seek to understand how the communities living within and outside the park impact its resources, how they are in turn affected by the park, and to assess workable solutions that can be identified for future effective park management.

2. Study area

The TATR is located in the central Indian district of Chandrapur, in the state of Maharashtra (Fig. 1). In 1935, an area of 116.55 sq. km was first demarcated as a sanctuary for wild animals, and subsequently declared the Tadoba National Park in 1955. In 1986, the area under protection was expanded to include the adjacent Andhari Wildlife Sanctuary, an area of 508.85 sq. km. In 1995, both protected areas were incorporated into the TATR under Project Tiger, a wildlife conservation project of the Indian Government aimed at protecting the Bengal tiger (Ghate, 2003; Khawarey and Karnat, 1997). The TATR covers an area of 625 km^2, in a landscape largely dominated by dry tropical forests, interspersed with grasslands and water bodies (Nagendra et al. 2006). This central Indian forest landscape is rich in biodiversity, with over 41 mammal species and 195 bird species (Khawarey and Karnat, 1997).

The TATR is situated in a landscape where people and forests have coexisted for centuries. The Tadoba National Park was created in an area where two villages were located, and later resettled. Likewise, the area where the boundaries of the Andhari Wildlife Sanctuary were marked contained six villages which lost many of their traditional rights over forest products after creation of the TATR (Khawarey and Karnat, 1997; Nagendra et al., 2006). Resettlement of these villages has long been on the agenda of the Maharashtra Forest Department. After much dispute, one of the villages, Botezari, and almost 50% of the households from another village, Kolsa, were moved outside the park in 2007.

The road network in the northeastern part of the reserve is quite well developed, providing greater access to the forest and leading to greater disturbance on this side. To the north, south and east, the TATR is surrounded by forest patches categorized as Reserve Forest and Protected Forest, lower categories of protection which act as a buffer offer on these sides. 53 peripheral villages fulfill a large part of their fuel, fodder, timber and non-timber forest requirements from the park (Khawarey and Karnat, 1997; Nagendra et al., 2006). The TATR also experiences substantial seasonal use from migrant herders, and is frequented by timber, bamboo and wildlife poachers (Ostrom and Nagendra, 2006). Over 60,000 tourists visit the park each year, and their number is growing, with a number of tourist lodges and hotels being set up around the park to cater to these visitors (Mawdsley et al., 2009). Despite recognition of the pressure on the park from these diverse sources, park authorities remain focused on resettlement of the villages as providing a major solution to problems of park degradation (Ghate, 2007; Ghate and Beazley, 2007). Little attention has been paid to identifying different groups of users, quantifying their relative impacts on the park, or to developing approaches to differentially manage these impacts.

3. Methods

3.1. Plant diversity

Between 2003 and 2005, a total of 240 circular plots were distributed across the TATR to sample plant biodiversity distributions. A stratified sampling design was used in order to cover a variety of vegetation types at varying distances from settlements within and outside the protected area. For six villages within the park, and two villages located just outside the park, between 29 and 31 plots were distributed at varying distances from the village boundaries using a stratified sampling approach to ensure that a diversity of vegetation types was sampled, with a number of plots randomly located within different vegetation types based on the relative distribution of these habitats. Such a sampling strategy enables us to sample the variation in plant diversity within the park, from relatively undisturbed core areas to degraded areas adjacent to the park outer boundary. Since two of the settlements were located just outside the park boundary, the plots representing distances from these settlements were removed from analysis, leaving a total of 181 field plots that were used for this study. Fig. 1 shows the distribution of the 211 field plots with respect to the TATR boundary and the six villages then located within the park.

Field plots were nested, with the outermost plot being 10 m in radius. Within this outer 10 m circle, the species, diameter at breast height (dbh) and height were recorded for all trees (defined as individuals with dbh >10 cm). A nested sub-plot of 3 m radius was used to record species, dbh and height for all saplings (defined as individuals with dbh <10 cm, but >1 cm). For each plot, we calculated five measures of species diversity and abundance – the total species richness (based on tree and sapling nested plots), tree species richness, tree density, sapling species richness and sapling density (Legendre and Legendre, 1988). We conducted a linear two variable regression model to assess the significance of the relationships between distance to the nearest interior village and park periphery, and these five indicators of plant biodiversity and density. The software R (R Development Core Team, 2009) was used for analysis.

3.2. Land cover change

A Landsat TM image of 5th November 1989 and a Landsat ETM + image of 29 October 2001 were used to map forest cover

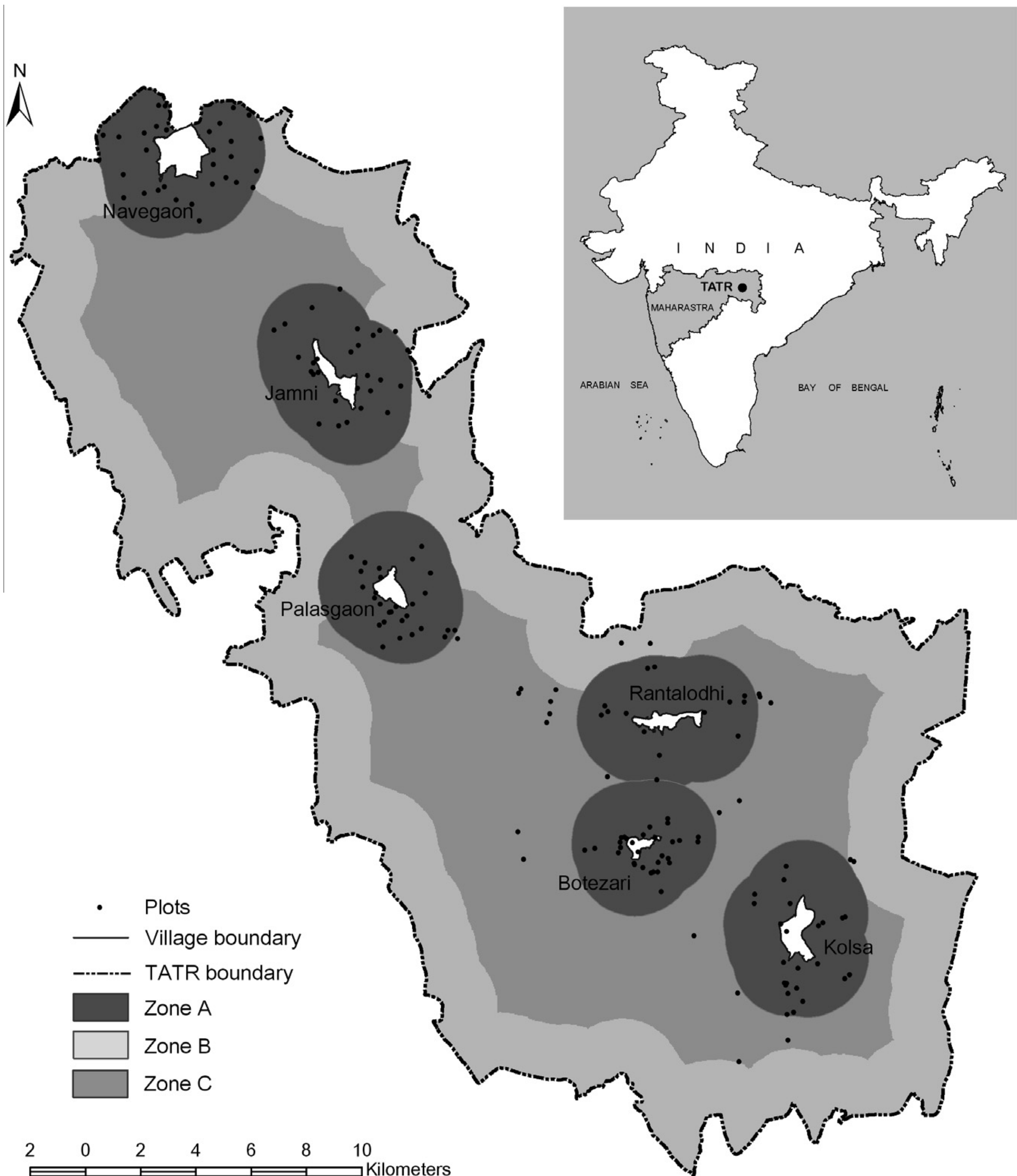

Fig. 1. Map of TATR showing the interior villages and the three zones of impact, with an inset map of India.

change between 1989 and 2001. Images were downloaded from the University of Maryland's Global Land Cover Facility site (glcfapp.umiacs.umd.edu). Both images were from the dry season, when agriculture is fallow, enabling us to differentiate crop fields from forests with maximum accuracy. The 1989 image was georeferenced to Survey of India topographic sheets, and the 2000 image was registered to the 1989 image, ensuring that the RMS error of image-to-image registration was <0.5 pixels (15 m), and further verifying this through an image overlay function and careful visual comparisons to ensure that images overlapped well without sliver areas of misregistration (Jensen, 2000).

Images were classified using supervised classification approaches, with ground training data was collected in December 2004, using ERDAS Imagine™ software, into three categories – dense forest (canopy cover between 10% and 40%), open forest (canopy cover <10%) and non-forest (predominantly agriculture, grassland, water, or village settlements). Classification accuracy was verified using an independent data set collected at the same

time, but not used as inputs into the classification. We established a producer's accuracy of 89.5% for the 2001 image and of 86.7% for the 1989 image. The accuracy of these individual classifications is quite high, and well above the 85% standard recommended for single-date classifications (Foody, 2002).

Classified images were overlaid on each other to delineate land cover change trajectories. While nine change categories are produced as a result of the overlay of these two images, each with three classes – we collapsed these nine categories into a set of four classes. These represent areas of stable forest (forested in 1989 as well as 2001), stable non-forest (devoid of forest cover in 1989 and 2001), deforestation (forested in 1989 but non-forest in 2001), and reforestation (non-forested in 1989 but forested in 2001). Further details about the procedure used for land cover classification and change analysis are provided in Nagendra et al. (2006). In general, the accuracy of the change image can be assumed to be a multiplicative product of the classification errors of single-date images (Foody, 2002) – which would imply that the error of this change image would be around 77.6%. However, in this instance since the change map collapses nine change categories into just four final land cover change classes, this will substantially reduce classification errors further and the resultant change image can be expected to be of an accuracy that is suitable for further detailed analysis of forest change and fragmentation pattern (Jensen, 2000; Foody, 2002).

We acquired six adjacent high resolution (1 m) IKONOS images of the park from October to December 2000 (Nagendra and Rocchini, 2008). The images were used to delineate the boundaries of the six villages located within the park at that time, and their adjacent agricultural land holdings. Three regions were then delineated within the park, representing different zones of interaction. Zone A was defined as a 2 km zone around the boundary of each village (including the settlement area and agricultural land holdings), and represented the area most impacted by the communities living within the park. Zone B was delineated as a 2 km interior buffer from the park boundary and located within the park, representing the area most heavily impacted by outside villages and other visitors. Zone C constituted the interior areas of the park, with the area that is presumably least impacted by outside visitors. Fig. 1 depicts these three zones. The use of a 2 km wide section within the park boundary and outside the interior villages was done to represent the areas of the park that are subject to maximum pressure from the villages surrounding the park as well as from the interior villages, due to grazing, fuelwood and fodder extraction, based on information provided from forest managers and local communities.

The three zones of impact were overlaid on the land cover change image, and used to compare the percentage of area covered by different land cover change trajectories across all zones. This analysis follows on similar analysis conducted in Nagendra et al. (2006), which used point locations to represent villages – but improves substantially on our previous study by delineating the settlements and agricultural lands of the interior villages, and masking them out from computations of land cover change.

3.3. Forest fragmentation

In addition to forest cover, the degree of connectivity or fragmentation provides a critical indication of its overall quality as good habitat for wildlife, insects and plants (Nagendra et al., 2004). The three zones of interaction were overlaid on the forest change map, and used to estimate critical measures of forest fragmentation – number of patches, patch size, patch shape, distance between patches, and clumpiness (McGarigal et al., 2002). This analysis follows on analysis of fragmentation conducted in Nagendra et al. (2006), but extends this further by looking at forest cover change categories instead of single time points, as well as improving on the earlier analysis by masking out areas covered by settlements and permanent agriculture.

3.4. Impact of the park on interior villages

During 2000–2003 we used the International Forestry Resources and Institutions (IFRI) protocol, a protocol of biophysical and social assessment with ten survey instruments (Ostrom and Nagendra 2006) to assess the socio-economic and institutional conditions of the six villages living within the park. We also conducted 101 household interviews with selected individuals in each village, with 22 individuals interviewed in Kolsa, 19 in Rantalodhi, and 20 in Palasgaon, Jamni, and Navegaon. Interviewees were selected in a stratified manner so as to sample across ethnic groups, income categories, and genders. During these interviews, we assessed the relationship of the respondents to the park, by asking about the products they regularly harvest from the forest, and about cattle and livestock depredations due to wildlife. We also assessed attitudes towards the park, by asking them a series of questions. We asked respondents whether they believed that the park management rules were devised fairly; whether they were applied fairly and impartially; whether they felt the park was important for conservation, whether they would be prepared to participate in such an effort, and if so, what their suggestions were for protecting the forest. These questions were not asked to respondents from Botezari village, as this village was scheduled for resettlement at the time of the interviews; indeed, it has subsequently been resettled outside the TATR.

Thus, we use biodiversity plots, remote sensing analyses and social-institutional surveys as three independent datasets to assess the nature of human impacts on the park in terms of three different aspects – plant diversity, land cover change and fragmentation, and people's perceptions. Although these datasets are from slightly different dates, there is not a substantial time difference especially given the setting of this study, in a protected area with indigenous communities, where social conditions, livelihood use strategies, biodiversity distributions and drivers of land use change and fragmentation are not likely to change substantially in a short period of time.

4. Results

4.1. Plant diversity

All five indicators of plant biodiversity and density show a positive relationship with distance from park periphery and interior village – that is, as distance from the interior village increases, all indicators of species diversity and density increase. Not all of these relationships are significant, however, as shown in Table 1. Total species richness and tree species richness are the only variables that exhibit a significant increase with increased distance from the park periphery. Sapling density and diversity are not impacted significantly as distance from the park periphery increases, however. This indicates that the main impact of the incursions from the park periphery is on the tree layer, most likely through the felling of specific trees for timber harvest, with only a minimal impact on sapling regeneration.

In contrast, as distance from the interior villages increases, total species richness increases significantly, along with a significant increase in sapling species richness and sapling density, while tree species richness and density remain unaffected. Thus, it seems that the interior villages do not impact the park as much in terms of harvesting timber and mature trees, but the harvesting and grazing activities conducted by the inhabitants of the interior villages ap-

pear to be impacting regeneration significantly, through reductions in sapling density and diversity. This is somewhat different from what we would have observed if plant diversity was impacted by the classic pattern of edge effects, where we may have expected species diversity to have been high at the edge, decreasing sharply at a slight distance from the edge, and then increasing gradually with increasing distance from the village or park periphery.

4.2. Land cover change

The forest landscape of TATR appears dynamic. Only about two-thirds of the total area is in stable forest or stable non-forest categories, while as much as a third of the landscape appears to be experiencing some change, with a mix of deforestation and reforestation (Table 2).

Zone B, constituting the peripheral areas of the park, appears to be the most depleted of forest cover with the lowest percentage of stable forest (61.28%) and the greatest percentage of stable non-forest cover (8.69%) compared to the other two zones. Significantly, the areas surrounding the interior villages in zone A have a greater percentage of their area under stable forest (6.28%) compared to zone C, the central region of the park (63.29%).

Yet, zone B appears to be the most stable over time, with a relatively lower percentage of its area in the two change categories (reforestation and deforestation) compared to the other two zones. Most change is taking place in the central area of the park, zone C, a worrying trend indicating that the degree of human impact in this part of the park may be increasing over time.

Table 1
Relationship between estimates of species diversity and density, and distance to park periphery and interior village.

Plot parameter	Statistical significance (p) of variable	
	Distance to park periphery	Distance to interior village
Total species richness	0.0259*	0.0208*
Tree species richness	0.0143*	0.2933
Tree density	0.4460	0.5020
Sapling species richness	0.4466	0.0067**
Sapling density	0.5356	0.0084**

* Significant at $p < 0.05$.
** Significant at $p < 0.01$.

Table 2
Forest cover change in the three zones of impact.

	Zone A – area impacted by interior villages	Zone B – area impacted at park periphery	Zone C – relatively isolated central area
% Deforestation	14.54	13.64	16.81
% Reforestation	18.07	16.39	17.77
% Stable non-forest	1.11	8.69	2.13
% Stable forest	66.28	61.28	63.29
Total area (km^2)	139.67	252.81	221.80

4.3. Forest fragmentation

The stable forest category shows the greatest fragmentation in the park periphery in zone B, with smaller sized patches, a low shape index, low clumpiness, and located at far distances from each other (Table 3). In the other two zones, the stable forest in the central areas of the park in zone C is more fragmented compared to the areas surrounding the interior villages in zone A. The patterns of distribution of the stable non-forest category are similar to those of the stable forest category. Deforestation however follows an opposite trend. Deforestation patches are larger and more spatially connected in zone C, compared to zones A and B, indicating that zone C is experiencing significant disruption in the spatial pattern and connectivity of its forest cover.

4.4. Impact of the park on interior villages

The six villages located within the park during the time of survey are fairly small sized, with an average of 96 households per village (Table 4). The smallest village Botezari, has just 56 households

Table 3
Forest fragmentation in the three zones of impact.

Land cover change category	Metric of fragmentation	Zone A – area impacted by interior villages	Zone B – area impacted at park periphery	Zone C – relatively isolated central area
Deforestation	Number of patches	8374	13,637	12,924
	Mean patch area (h)	0.24	0.25	0.29
	Mean shape index	1.19	1.19	1.22
	Mean nearest neighbor distance (m)	70	70	67
	Clumpiness	0.23	0.25	0.26
Reforestation	Number of patches	5582	9783	8787
	Mean patch area (h)	0.45	0.42	0.45
	Mean shape index	1.23	1.23	1.22
	Mean nearest neighbor distance (m)	70	70	70
	Clumpiness	0.40	0.38	0.40
Stable non-forest	Number of patches	367	1632	933
	Mean patch area (h)	0.42	1.35	0.51
	Mean shape index	1.14	1.24	1.18
	Mean nearest neighbor distance (m)	208	111	151
	Clumpiness	0.53	0.72	0.54
Stable forest	Number of patches	466	1228	792
	Mean patch area (h)	19.87	12.62	17.72
	Mean shape index	1.57	1.34	1.39
	Mean nearest neighbor distance (m)	60	65	60
	Clumpiness	0.71	0.71	0.67

Table 4
Variables indicating the relationship between the park and the six interior villages.

	Navegaon	Jamni	Palasgaon	Kolsa	Botezari	Rantalodhi
Total households	101	92	88	133	56	105
% Women	50.4	50.0	49.4	49.6	32.6	50.5
% Land owning households	39.6	89.1	55.7	88.7	50.0	81.9
% Literacy	54.9	82.2	54.6	55.0	66.5	53.2
Livestock (cattle + goats)	380	244	255	792	187	355
Access to essential facilities	Moderate	Moderate	Poor	Poor	Very poor	Very poor
% Dense forest in 2001	54.8	82.1	79.6	58.4	68.1	75.8
% Open forest in 2001	39.8	16.1	18.9	37.0	30.4	22.4
Households interviewed	20	20	20	22	32	19
Species harvested for timber	Anogeissus latifolia, Cleistanthus collinus, Chloroxylon swietenia, Lagerstroemia parviflora, Phyllanthus emblica, Pterocarpus marsupium, Tectona grandis, Terminalia alata	Anogeissus latifolia, Bambusa arundinacea, Cleistanthus collinus, Chloroxylon swietenia, Lagerstroemia parviflora, Pterocarpus marsupium, Tectona grandis, Terminalia alata	Chloroxylon swietenia, Cleistanthus collinus, Diospyros melanoxylon, Lagerstroemia parviflora, Phyllanthus emblica, Tectona grandis, Terminalia alata, Terminalia belerica	Acacia catechu, Bambusa arundinacea, Chloroxylon swietenia, Cleistanthus collinus, Lagerstroemia parviflora, Lannea coromandelica, Madhuca longifolia, Phyllanthus emblica, Tectona grandis, Terminalia alata, Terminalia belerica	Anogeissus latifolia, Chloroxylon swietenia, Cleistanthus collinus, Lagerstroemia parviflora, Phyllanthus emblica, Semecarpus anacardium, Tectona grandis, Xylia xylocarpa	Anogeissus latifolia, Cleistanthus collinus, Diospyros melanoxylon, Lagerstroemia parviflora, Madhuca longifolia, Pterocarpus marsupium, Tectona grandis
Species harvested for fuelwood	Acacia catechu, Anogeissus latifolia, Bambusa arundinacea, Chloroxylon swietenia, Cleistanthus collinus, Diospyros melanoxylon, Holarrhena antidysenterica, Lagerstroemia parviflora, Madhuca longifolia, Phyllanthus emblica, Pterocarpus marsupium, Tectona grandis, Terminalia alata, Terminalia belerica, Zizyphus glaberrima	Acacia catechu, Anogeissus latifolia, Bambusa arundinacea, Chloroxylon swietenia, Cleistanthus collinus, Diospyros melanoxylon, Madhuca longifolia, Pterocarpus marsupium Semecarpus anacardium, Tectona grandis, Terminalia alata, Terminalia belerica, Zizyphus glaberrima	Acacia catechu, Anogeissus latifolia, Bambusa arundinacea, Buchanania lanzan, Chloroxylon swietenia, Cleistanthus collinus, Diospyros melanoxylon, Lagerstroemia parviflora, Madhuca longifolia, Phyllanthus emblica, Pterocarpus marsupium, Tectona grandis, Terminalia alata bhera,	Anogeissus latifolia, Bambusa arundinacea, Cleistanthus collinus, Holarrhena antidysenterica, Lagerstroemia parviflora, Madhuca longifolia, Phyllanthus emblica, Pterocarpus marsupium, Tectona grandis, Terminalia belerica	Cleistanthus collinus, Lagerstroemia parviflora, Phyllanthus emblica, Tectona grandis, Zizyphus glaberrima	Anogeissus latifolia, Bambusa arundinacea, Chloroxylon swietenia, Cleistanthus collinus, Diospyros melanoxylon Holarrhena antidysenterica, Lagerstroemia parviflora, Madhuca longifolia. Phyllanthus emblica, Pterocarpus marsupium, Tectona grandis, Terminalia alata, Xylia xylocarpa, Zizyphus glaberrima
Non-timber forest products harvested	Buchanania lanzan, Diospyros melanoxylon, Madhuca longifolia	Buchanania lanzan, Diospyros melanoxylon Madhuca longifolia, *Syzygium cumini*, toddy, clay	Buchanania lanzan, Diospyros melanoxylon, Madhuca longifolia, toddy, clay, firewood, grass	Diospyros melanoxylon, Madhuca longifolia, toddy, honey	Buchanania lanzan, Diospyros melanoxylon, Madhuca longifolia, Phyllanthus emblica	Buchanania lanzan, Diospyros melanoxylon, Madhuca longifolia
% Households with wildlife damage in past year	100	95	75	68	67	84
Animals responsible for loss	*Axis axis, Boselaphus tragocamelus, Cervus unicolor, Sus scrofa*	*Axis axis, Cervus unicolor,* Psittacula krameri, Sus scrofa	*Axis axis, sambhar, Sus scrofa*	*Axis axis, Bos gaurus, Sus scrofa*	*Sus scrofa*	*Axis axis, Bos gaurus, Sus scrofa*
% Respondents who think forest should be protected	82	82	75	100	–	100
% Respondents who think forest is important for their subsistence	100	100	90	90	–	100

(*continued on next page*)

Table 4 (*continued*)

	Navegaon	Jamni	Palasgaon	Kolsa	Botezari	Rantalodhi
% Respondents who think the forest is important for economic reasons	100	100	90	90	–	100
% Respondents who think guidelines for forest use and management are fair	20	40	20	77	–	16
% Respondents who think application of penalties is done fairly	85	90	90	55	–	32
% Respondents who have been employed to assist in forest management	65	85	65	68	–	21
% Respondents who wish to participate in forest management	75	75	50	64	–	68

with 187 livestock, and was resettled outside the park in 2007. The largest village Kolsa with 133 households owning 792 livestock is in the process of being resettled, with 49 households already having moved outside the park at the time of writing this paper. Except for Jamni, literacy levels are fairly low. These villages are dominated by ethnic indigenous tribes, largely from the Gond community. Based on data in Ghate (2003), which enumerates the access of these villages to basic amenities including primary health care centers, primary schools, roads and fair price provision stores, these villages were categorized into three groups. The northernmost villages Navegaon and Jamni are closest to the park main gate and have moderate access to essential facilities (Fig. 1) while the most isolated are the erstwhile Botezari village, and Rantalodhi, which are located in the interior, and lack basic access to essential amenities (Ghate, 2003).

All villages are situated in an area surrounded by a mix of dense and open forest, with very little surrounding non-forest. They are highly dependent on the forest for their daily existence, and identified 19 species utilized for timber, 17 for fuelwood, and 5 for non-timber forest products, harvested for personal use as well as for sale. Respondents also indicated that they harvested a range of medicinal products from the forest, mainly seasonal herbs that were not always identifiable.

Given the high density of surrounding forest area, it is not surprising that a high proportion of the respondents interviewed indicated that they experienced losses due to wildlife. The majority of losses were due to crop raiding, although some cases of livestock death and a few significant cases of human attacks were also reported. Compensation was only provided in a few instances, and the entire loss was rarely compensated. A variety of animals were implicated in crop raiding, from the wild pig (*Sus scrofa*) to sambhar (*Cervus unicolor*), gaur (*Bos gaurus*), and even parakeets (Psittacula krameri).

Despite the high losses suffered due to wildlife depredations, most respondents – between 90% and 100% across all villages – indicated that the continued existence of the forest was critical for their subsistence, as well as to fulfill their economic needs. This indicates that forest products supply not just a significant part of their daily subsistence requirements, but are also being sold, and this is critical for providing them with cash income. A majority of respondents – between 75% and 100% of the respondents per village – said that the forest required continued protection. In Kolsa village, 77% of the interviewees thought these rules were fair, but in other villages, only between 16% and 40% of the respondents believed that the rules formulated for forest management by the park authorities were fair. Yet, most respondents thought that the *application* of these rules, and of penalties for infractions, was done in a fair manner – this may be a consequence of the fact that many people living inside the park receive some employment from park authorities for park maintenance, monitoring and patrolling. In Rantalodhi, the most isolated village, where there are few such opportunities for employment, only 32% of respondents thought that rules were applied in a fair manner.

The villages within the park have had a controversial, sometimes violent engagement with park authorities (Nagendra et al., 2006). Yet, an overwhelming majority of respondents (89%) indicated that they felt the park should continue to be protected. When asked if they had any concrete suggestions to help in park management, 14% indicated that the forest required strong protection, while 17% stated that the park authorities should involve the local people in monitoring the park to reduce illegal harvesting and poaching. Some of these respondents stated that the interior villages knew the forest best, and could be of great assistance to the park managers in catching poachers, and preventing forest fires. A few (11%) of the respondents indicated that they should be provided with employment opportunities to enable them to work within the park. Only 6% of the respondents mentioned resettlement as a solution to the challenges of park management. Some respondents openly stated that they did not wish to engage with park authorities – although a minority (6%), their responses are significant. Others indicated that they had no interest in assisting the Forest Department, since they had received no help from them.

5. Discussion

Spatial variations in conservation outcomes are clearly visible in different locations within the park, as also observed in other protected areas in India (Robbins et al., 2007) and Uganda (Olupot et al., 2009). Interior villages do have an impact on plant diversity, as has been recently reported for another park in Nepal (Christiansen and Heimlamnn-Clausen, 2009). While no significant impact was found on tree density and diversity, sapling density and diversity decreased closer to interior villages, indicating that the forest extraction and grazing activities of these communities is impacting regeneration, while leaving the tree layer largely intact. The impact of the villages located just outside the park appears to be different, and is observed in terms of reduced overall plant diversity as well as tree diversity, indicating that incursions at the park periphery appear to be largely aimed at the extraction of specific species of trees, most likely for their timber value. Land cover change and fragmentation analyses show similar trends. The area at the park periphery is the most depleted of forest cover, with greatest forest fragmentation compared to the areas surrounding the interior villages. Thus, while the four villages now existing within the park do impact the forest, the 53 villages located just outside the park appear to constitute a greater challenge for conservation.

Yet park authorities remain predominantly focused on resettling the interior villages outside the park. Much effort has gone into formulating resettlement packages, and the bureaucratic process of resettlement has consumed a great deal of the attention of forest managers (Ghate, 2007; Beazley 2009). While some of the interior villages have expressed a preference for resettlement in order to gain better access to basic facilities (Ghate and Beazley, 2007; Beazley, 2009), as is also known for other Indian parks (Karanth, 2007) the process of resettlement of the erstwhile Botezari village and part of the Kolsa village in 2007 has been highly controversial. In May 2009, just a few weeks before writing this manuscript, 16 villagers from the resettlement location returned to their former settlements within the park with the intention of re-building homes and stating there, knowing well that they were facing a strong risk of prosecution. This incident, and the consequent arrest of these villagers, has negatively impacted the likelihood that other households will now consider moving outside the park.

All the interior villages are highly dependent on the park for their basic subsistence and economic needs. They face severe constraints due to the restrictions on their use of their forest by park authorities, and overwhelmingly indicate that the rules devised by forest managers are unfair to them. Their location within the park also creates severe problems due to the lack of access to basic facilities, and frequent wildlife attacks on crops, livestock and even human life. Despite these inimical conditions, the communities living within TATR overwhelmingly indicate their opinion that the forest should be preserved, stating that the park required better protection, and that this could be done quite easily by involving local communities in monitoring. Similar findings have been indicated for other parks in India (Mukherjee, 1997; Mukherjee and Borad, 2004), indicating that forest communities do understand and strongly appreciate the importance of conservation, and can be close allies in the battle to save forests, if properly approached.

There is substantial spatial variation between villages, both in terms of their access to basic facilities, and their vulnerability to wildlife attacks (as also found by Naughton-Treves (1998), in Uganda; Newmark et al. (1994), in Tanzania and Madhusudan (2003), in India). This lack of equity needs to be addressed by park management. To take one extreme, Rantalodhi has the least access to employment opportunities or basic facilities, and the inhabitants of this village predominantly believe that the rules devised by park authorities are unfair, and applied unfairly. In contrast Navegaon and Jamni, the two villages closest to the main park gate, have the greatest access to amenities and employment opportunities. Despite concurring with Rantalodhi that the rules to manage the forest are unfair, they differ from Rantalodhi in their perception that the application of rules is done in a fair manner. Yet not all respondents in Jamni and Navegaon think forest should be protected, while all interviewed residents of Rantalodhi are willing to cooperate with park authorities to protect forest, and have consistently maintained that they would rather stay in the forest than be resettled (Beazley, 2009). This may be a consequence of the fact that Rantalodhi is so much in the interior, with a higher dependence on the forest this village. Such spatial variation in attitudes towards conservation may be far more widespread than is currently recognized (Jim and Xu, 2002; Allendorf et al., 2007).

Our results suggest that much can be achieved by better protection of the peripheral areas of the park, as well as interior areas which appear to be now experiencing increased degradation. The Forest Department should supplement their efforts towards resettlement by increased monitoring of the park periphery, and stricter protection. This cannot be done effectively unless local communities involved. Park managers can enlist interior villages as partners in the conservation effort instead of only treating them as forces inimical to conservation who should be resettled. The spatial differences we observe in the conditions in the park core, edge and areas adjacent to interior villages, as well as the variation amongst villages, need to be incorporated into future strategies for better management of the park and inclusion of the communities who wish to remain in the park as allies rather than enemies.

The spatial variations observed here are unlikely to be unique to the protected area we study, and underline the significance of such an approach of looking at conservation efficacy along multiple axes, and identifying patterns of variation and their underlying causes within the landscape. Such analyses can help significantly in designing more focused, locally specific and ultimately useful, inclusive and sustainable strategies for conservation in developing countries.

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