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Size matters: Scale mismatch between space use patterns of tigers and protected area size in a Tropical Dry Forest

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ABSTRACT

India harbours the largest wild tiger population in the world and Tropical Dry Forest areas constitute the largest habitat for them. Recent extinctions, however, from two high profile tiger reserves, highlight the vulnerability of tiger in this habitat. Our examination of historic range areas for tigers shows that populations are disappearing at a faster rate in Tropical Dry Forest (64% sites suffering local extinction in 100 years) than in any other suitable habitat in India. Focusing on data from the Tropical Dry Forest of Panna Tiger Reserve in central India, we examine the spatial ecology of the tiger population prior to its local extinction. We analyse home range sizes, overlaps and shifts, as well as the range expansion and contraction of radio-collared tigers between 1996 and 2005. In this reserve, the average annual home range sizes for both males ($n = 2$) and females ($n = 4$) were three to four times larger than those reported so far from other tropical habitats in India — male: mean 179.3 ± 11.8 km^2 (95% Fixed kernel; $n = 7$); female: mean 46.6 ± 3.7 km^2; (95% Fixed kernel; $n = 16$). Adult female home ranges were exclusive and overlapped little with neighbouring female ranges (3 ± 1.46%, $n = 6$). Male home ranges were not exclusive: resident floater males shared space with territorial males and mated with resident females. Home ranges of all breeding radio-collared tigers extended beyond the protected area boundary and were exposed to edge effects that exist at the periphery and outside. With such spatial use patterns, security and management measures provided within the boundary are unlikely to be very successful in protecting the population. Protected Areas in Tropical Dry Forest across India are relatively small (366.92 ± 422.12 km^2 SD) and historical trends point towards a scale-mismatch that exists between the size of Protected Areas and the space use requirements of tigers. This scale mismatch adds to the vulnerability of existing small populations and perhaps explains why tiger populations in Tropical Dry Forest have disappeared at a faster rate than in any other tiger habitat of the sub-continent.

1. Introduction

The tiger *Panthera tigris* occupies diverse habitats throughout its distribution range, from the cold temperate forests of the Russian Far East to the hot and humid rainforests and tidal forests of the tropics (Wikramanayake et al., 2004). It occupies these habitats at varying densities ranging from less than 1 to ~18 tigers per 100 km^2 (Carbone et al., 2001; Jhala et al., 2011; Karanth et al., 2004a, 2004b). In the Indian sub-continent, Tropical Dry Forest (TDF) is the largest (>46%) habitat type that supports tiger populations (Smith et al., 2011; Wikramanayake et al., 1998). Despite its importance, most studies in this habitat have only focussed on food habits and estimation of population densities of tigers (Bagchi et al., 2003; Biswas and Sankar, 2002; Karanth et al., 2004a; Kumar, 2000). Home range patterns of tigers can be highly variable across their range and thus can be informative of their space requirements. For example, known home-ranges of tigers vary from a minimum of 16 km^2 in the alluvial flood plains of the Indian sub-continent to several hundreds of square kilometres in the cold climes of the Russian Far East (Chundawat et al., 1999; Goodrich et al., 2010; Jhala et al., 2010; Sunquist, 1981).

Many problems with wildlife populations arise as a consequence of a mismatch between the scale of management and that of the ecological

Abbreviations: TDF, Tropical Dry Forest; PTR, Panna Tiger Reserve.

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processes or natural resources being managed (Cumming et al., 2006; Delsink et al., 2013). In several countries around the world, the size of PAs is often insufficient to hold viable populations of species, especially those that have large space-requirements. The need for adequate space is one of the most important ecological parameters for effective management and conservation of wide-ranging species, such as the tiger (Woodroffe and Ginsberg, 2000).

Home range size of a species is a fundamental behavioural response that results from an individual's interaction with the environment (Benson et al., 2006; Borger et al., 2008; Burt, 1943; McNab, 1963). An understanding of typical habitat-specific home range size is important to provide adequate protected space to tigers in the different habitats they occupy. Studies have documented the role protected areas (PAs) have played in reducing the extinction risk in mammals in India (Karanth et al., 2010) and studies have also documented the importance of PA size in the conservation of wide ranging carnivores (Woodroffe and Ginsberg, 1998). In India, a network of forty eight tiger reserves has been established specifically for the conservation of tigers and their habitat (http://projecttiger.nic.in). Despite this, India has witnessed local extinctions of at least two tiger populations—from the Sariska Tiger Reserve in 2004 and from the Panna Tiger Reserve in 2009. Both of these Tiger Reserves fall in the TDF habitat; these extinctions underline the urgency for a better understanding of the minimum ecological requirement to manage a viable tiger population in this habitat. Our preliminary analysis and the two recent local extinctions of tiger populations from Tropical Dry Forest suggest that in addition to the size of the protected area, certain forest habitats might be more vulnerable than others. In this paper, we examine historic and current records of tiger distribution in India to identify areas and habitat types where tigers were lost in the past 100 years, and use this data to model the vulnerability of protected areas to local tiger extinction based on the size of the protected area and its predominant forest type.

Our study documented tiger space-use patterns of the original tiger population of the Panna Tiger Reserve (PTR) in central India before its extinction and in this paper we conduct a more detailed analysis of those tigers' home ranges. Finally, we explore whether there is a scale mismatch in the space required by tigers and that provided within the protected boundaries of Tiger Reserves and other PAs that could impact the long-term conservation of tiger populations of the Indian subcontinent. This study documents tiger space-use leading up to a local extinction of the studied population and we hope that it provides information to help better management of other tiger populations.

2. Study area

The PTR in Central India encompasses 543 km^2 of Tropical Dry Forest. The perennial river Ken runs through the northern part of the Reserve for almost 50 km. The PTR is characterised by unique step topography and each step or plateau is separated by 10–80 m high escarpments. Though the average annual rainfall is high (1100 mm), most of the rain (60–70%) occurs during two monsoon months — July and August. This wet season is followed by a 7–8 month dry spell continuing from mid-October to early June. Due to its unique topography and long dry season, water becomes a major limiting factor during the summer months when temperatures can regularly exceed 45 °C. There were 13 villages within the Reserve at the time of the study (1996–2005), with a total human and livestock population of 6000 and 9500, respectively. The dominant vegetation type of the area is described as “Dry Teak Forest” (Champion and Seth, 1968). Extensive high density forest occurs along the base of the escarpments, in the deep gorges and in the low lying area and this is intermixed with small patches of grassland and open woodland on the drier slopes. The well-drained plateaux are characterised by wooded to open savannah grasslands. The mixture of dense woodland and dry open savannah created a diverse habitat structure that supported a high density of ungulates [46.36 ungulate/km^2, in 2003 (Chundawat and Sharma, 2008)] and tigers [6.94 tigers/100 km^2 in 2002 (Karanth et al., 2004a)] during the study period. The main prey for tigers in PTR were two deer species — sambar (*Rusa unicolor*) and chital (*Axis axis*); three antelope species — nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella bennettii*) and four-horned antelope (*Tetracerus quadricornis*); wild pig (*Sus scrofa*) and domestic livestock.

3. Methods

3.1. Historic range contractions in India

To identify areas where tigers were locally extirpated in the past hundred years and where they survived, we used maps from various sources. We used Gopal et al. (2014) to generate the historical distribution map, which reports tiger presence in the Indian subcontinent (past 100 years). We used current tiger distribution from the all-India tiger survey (Jhala et al., 2011) and a map of all the PAs collated from sources such as the Ministry of Environment and Forest and Climate Change web site (http://www.moef.nic.in/downloads/public-information/protected-area-network.pdf) and the World Database on Protected Areas (WDPA).

In a GIS, we first assigned PA size (in km^2) and the corresponding habitat type following the classification in Wikramanayake et al. (1998) to each current tiger location. This composite protected area layer was overlaid with the historical layer to identify locations that had tigers 100 years ago. We then overlaid the location layer with the current tiger distribution layer to identify locations that still had tigers in 2010. From this analysis for each location we obtained associated PA size, forest types, tiger presence 100 years ago and tiger presence in 2010. Since PAs were generally established in the best surviving habitats, we used these as point samples to quantify loss of tiger populations in different habitats. We included only potential tiger bearing PAs that were larger than a conservative 50 km^2 for estimating average PA size in order to avoid biases from smaller PAs that were not designated for tiger protection. In total, 203 PAs were classified into five predominant forest categories, Tropical Dry Forest (TDF), Alluvial Grassland and Sub-tropical Moist Forest (AGD), Mangroves, Tropical Moist Deciduous (TMD) and Tropical Moist Forest (TMF) (Wikramanayake et al., 1998). We excluded mangroves from this analysis because of low sample size ($n = 2$ PAs). We chose to use these well accepted broad habitat types so that they are comparable to other parts of the tiger's range in tropical areas.

We used generalised linear modelling with a logistic link (logistic regression) to assess the effect of size of the PA and its corresponding predominant forest type on the probability of tigers going locally extinct. The categorical variable ‘forest type’ was converted to three dummy variables for analysis and used the z-score transformation to normalise the PA size data before analysis. We used the glm tool in R to develop competing models exploring the singular and additive effects of forest type and area on local extinction of tigers. Additionally, we also tested the singular, additive and interactive effects of tropical dry forest category alone with Protected Area size. Akaike Information Criteria (AIC) values were used to derive the “best” competing model from the choice set.

3.2. Space use of tigers

Field studies were conducted between 1996 and 2005 to monitor tiger movement via radio telemetry. Tigers were anaesthetized from elephant back by a team of qualified veterinarians using a combination of Medetomidine (trade name: Zalopine) and Ketamine hydrochloride (except in one instance when a combination of Xylazine HCL and Ketamine HCL was used). A specific reversal agent Atipamazole (trade name: Antisedan) was used to reverse the effect of Medetomidine (Vaha-Vahe, 1989). We used VHF (frequency 150.00–151.00 MHz) radio-collars fitted with an activity sensor (MOD 400 Telonics Inc., Arizona, USA) to track the collared individuals. We estimated the age