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Survival strategy–Temporal segregation of different age and sex classes of a Bengal tiger (*Panthera tigris tigris* Linnaeus) population in Pench Tiger Reserve, Madhya Pradesh India

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Abstract

Temporal activity patterns of different age and sex classes of a Bengal tiger population were studied at Pench Tiger Reserve, Madhya Pradesh between May 2006 and July 2009 using systematic camera traps. Based on the exact time of photo-capture tigers, information on temporal activity patterns of following age and sex categories of individual tigers (resident male (n= 55 photographs), female with cubs or breeding female (n= 70 photographs), female without cubs or non-breeding female (n= 72 photographs) and transient male (n= 42 photographs)) were recorded. Breeding females utilized significantly different activity period compared to transient males (P< 0.001) and females without cubs (P<0.001). Overall activity period between breeding female and resident male did not differ significantly (P >0.6) during the study period. The observed temporal segregation may provide valuable information on cub survival strategies adopted by breeding tigresses, potentially enhancing their reproductive success in a tropical deciduous forest. The adoption of camera trap-based population monitoring studies is advocated for the reproductive behavior of elusive large carnivores such as tigers in the wild on a long-term basis.

Key words: Activity time scale, behavior ecology, Central Indian Landscape, survival pattern

Introduction

Animal behavior is an important component of conservation biology (Berger–Tal et al., 2011) and, hence, is of considerable interest to researchers and wildlife managers (Caro and Durant, 1995). Behavioral studies can increase our understanding of species' habitat requirements (Pienkowski, 1979), reproductive behavior (Cant, 2000) and dispersal or migration (Doerr et al., 2011), and elucidate impacts of habitat fragmentation (Merckx and Van Dyck, 2007) or climate change (Moller, 2004). Animal behavior can also be a useful monitoring tool, with individual- and group-level responses used to evaluate the impacts of management (Morehouse et al., 2016). It is important, therefore, to incorporate behavior into conservation planning; its omission limits efficacy of conservation actions and could lead to failure (Berger–Tal et al., 2011).

Quantifying the behavior of wild animals presents significant challenges. Direct observation of animals can allow the evaluation of individual responses to environmental stimuli. Furthermore, only a limited number of species and habitats are amenable to direct, field-based observations (e.g. larger species and those that can be habituated; and in open and accessible habitats). Many of these have already been the focus of direct behavioral research (Schaller, 1967; Kruuk, 1972; Caro, 1994) or may be atypical of more habitats that are common and can lead to inconsistent results (Mills, 2014).

The activity pattern of a species is an important aspect of its behavioral ecology, reflecting physiological characteristics and ecological interactions (Norris et al., 2010; Frey et al., 2017; Leuchtenberger et al., 2018). How an animal uses time and distributes its activity within the diel cycle is an important niche dimension (Norris et al., 2010; Pianka, 1973). In general, species regulate their activity according to the daily light-dark cycle and may increase activity in a particular period. This allows their classification as diurnal or nocturnal, crepuscular or even cathemeral (Mistlberger and Antle, 2011). Wild animal species could be most active either during daytime or at night or even at dawn and dusk depending upon their circadian rhythm, which in turn depends upon various bodily physiological processes. Detailed information on activity rhythms is crucial in understanding species ecology, adaptation to the environment, and reasonable management strategies for biodiversity conservation. Activity pattern by ecologically similar carnivores were demonstrated in diverse systems (Chen et al., 2009; Di Bitetti et al., 2009; Hayward and Slotow, 2009). The daily activity rhythms of wildcat species, such as - tiger (*Panthera tigris* Linnaeus), leopard (*Panthera pardus* Linnaeus), puma (*Puma concolor* Linnaeus), jaguar (*Panthera onca* Linnaeus), Iriomote cat (*Prionailurus iriomotensis* Imaizumi), Eurasian lynx (*Lynx lynx* Linnaeus), wildcat *Felis silvestris* Schreber and leopard cat (*Prionailurus bengalensis* Kerr) are usually nocturnal or crepuscular (Seidensticker, 1976; Majumder et al., 2012b; Heurich et al., 2014; Tang et al., 2019; Lazzeri et al., 2022).

Although an increasing number of studies have documented animal activity patterns, time partitioning strategies are still poorly understood. For carnivores, temporal activity is likely largely driven by the circadian activity of their main prey species (Ramesh et al., 2012), as well as by thermoregulation constraints that are influenced by time of the day and season (Pigeon et al., 2016). Understanding activity patterns of large mammalian carnivores is particularly important because in some regions large carnivores frequently come into conflict with humans through livestock predation. Carnivore activity patterns have mostly been studied using VHF radio-tracking (Avenant and Nel, 1998), sensors to record activity data (Cozzi et al., 2012), GPS telemetry (Martins and Harris 2013), or camera trapping (Foster et al., 2010). Camera trapping is ideally suited to investigating activity patterns of predators and other wildlife. In addition to eliminating the need for animal capture, camera traps provide date and time-specific information on occurrence of a variety of species, thereby allowing investigations of inter-specific competition (de Satgé et al., 2017; Majumder et al., 2012a) and predator-prey interactions (Ramesh et al., 2012; Puls et al., 2021).

Activity pattern of tigers have been observed either through direct observation from hide (Schaller, 1967), radio-telemetry (Seidensticker, 1976; Chundawat et al., 2002; Majumder et al., 2012) or through camera traps (Ramesh et al., 2012; Majumder et al., 2012b). Presently, time-stamped camera data are increasingly used to study temporal patterns in species and community ecology, including species' activity patterns and niche partitioning. A tiger's time is largely consumed by the need to find food, and tigers typically travel widely to find enough to eat. Not surprisingly, there are few reliable estimates of the distances travelled in the course of a night's hunting. While some hunting activity occurs in the daytime, tigers are mostly nocturnal, exhibiting a pattern of activity that coincides roughly with that of their principal prey (Sunquist, 1981; Seidensticker and McDougal, 1993; Sunquist et al., 1999; Karanth and Sunquist, 2000; Ramesh et al., 2012). However, understanding of the temporal activity patterns amongst various age-sex classes of tiger population in a tropical forest area found to be very crucial for its ecological understanding and effective management. I hypothesize that breeding tigers adopt strategies to survive and ensure cub survival, and in doing so might partition activity time with males/non-breeding females. In this paper, I examined temporal activity patterns of various age and sex classes of a tigers in Pench Tiger Reserve, Madhya Pradesh, to better understand their survival strategy in the tropical forest of Central India. I do this with a first-of-its-kind study of tiger survival strategy and breeding biology using camera trap based temporal activity pattern. Maffei et al. (2002) suggested that monitoring mammals by means of 24-hour camera traps provides reliable data on activity pattern of that species. Since this is a non-invasive tool, it presents advantages over other techniques such as telemetry, which requires economic, human and time resources and sometimes results in less information than that can be obtained with the camera traps in periods of 2 or 3 months (Karanth and Nichols, 1998). While critics suggest drawbacks of old small data sets and short span of time but owing to the importance of the species and the ecosystem, every bit of information is crucial for the management, which need to be interpreted with caution. Our data set was used to investigate our hypothesis within the lifespan of the tiger. On average, a tiger lives 12–15 years in the wild. So it was crucial to examine whether the ecological strategy adopted by various age and sex classes of tigers could impact their survival, and eventually population growth or not. This study provided important ecological insight to conservation communities as the study site i.e. Pench Tiger Reserve (Pench) along with Kanha Tiger Reserve constitutes one of the 11 level-I `Tiger Conservation Units' (TCU) in India classified by Wikramanayake et al. (1998), where tiger population acts as source population in central Indian Landscape (Jhala et al., 2011).

Material and Methods

Study area

The 758 km² of Pench, Madhya Pradesh comprises of Pench National Park or PNP (292 km²), Pench Wildlife Sanctuary or PWS (118 km²) and Reserved Forest (348 km²). The broadly classified forest types of Pench are tropical dry deciduous and tropical moist deciduous forests (Champion and Seth, 1968). Teak *Tectona grandis* L. and its associated species in the area represent a transition from tropical dry deciduous to tropical moist deciduous forests (Fig. 1). The terrain is undulating (350–650 m) in most areas of the tiger Reserve. The climate of Pench is sub-tropical characterized by winter (October-February), summer (March-June) and monsoon (July-September) with a mean annual rainfall of 1400 mm. Temperature ranged from 2 °C in winter to 49.5 °C in summer during the study period. The draw drowns area coming under the submergence of Totladoh reservoir is 11.7 km² and covers 1.55% of Pench (Sankar et al., 2001). As summer approaches, these areas, from where the water gradually recedes downstream, turns into lush green meadows attracting high numbers of wild herbivores. Apart from tiger, the other carnivore species found in Pench are leopard, dhole (*Cuon alpinus* Pallas), jackal (*Canis aureus* Linnaeus) and jungle cat (*Felis chaus* Schreber). The wild ungulates found here are chital (*Axis axis* Erxleben), sambar (*Rusa unicolor* Kerr), nilgai (*Boselaphus tragocamelus* Pallas), gaur (*Bos gaurus* Smith), barking deer (*Muntiacus muntjak* Zimmerman), chousingha (*Tetracerus quadricornis* Blainville) and wild pig (*Sus scrofa* Linnaeus) (Majumder, 2011).

No human habitation is found inside the intensive study area (ISA) i.e. PNP and PWS (410 km²) during the study period between 2006 and 2009. However, domestic livestock such as buffaloes (*Bubalis bubalis*) and cattle (*Bos indicus*) graze along the boundaries of the ISA (Dungariyal, 2008; Majumder, 2011). During this period, there were over 51,648 inhabitants in 107 villages around the notified buffer zone of Pench Tiger Reserve. The locals are predominantly tribal (62%) belonging to Gond and Baiga community.

Study design

A pair of camera traps i.e one opposite to another were deployed in a systematic 2 km X 2 km grid, covering ≥ 250 km² (Table 1 and Fig. 2) and the average minimum distance between two camera locations varied from 1.5 to 2 km. Active and passive infrared-triggered camera traps were used for the present study. Active infrared trail monitoring system consisted of two units: a transmitting unit that sends an infrared beam, and a receiving unit which is set across the target area. A picture is taken when the infrared beam is broken. Passive infrared systems are single units that use heat and motion detector to trigger the camera. Various combinations of remotely triggered ''camera traps'' have been used to arrive at a reliable estimate of the population of tigers in different tiger reserves. I used widely available film camera system in active infrared trail monitoring system i.e. Trailmaster™ and Infrared Digital camera system Moltre™ IR and White Flash between May 2006 and July 2009. Camera traps have been deployed in the systematic grid to avoid any spatial gap. Camera trap locations have been selected based on the indirect evidences of tigers. To maximize the capture, camera traps were placed in the best suitable spot in the grid. Camera trapping devices were placed one opposite to another to photograph simultaneously both flanks of an animal. To eliminate mutual flash interference, the two cameras were not positioned directly facing each other.

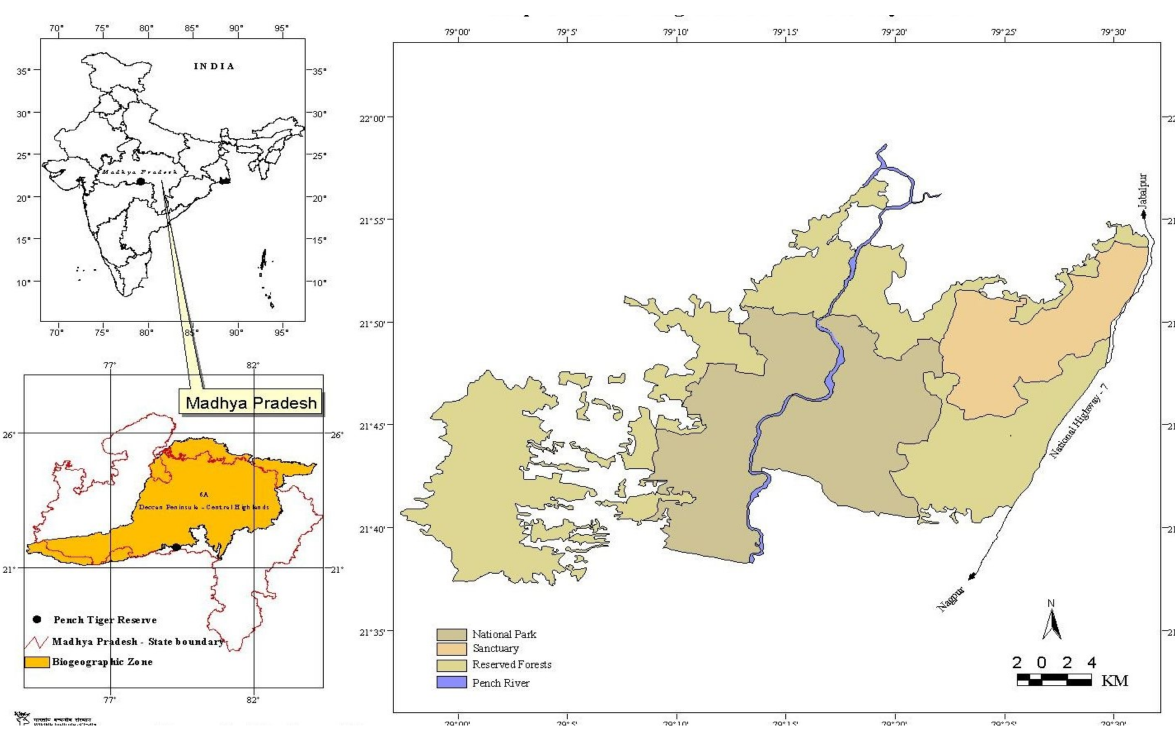

Figure 1: Study area Pench Tiger Reserve, Madhya Pradesh (Source: WII report).

Table 1: Characteristics of camera trap efforts used during the sampling period in Pench Tiger Reserve, Madhya Pradesh (2006 to 2009).

Session	Period	MCP (sq km)	Total no of CT	Total Number of Trap days	Total Trap nights
1	27-5-06 to 31-7-06	151	36	65	2376
2	23-1-08 to 28-5-08	274	52	127	6604
3	17-1-09 to 15-6-09	274	50	150	7500

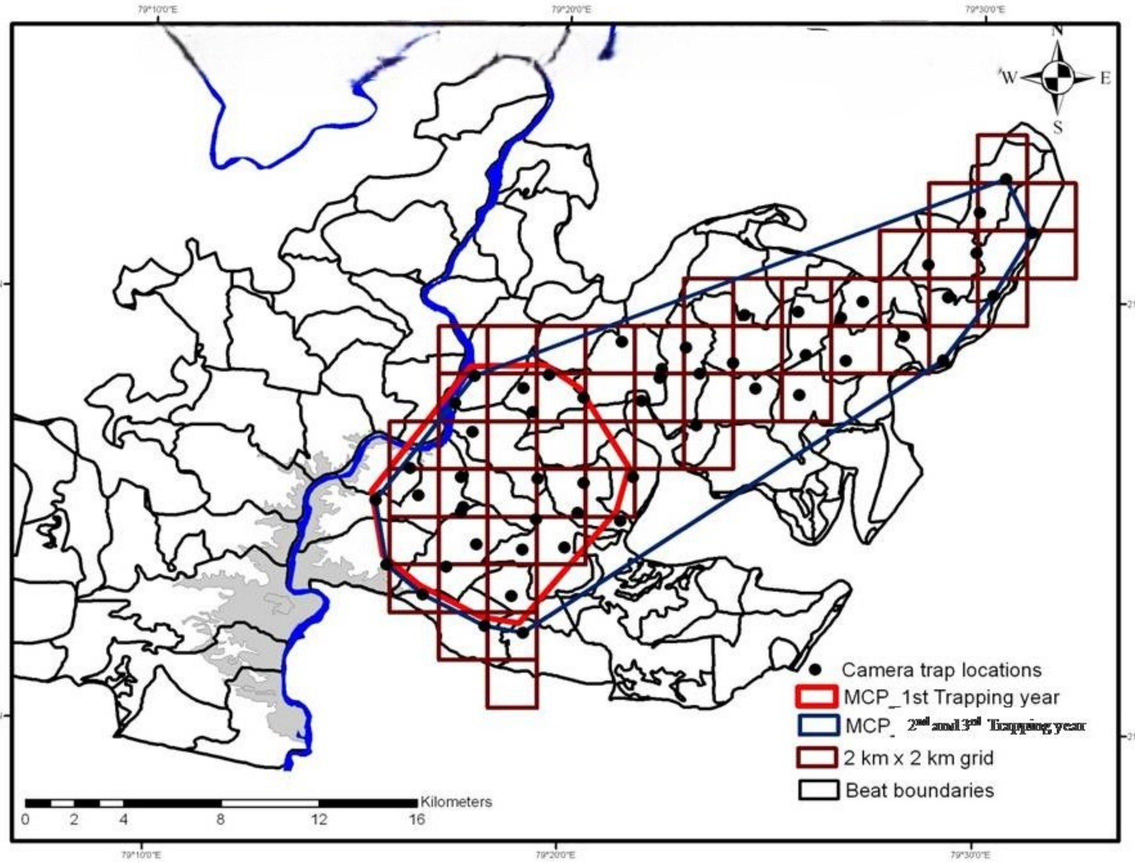

Figure 2: Camera trap locations in Pench Tiger Reserve, Madhya Pradesh, India.

The camera delay was set at minimum (0.1= 6 sec for both active and thermal sensor cameras and 1 min for passive motion sensor cameras) to minimize chances of missing pairs or cubs with mother and based on our initial trial and error approach keeping the gait and the size of the animal., No bait or lure was used to attract tigers towards the camera stations. Proper camouflaging of cameras was done to avoid trap shyness (Majumder et al., 2017). Even I moved camera traps ± 100 m from original locations to reduce instances of trap shyness and increase the probability of capture. New spots were selected based on the available tiger signs.

All camera traps were monitored on a daily basis and data were recorded in a standard format for each year. To minimize bias in the identification process, all tiger photographs were examined independently by one person. Each photograph of an individual represented a capture occasion. To maintain independency in pictures clicked, a gap of 45 minutes were kept as per the standard protocol followed in All India Tiger Estimation programme (Jhala et al., 2015) and also based on the local field knowledge. While pooling of camera trap photographs, based on field observations, two hour time intervals were kept to study activity patterns of various age and sex classes of tiger.

Age sex categories

An understanding of the organization of a population is important for its long term conservation as it gives us information not only on the internal balance between various components [age and sex] of the population of a species, but also how various components of a population interact with their environment (Majumder et al., 2017). In accordance with Burlow et al. (2009), Karanth and Stith (1999) and Majumder et al. (2017), following age-sex categories of tiger have been assessed for the present study, 1) Resident male – this category includes only those adult male tigers found with established territories ≥ 2 years in the study area, 2) Female tiger with cubs - this category includes only those adult female tigers found with established territories ≥ 2 years in the study area and with cubs, 3) Transient male- this category includes only those male tiger capture once throughout the trapping session and not photo-captured in subsequent trapping occasions. 4) Non breeding female or female without cubs- Female tiger photo-captured without cubs and 5) Cubs - this category includes age class of tiger ≤12 months.

The study area management has an excellent practice of regular tracking and monitoring of resident tigers by camp elephants which also enhanced the accuracy on breeding and non-breeding individuals. To cross validate the camera trap data set, information of radio collared individuals and regular monitoring data have been used.

Data Analysis

As camera traps were operated for 24 hrs basis during the study period, information on temporal activity pattern was obtained for different age and sex categories of tiger. No significant (p> 0.06) difference was observed between their seasonal activity patterns hence their total photographs were pooled for three years (2006, 2008 and 2009) into two hour time categories. Watson U^2 test (Mardia and Jupp, 2000) in Oriana Version 3 (Kovach Computing Services) was performed to evaluate the difference in time activities between different age and sex categories.

Overlapping of activity period

To illustrate the temporal segregation, I investigate the overlapping on activity pattern between aforesaid age and sex classes of tigers. Following combinations of age and sex classes i.e. i) Resident breeding male and female with cubs, ii) female with cubs and female without cubs, iii) Resident breeding male and transient male, iv) Female with cubs and transient male, v) Female without cubs and transient male and vi) Resident breeding male and Female without cubs were compared using T test and One-Way Analysis of Variance (Zar, 1984) by NCSS software (NCSS 2021, v21.0.2) (Ridout and Linkie, 2008). The pattern of overlap on activity periods would help us to determine their coexistence pattern and avoidance in a deciduous forest. The temporal activity of age and sex of tigers may reflect trade-offs between avoidance of competitors and optimizing reproductive success.

Results

Based on the exact time of photo-capture of identified various age and sex categories of individual tiger: such as Resident male (n= 55 photographs), female with cubs or breeding female (n= 70 photographs), female without cubs or non-breeding female (n= 72 photographs) and transient male (n= 42 photographs), information on temporal activity patterns of tigers were recorded. Detail of male, female and cub populations have been given in Table 2.

Overlapping of activity period

Activity period of resident male, female with cubs, female without cubs and transient male tigers were compared to study any significant overlap on their activity periods (Figs. 3–8). It was observed from both T test and One-Way Analysis of Variance that breeding female i.e female with cubs significantly utilized different activity period with transient male (P<0.0001) and female without cubs (P< 0.0001) whereas overall activity period between breeding female and resident male did not differ significantly (P >0.6) during the study period. Resident male significantly differed on activity time period with transient male (P< 0.0001) but not with female without cubs (P >0.08).

Discussion

An important aspect in temporal activity pattern studies show animals' behavioral responses to other individuals in the population. Patterns of co-occurrence among sympatric large predators i.e. tiger and leopard are governed by their density, distribution, diet, activity overlaps, and behavioral strategies (Chatterjee et al., 2023). Amongst mammals, the activity of predators is often synchronized with the activity of their prey (Daan and Aschof, 1981; Zielinski et al., 1983; Monterroso et al., 2013), or shaped by the need of avoidance of humans or other competitors (Wang et al., 2015; Mori et al., 2020; Murphy et al., 2021). As a matter of fact, nocturnal activity is one of the strategies that wildlife adopts to avoid encounters with humans (Gaynor et al., 2018; Nickel et al., 2020). Wildcats show several physical and physiological adaptations to nocturnal or crepuscular activity, mainly involving hunting and courtship behavior. These adaptations include an acute auditory sense, an improved tactile sense from vibrissae and other hair tufts, and an acute sense of smell for maximizing the activity at dark (Tabor, 1983), which may explain why they are mostly reported as nocturnal species.

Table 2: Population estimation of tiger in Pench Tiger Reserve, Madhya Pradesh (2006 to 2009).

Year	Parameters	N	No of Capture	p-hat M (h)	Population ±SE M (h)	Cubs
2006	Male	3	48	0.18	3±0.01	8
	Female	11	42	0.04	13.9±2.5	
	Over all	14	90	0.06	17±2.6	
2007–2008	Male	6	33	0.05	6.6±2.6	19
	Female	12	38	0.02	12±0.9	
	Over all	18	71	0.02	22.1±4.4	
2009	Male	8	18	0.015	8.2±2.6	6
	Female	9	18	0.01	13.5±5.9	
	Over all	17	45	0.011	21.1±2.4	

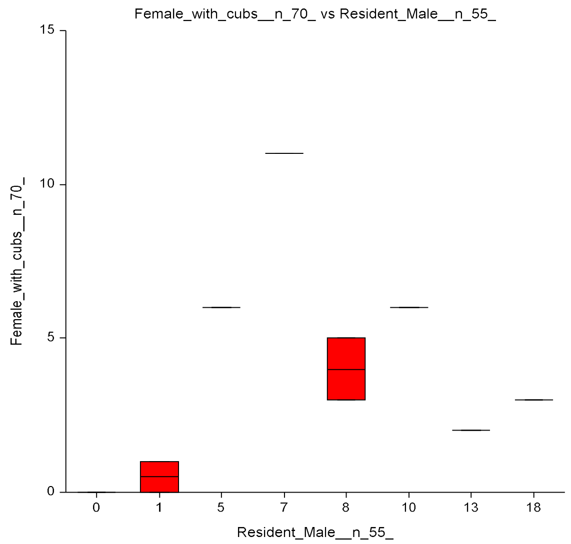

Figure 3: Female with cub vs resident male comparison.

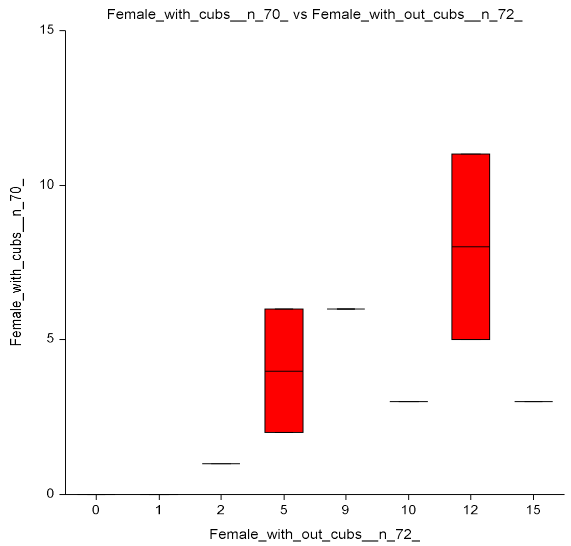

Figure 4: Female with cub vs female without cub comparison.

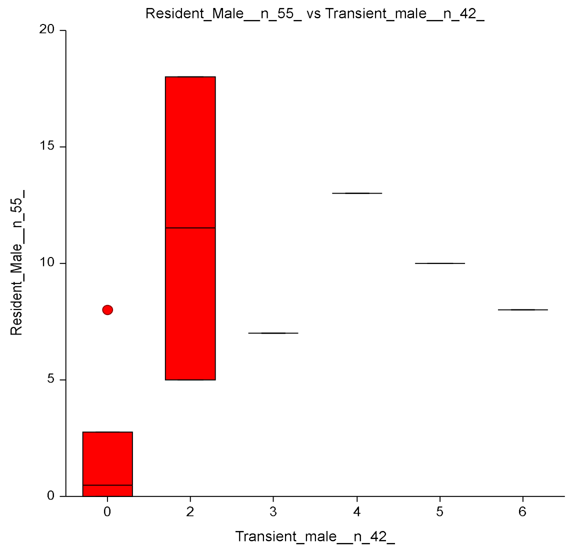

Figure 5: Resident male vs transient male comparison.

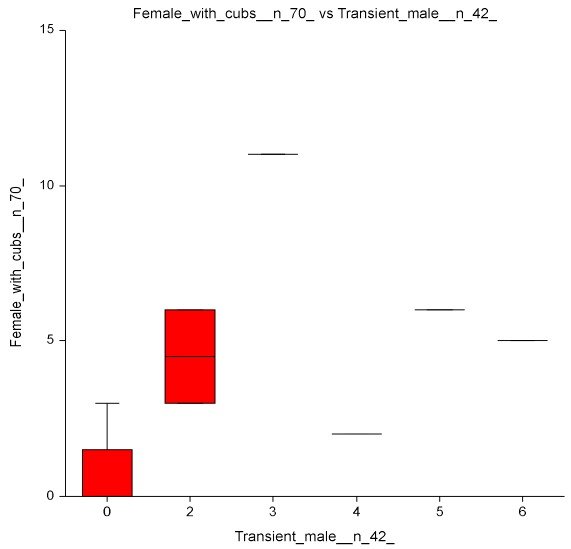

Figure 6: Female with cub vs transient male comparison.

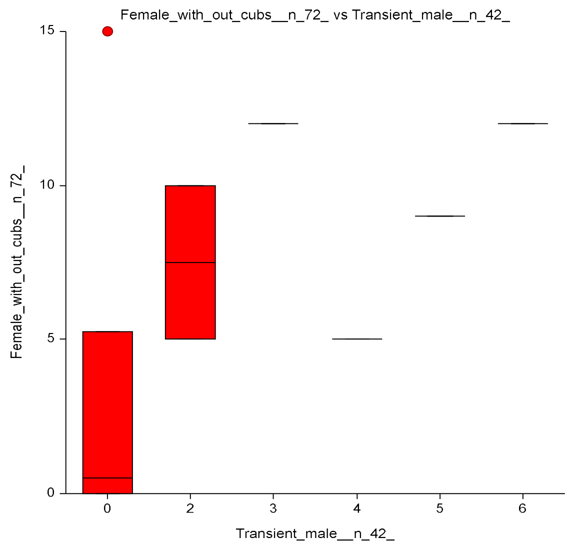

Figure 7: Female without cub vs transient male comparison.

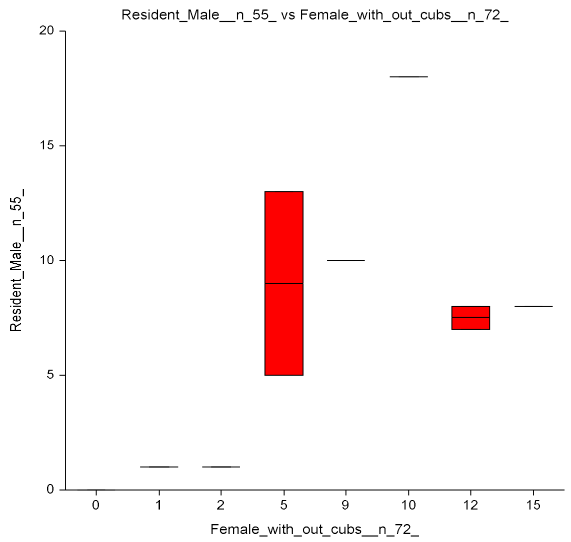

Figure 8: Resident male vs female without cub comparison.

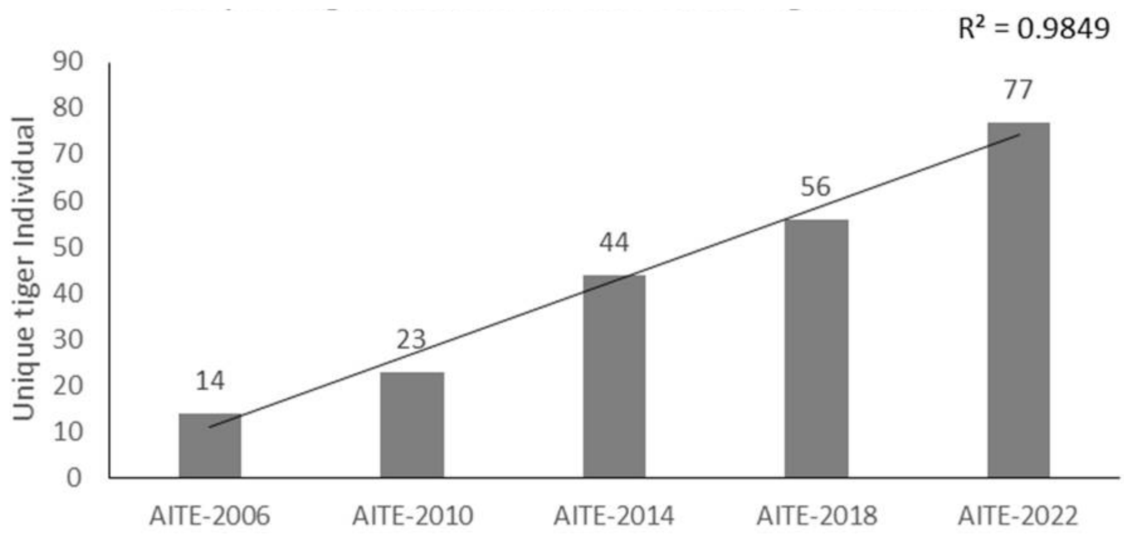

Figure 9: Unique tiger population growth rate in Pench Tiger Reserve, M.P. based on various cycles of All India Tiger Estimation (AITE) (Data Source: National Tiger Conservation Authority and Wildlife Institute of India's tiger estimation reports).

Various age and sex classes of tiger used different temporal activity peak in the present study, potentially to enhance their reproductive success and survival strategy. According to Singh et al., (2014), "Observations and results from behavioral decisions made by tigers are important to understand the species and the factors that facilitate their conservation". Breeding tigress might adopt a strategy to protect her cubs from infanticide, utilizing different temporal activity periods compared to female without cubs and transient male tigers. In many instances of non-parental infanticide observed in carnivores, especially in cats, the male of species kills the cubs of a female to make her sexually receptive. Novak (1999) recorded transient/floating male committed infanticide of tiger cubs of other male. Baker et al., (2012) observed, female jaguar did not tolerate the presence of non-parent male in fear of infanticide. Packer and Pusey (1983) reported that, new males of a lion pride killed any existing young cubs fathered by the defeated male lion and Macdonald (1984) observed that, as many as 80% of lion cubs die before they reach the age of two due to infanticide by non-parent male.

Resident breeding male and female with cubs utilized the same activity peak. I speculate this might to ensure survival of their cubs, and protect them from possible infanticide from other males. Interestingly, parental care by male tiger was also reported in the wild at various study sites of India (Majumder et al., 2013; Gupta, 2016). Although adult male tigers are largely solitary (Schallar, 1967; Sunquist, 1981), according to Cavalcanti and Gese (2009), "A species may be considered solitary, but an individual may eventually meet with conspecifics". Barlow et al. (2009) observed that loss of resident males increases cub mortality substantially through infanticide and temporarily limits the supply of individuals available for replacing residents who die. The high survival rate of cubs (> 73%) in Pench might be due to protecting strategy adopted by residential breeding male in their early growing stage (Majumder et al., 2017).

The transient male showed significant differences ($P < 0.001$) in temporal activity pattern with resident adult male, which could be to reduce intra-specific competition (Schaller, 1967). Resident male tigers compete for access to breeding females and territory sizes expand and contract depending on the number of resident females a male can successfully defend (Schaller, 1967; Majumder et al., 2012). Previous studies revealed that intense competition among male tigers to access breeding females, just acquiring a territory and defending it long enough to mate, results in high turnover rates and large differences in reproductive success among territory holders. Intra-specific fighting and incidences of infanticide, especially in high-density tiger populations, often accompany changes in territory holders (Sunquist, 2010).

The present study is probably the first it kind to determine temporal segregation of various age-classes of tiger as their survival strategy using camera trap devices. Monitoring of large carnivores is extremely difficult owing to its extensive spatio-temporal distribution, secretive life, low detectability and low densities (Majumder et al., 2017). However, issues regarding sampling design in a camera trap studies have received less attention (Silver et al., 2004). Since the data collected from this study seems adequate to answer various questions pertaining to sampling design, I attempted to do so.

During the study period the trapping area was expanded from the first trapping session to the rest of the trapping sessions due to availability of trapping resources. Since tigers are long-lived (Sunquist, 1981; Smith, 1993) and sampling was carried out between

100 and 150 days during the present study, it was found that the sample population was demographically closed and assumption of demographic and geographic closure was not violated. Based on the empirical data from my present study, the observed temporal segregation in various age and sex classes may provide insight on cub survival strategies adopted by breeding tigresses, finally, aiming at their reproductive success in a tropical deciduous forest. Apart from high prey density and proactive management intervention, the strategy adopted by various age and sex classes of tigers might be one of the most important reasons for constant increase in tiger numbers in this tropical deciduous forest. Results of various cycles of All India Tiger Estimation (AITE) programme has revealed a gradual increase of tiger population over the period from 2006 to 2022 (Fig. 9) (R^2= 0.9849) in Pench Tiger Reserve, Madhya Pradesh (Jhala et al., 2008, 2011, 2015, 2019; Qureshi et al., 2023).

Conserving tiger in any human dominated landscape of India is a daunting task for forest managers. In the Indian sub-continent most of the forested habitat is fragmented and connected by narrow corridors (Jhala et al., 2011). Therefore it is vital that this critical nursery of tiger is protected and should be monitored regularly, using advanced scientific tools and technologies. This paper will act as a catalyst, advancing the adoption of camera trap based reproductive behavioral study of any illusive large carnivore at *in situ* condition.

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Author contributions

Aniruddha Majumder has collected and analyzed data and written this Manuscript by himself.

Conflict of interest

I declare that there are no conflicting issues related to this research article.

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