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Research Article

The spacing pattern of reintroduced tigers in human-dominated Sariska Tiger Reserve

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Abstract

This study aimed to estimate the tiger home range size and obtain information on the movement pattern of reintroduced tigers in the human-dominated Sariska Tiger Reserve. The observed extensive home ranges (100% MCP method) of tigresses ST3 (172.75 km²), ST9 (85.25 km²), and ST10 (80.10 km²) can be attributed to low prey base and very high anthropogenic forces. Similarly, the observed small home range of tigresses ST7, ST2, ST14, and ST8 *viz*. 16.59 km², 19.34 km², 36.58 km², and 43.04 km² respectively is due to high prey abundance in their respective areas. The high home ranges of subadult ST13 & ST15, respectively, up to 687.58 km² and189.46 km² is due to the initial exploration of their territory. After settling in their respective territories, ST13 in North of STR and ST15 in the south, their mean monthly home ranges respectively decreased to 61.37 km² and 47.67 km². The observed larger mean home ranges (based on 100% MCP method) of ST4 (85.40 km²) and ST6 (79.94 km²) as compared to young ST13 (61.369 km²), ST11 (57.63 km²), and ST15 (47.67 km²) may be due the reason of early occupancy of the respective areas by these old tigers. Non-expansion of the home ranges of any of the remaining four male tigers (ST4, 6, 13, and 15) after the killing of ST11male tiger in STR suggests non-exploratory behavior of already settled male tigers. The observed high average monthly displacement of the home range for sub-adult ST15

can be justified regarding its dispersal from the natal area to the south of STR. Exploring the southern part of the reserve and finally settling in a smaller area with minimum displacement of monthly home ranges can be other justification as well.

Keywords: Dispersal, home range, monitoring, movement pattern, reintroduced tigers

Introduction

Tiger (*Panthera tigris* L.) is the largest of all felids and is found in diverse habitat types with remarkable tolerance to the variation in altitude, temperature, and rainfall regimes (Sunquist et al., 1999). The substantial differences in prey abundance (Sunquist et al., 1999) due to environmental variations is the reason in its distribution range from tropical forests of Southeast Asia to temperate, boreal forests of Russia Far East. The home range is generally traversed by an individual animal or group of animals during activities associated with feeding, resting, reproduction, shelter seeking, and other factors essential to an animal's survival (Burt, 1943; Harestad & Bunnell, 1979; Sanderson, 1966). It has been argued that solitary female felids should maintain home ranges just large enough to contain enough prey to meet the energetic demands of reproduction, with exclusive home ranges expected only when resources are distributed evenly, both spatially and temporally (Sandell, 1989). Many studies have documented male felid home-range sizes much more extensive than expected based on energetic demands, suggesting that other factors such as maximizing breeding opportunities influence male home-range size and degree of exclusivity (Sandell, 1989).

Following the extermination of tigers (*Panthera tigris tigris*) in Sariska tiger reserve (hereafter will be called STR), western India in 2004 due to poaching, the reintroduction of tigers was done from Ranthambhore tiger reserve by translocating an initial population of five tigers (two males and three females), with a plan of supplementation of two tigers (male and female) in every three years for six years (Sankar et al., 2005). This was the first example of the successful relocation of big cats in the Indian subcontinent. A total of 9 tigers from Ranthambhore have already translocated to Sariska using different means of transport. Three male (ST1, ST4, ST6) and five female (ST2, ST3, ST5, ST7, and ST8) tigers were brought from Ranthambhore. In the year 2012, ST2 delivered two cubs (ST7 and ST8). The orphan cubs, ST9 and ST10 were born from Ranthambhore in 2013. A young male ST16 was translocated in 2019. While ST10 delivered two cubs (ST11 and ST12), and ST2 produced its second litter of two cubs (ST13 and ST14) in the year 2014. With the reported birth of two cubs to ST14 in 2018, three cubs to ST12, and one cub to ST10 in 2020, and with the mortality of four tigers (ST1, ST11, ST5, and ST4) the current population of tigers in STR is 16 with one cub. None of the tigers born in Sariska was radio-collared except ST11 and ST13; both are male. When the sub-adult male ST13 strayed out and became resident of the inhospitable Rajgarh forest area for eight months, it was localized and immobilized, radio-collared, and again translocated in Sariska. Based on the established significance of radio-telemetry (Trent & Rongstad, 1974; Sunquist, 1981; Smith et al., 1987a; Smith et al., 1987b; Quigley et al., 1989; Soisalo et al., 2006; Eric et al., 2008; Kelly et al., 2008; Jhala et al., 2009) so far nine tigers were radio-collared and rest of others are monitored based on pug marks and camera traps.

While observing the straying of ST13 outside the reserve and the movement pattern of sub-adult male tigers ST15 in 2017 to 2018 and possible increment of tiger number in the future, we attempted to map and compare the home ranges of different tigers in STR. The study will help better organizational planning concerning possible human-tiger conflict with the future dispersal of cubs

of ST14 and ST12 in a human-dominated landscape. We also hypothesized that (1) that there is an increase in the home range of male tigers after the mortality of ST11 in the middle of Mar 2018, and (2) there is a clear segregation of monthly home ranges of male tigers.

Material and methods

Study area

The study area, the STR is situated in the Aravalli hill range and lies in the semi-arid part of Rajasthan (Rodgers & Panwar, 1988). The terrain is undulating to hilly and has numerous large (Sariska—Kalighati and Umri, etc.) to narrow valleys, two vast plateaus—Kiraska and Kankwari, and two large lakes, Mansarovar and Somasagar.

It is located in the Alwar district of the state of Rajasthan. After expanding its area, it was increased from 881 square kilometers to 1213.31 square kilometers due to buffer area (Fig. 1) with some part of buffer (Jamwa Ramgarh Sanctuary) in the district of Jaipur.

The vegetation of Sariska is tropical dry deciduous forests (Champion & Seth, 1968), with *Anogeissus pendula* as the dominant species in the undulating area and on the hills. *Boswellia serrata* and *Lannea coromandelica* grow on steep rocky areas. *Acacia catechu*, *Zizyphus mauritiana,* and *Butea monosperma* are found in valleys. *Dendrocalamus strictus* is extremely limited in distribution and is located along the well-drained reaches of the streams and moist and colder part of the hills. Among bushes, *Grewia flavescence* and *Capparis sepiaria* form essential components of vegetation of the reserve.

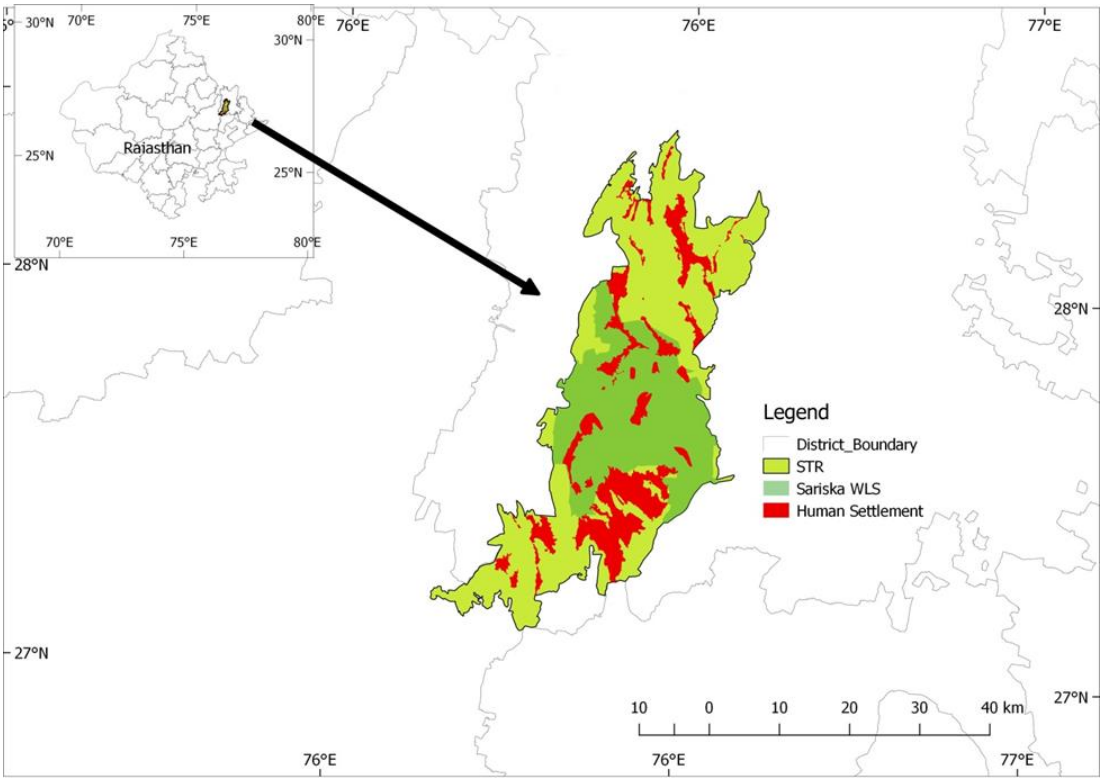

Figure 1. Map showing STR with human settlements inside

Apart from the tiger *Panthera tigris*, other carnivores include leopard *(Panthera pardus)*, striped hyaena *(Hyaena hyaena)*, jackal *(Canis aureus)*, jungle cat (*Felis chaus*), common mongoose *(Herpestes edwardsi*), small Indian mongoose (*H. auropunctatus*), ruddy mongoose

(*H. smithi*), palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*) and ratel (*Mellivora camensis*). Chital (*Axis axis*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), and wild pig (*Sus scrofa*) are the dominant natural prey species for tigers found in Sariska. Other wild prey species found are common langur (*Semnopethicus entellus*), Rhesus macaque (*Macaca mulatta*), porcupine (*Hystrix indica*), rufous tailed hare (*Lepus nigricollis ruficaudatus*), and Indian peafowl (*Pavo cristatus*). About 175 villages are situated in and around Sariska Tiger Reserve. Out of these, 29 villages (now 26 after the relocation of three villages) are in the Critical Tiger Habitat/ Core area, and the rest 146 villages are outside the forest area. About 2254 families live in the core area, while about 12000 families live around the critical tiger area (Shekhawat, 2015) thus making this reserve a human-dominated landscape that is subjected to immense anthropogenic pressures. There are ten villages located inside the National Park area, which are still due for relocation since 1984. The human population is over 1700 in the villages of National Park and a population of 10,000 livestock, including buffalo, cow, goat, and sheep (Sankar et al., 2009). The rest of these villages' human population is around 6000, and the livestock population is more than 20,000 (Sankar et al., 2009).

Material and methods

The monitoring of reintroduced tigers with radio-telemetry (VHF-Argos Satellite) was taken as a foremost priority in the human-dominated landscape of Sariska Tiger Reserve. The radio-collared tigers were monitored periodically through ground tracking using "homing in" and "triangulation" techniques (Deat et al., 1980; Macdonald & Amlaner, 1980; White & Garrot, 1990). ST2, ST7, ST8, ST12, ST14, and ST15 are monitored based on their pugmarks. The tigers were tracked by different monitoring parties (n=12) who always follow the tigers assigned to them. Each monitoring party consists of two persons, one forest guard, and a local villager trained in monitoring tigers using VHF collar and pugmarks.

To estimate the number of locations necessary to estimate home-range size, we plotted the number of areas (chosen randomly concerning date) against home-range size for tigers tracked for at least 1 year and with at least 100 locations. The asymptote indicated the minimum number of locations needed to estimate the home-range size. The interpretation and comparison of home-range size were also measured by 100% MCP (Mohr, 1947; Anderson, 1982; Southwood, 1996). The use of MCPs was justified because of the sample size in the one-year study period and the temporally clustered nature of fixes that resulted in the autocorrelation of results (Swihart & Slade, 1985). MCP tool (mapping a polygon based on the extreme point positions of a cluster) of QGIS was used. We estimated each tiger's age based on their reintroduction record, known birth dates of young belonging to radio-collared mothers, evidence of having reproduced, and breeding behaviors noted after capture. Based on these data, we classified animals as juveniles (<1.5 years), sub-adults (1.5–3 years), or adults (>3 years—Goodrich et al., 2001; Kerley et al., 2003; Nikolaev & Yudin, 1993). With the objective as defined in the introduction, attempts were made for studying the area utilization of different tigers, especially concerning male tigers in STR from Sep 2017 to Aug 2018.

Results

Among tigresses, the home ranges (100% MCP) varies from 16.59 km² (ST7) to 172. 75 (ST3). Fig. 2 shows the column chart depicting all tigers' home range based on their location data from Sep 2017 to Aug 2018. Extremely low area occupancy *viz*. 19.34 km² and 16.59 km² for tigresses ST2 and ST7 were observed. Maximum area occupancy (172.75 km²) of tigress ST3 was observed during the observation period. That of ST 9 follows it, showing an area occupancy of 85.24 km²,

ST10 (80.10 km²), ST5 (51.91 km²), ST12 (50.87 km²), ST8 (43.04 km²), and 36.58 km² for ST14.

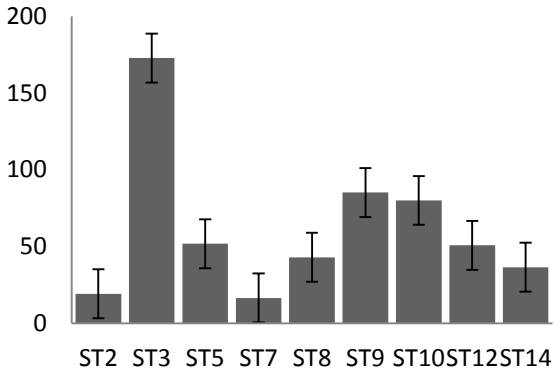

Figure 2. Column chart depicting the home range of all tigresses based on their location data from Sep 2017 to Aug 2018

A comparatively higher home range for tigers relocated earlier was observed in STR compared to new tigers born later. The maximum home range was found for ST11 (646.04 km²). It is followed by ST4 (598.80 km²), ST13 (372.49 km²), and ST6 (286.71 km²). While attempting to get mean of home ranges of all months from Sept 2017 to August 2018, maximum was observed for ST4 (85.40 km²), ST6 (79.94 km²), ST13 (61.39 km²), ST11 (57.63 km²), and the minimum was recorded for ST15 (47.67 km²) (Table 1).

Table 1. Comparison of cumulative and mean monthly home ranges male tigers in STR

Tiger	Approximate Age (years)	Cumulative home range km² 100% MCP	Mean monthly home range in Km²
ST 11	4	646.04	57.63
ST15	2.5	326.73	47.67
ST13	4	372.49	61.39
ST4	13	598.80	85.40
ST6	12	286.71	79.94

Although during the initial months of separation from mother tigress ST9, the area occupancy of ST15 was observed to be maximum in Oct 2017 (*viz*.189.5 km²), later it decreased gradually when it settled in an area located in the southern part of STR (Table 2).

Table 2. Monthly area occupancy (km²) of male tigers in STR

Month	ST 11	ST15	ST13	ST4	ST6
Sep	66.9	18.6	44.8	119.4	98.3
Oct	43.6	189.5	39.6	118.0	79.6
Nov	37.0	62.4	35.5	263.4	64.9
Dec	56.1	43.9	32.9	84.0	51.1
Jan	75.4	105.4	77.8	100.1	97.3
Feb	57.8	18.9	26.1	96.1	143.2
Mar	66.7	19.9	81.3	34.6	77.3
Apr	0.0	10.5	67.9	23.7	59.9
May	0.0	11.7	121.7	38.6	39.2
Jun	0.0	22.6	78.1	42.7	53.8
Jul	0.0	43.6	73.1	56.2	96.4
Aug	0.0	25.2	58.0	47.9	98.3

While attempting to hypothesize whether there is an increase in male tigers' home range after the mortality of ST11 in the middle of March 2018, a decreasing trend in mean area occupancy by different tigers was observed from Sep 2017 to Aug 2018, negating the hypothesis (Fig. 3).
Attempts were made to know the extent of overlapping of the area occupancy of different male tigers. Although the overlap of the tigers' area was observed when the MCPs for the cumulative data of all the months were plotted on the map (Fig. 4) but clear segregation of area occupancy among all-male tigers was observed when analyzed for individual months *viz*. Mar 2018 to Aug 2018 supporting the hypothesis of a clear separation of monthly home ranges of male tigers (Fig. 5).

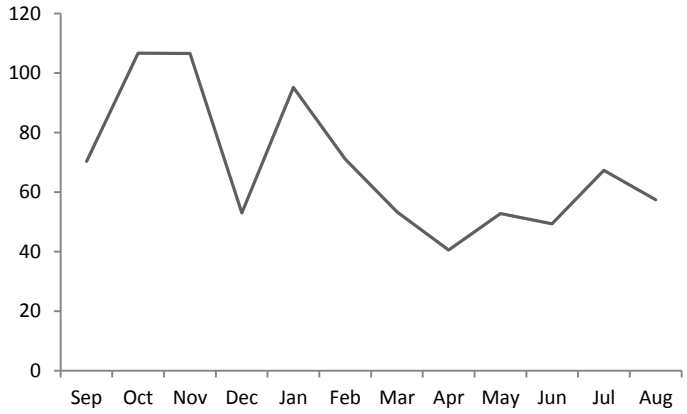

Figure 3. Line graph showing the trend of the average area of four male tigers

Table 3. Area overlapping between the tigers as observed during different months (Sept 2017 to August 2018)

	ST4-ST6	ST4-ST11	ST4-ST13	ST6-ST11	ST6-ST15
Sep 17	**	24.95	1.7	**	1.79
Oct 17	**	**	6.48	**	16.7
Nov17	**	30.03	22.74	0.74	**
Dec 17	**	**	0.67	**	**
Jan 18	0.36	**	17.29	0.64	**
Feb 18	34.67	**	4.6	**	**
Mar 18	**	**	**	**	0.49
Apr 18	**	**	**	**	0.04
May 18	**	**	**	**	0.2
Jun 18	**	**	**	**	**
Jul 18	6.57	**	**	**	2.23
Aug 18	4.33	**	**	**	0.84

The maximum overlap of the area occupancy until February 2018, especially between ST 4-ST11 and ST4-ST13 was observed among the young male tigers (Table 3). It was when they were found to be establishing their territories and exploring more and more areas in reserve. A sharp decline in the overlap was observed from March 2018 onwards after the mortality of ST11. It was found that male tigers overlapped almost entirely with some females but very little with others. So we divided male-female overlap into two categories, sympatric and neighboring. Except for the youngest sub-adult male ST15, all the males have overlapping home ranges with females with ST4 overlapping with area occupancy of almost all of the females (sympatric). The home range of ST6 also overlaps with all females except ST10 and ST12. The observation of an extensive female overlapping home range of ST11 was due to its exploratory nature of sub-adult male behavior before settling.
The contraction-expansion of the home ranges of tigers is attributed to a decrease or increase of

home ranges of individual tigers, as depicted in table 2. The monthly shift (home range displacement) can be expressed as the distance between the centroids of two polygons of home ranges as observed for two different months of the tiger under observation using GIS software. Table 4 shows the home range displacement (polygon centroid displacement) for various months as observed for other male tigers, as seen from Sep 2017 to Aug 2018. We found the maximum average monthly displacement of the home range (4.23 km) for ST15 to establish its territory during the period. It is followed by that of ST4 (2.04 km), ST13 (1.88 km), ST6 (1.69 km), and the minimum was recorded for ST11 (1.51 km) that was killed on March 18 (Table 4).
We observed a very high monthly displacement of home range for ST15 during the initial months of territory exploration. Then a decrease was observed in its monthly displacement when it settled down (Fig. 6).

Table 4. Home range displacement (polygon centroid displacement) for various months as observed for different male tigers, as seen from Sep 2017 to Aug 2018

Tiger → **Displacement of home ranges for Months in kms ↓**	**ST4**	**ST 6**	**ST11***	**ST13**	**ST15**
Sep-Oct	4.46	0.983	0.18	1.08	19.74
Oct-Nov	3.42	0.7	0.8	1.62	5.83
Nov-Dec	3.21	3.78	3.53	1.21	4.5
Dec-Jan	3.38	0.263	2.8	2.54	4.4
Jan-Feb	2.81	4.17	1.38	3.8	3.8
Feb-Mar	2.67	3.9	0.39	2.4	5.85
Mar-Apr	0.9	0.661	0	0.85	2.27
Apr-May	0.98	1.97	0	1.67	0.69
May-Jun	0.72	0.791	0	1.53	1.32
Jun-Jul	0.69	1.7	0	1	1.48
Jul-Aug	1.2	1.34	0	4.91	0.85

**ST11 mortality in March 2018*

Discussion

Past studies demonstrated that tigers' female spatial organization is because of female tigers' area occupancy patterns (Sandell, 1989; MacDonald, 1983). Most of the Amur tiger *Panthera tigris altaica* home ranges were associated with lack of sufficient prey and low habitat quality (Goodrich et al., 2005; Goodrich et al., 2010; Miquelle et al., 1999). Whereas in the Indian sub-continent relatively small size of adult female home range is attributed to the spatially homogenous and high abundance of prey species (Sunquist, 1981; Smith et al., 1987a; Smith, 1993). The present study's observation demonstrated small area occupancy of tigresses ST7, ST2, ST14, and ST8 *viz*. 16.59 km², 19.34 km², 36.58 km², and 43.04 km² respectively is due to high prey abundance in their respective areas is consistent with earlier studies. Further, the observation of these tigresses' proximity may also be attributed to female philopatry as the ST7, ST8, and ST14 are the progeny of ST2 and resulted from home range contraction of ST2. The observed area occupancy of ST2 contracted from 181.4 km² (Sankar et al., 2010) to 19.34 km². Such female philopatry has been documented in many carnivore species, with sub-adult females often inheriting a portion of their natal home range and males generally dispersing longer distances than females (Goodrich et al., 2010). In two of the documented cases in Sikhote-aline Biosphere Zapovedik, Russia, mother tigresses *Panthera tigris altaica* divided their territories for her offspring. Although there are studies suggesting inheritance of maternal home ranges for Bengal tigers probably serves to increase the

reproductive success of daughters (McDougal, 1977; Smith et al., 1987a), however only one female cub (ST14) of ST2 out of her three female cubs from two litters successfully reared cubs. The substantial area occupancy of ST3 (172.75 km²), ST9 (85.25 km²), and ST10 (80.10 km²) can be attributed to a low prey base and very high anthropogenic forces. Owing to their different lineage of ST3, ST5, ST9, and ST10, these tigresses have been compelled to settle in relatively disturbed areas with low natural prey base and comparatively disturbed areas.

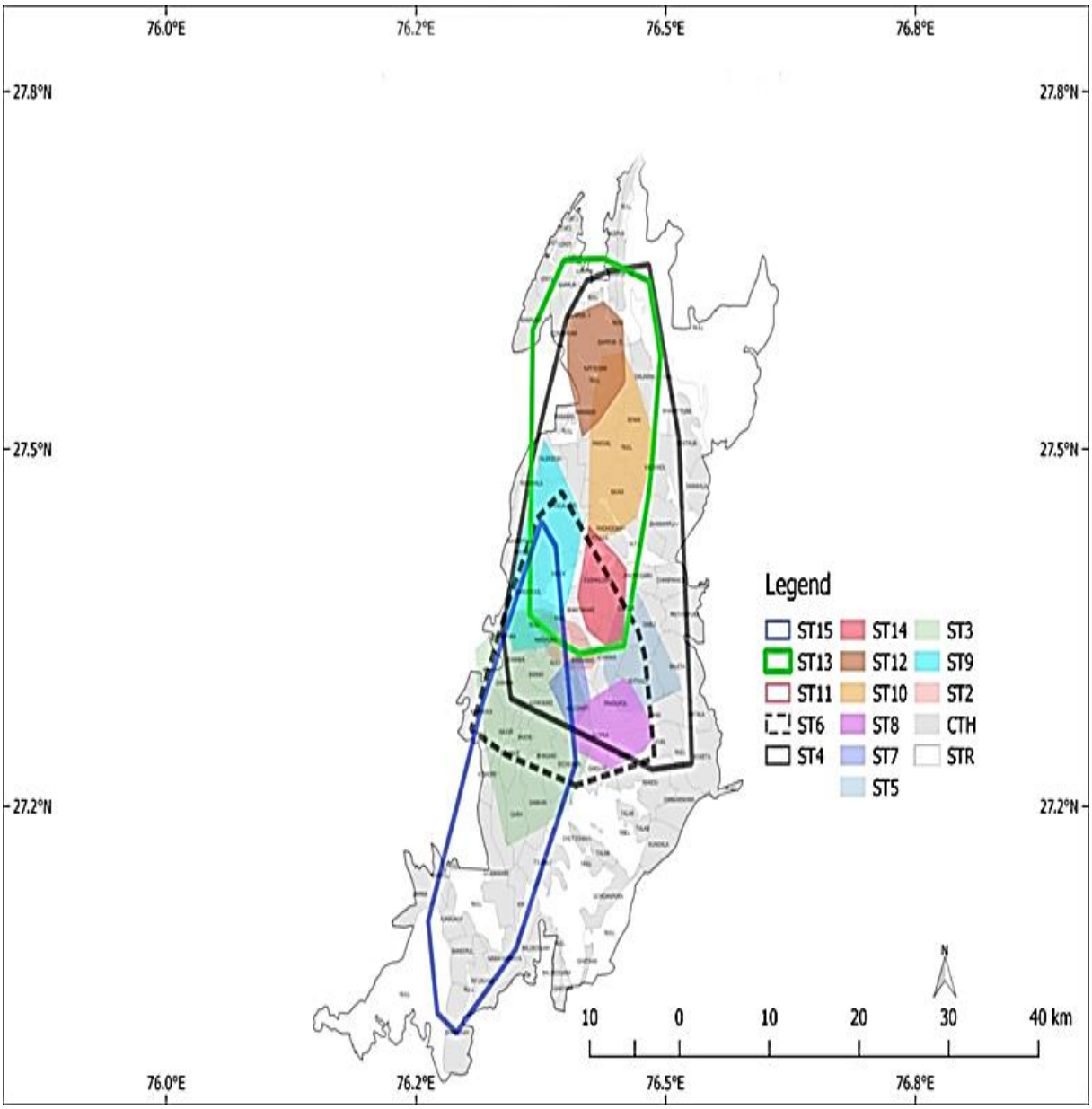

Figure 4. Map of STR showing movement pattern of all male and female tigers based location from September 2017 to August 2018. The location data of ST 11 is till March 2018 due to its reported killing in March 19

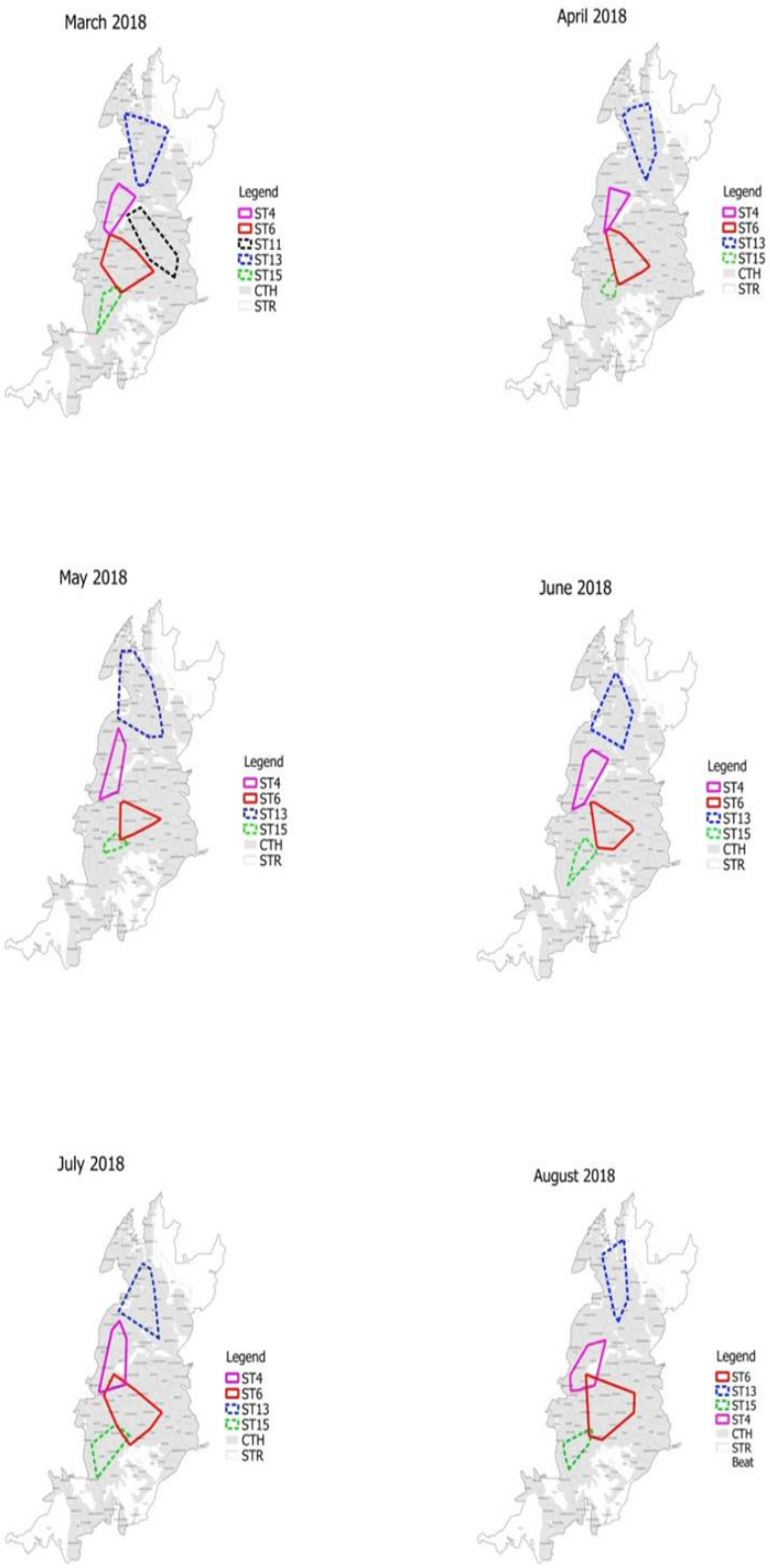

Figure 5. Maps of STR shown with area occupancy of all 4male tigers for individual months from March 2018 to August 2018

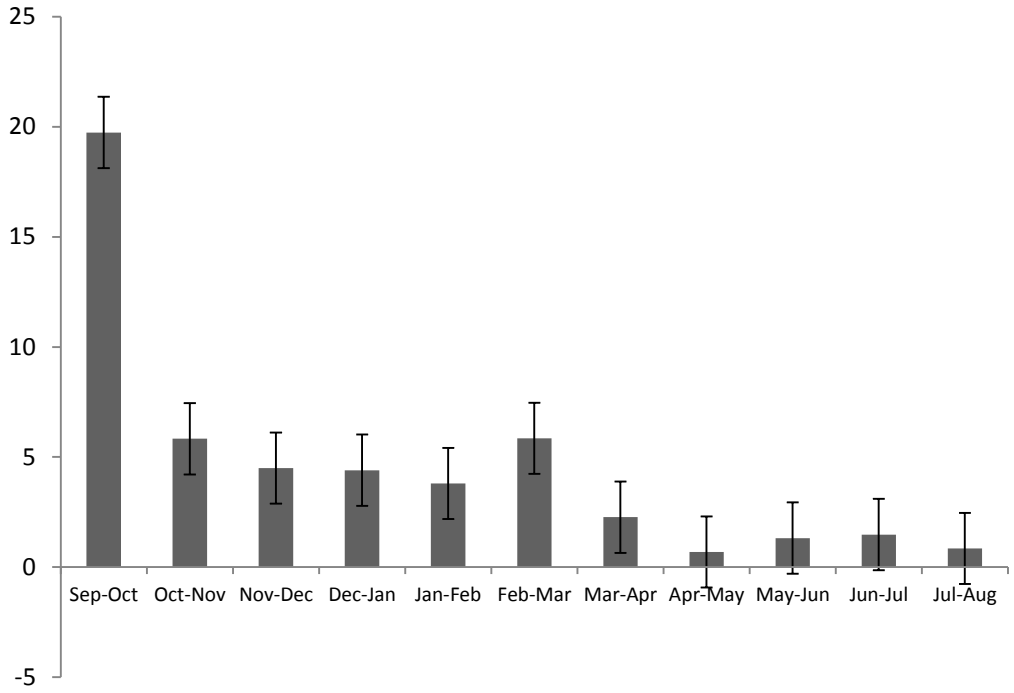

Figure 6. Column chart showing the monthly home range displacement of sub-adult ST15

Earlier studies on the movement pattern of reintroduced tigers in Sariska (Sankar et al., 2010) reporting a high annual home range of tigers in Sariska up to 220 km² as compared to other studies in the Indian sub-continent (Seidensticker, 1976; Schaller, 1967; Chundawat, 2001) may be attributed to their initial habitat exploration after reintroduction (Sankar et al., 2010). The observed high area occupancy of ST13 (up to 687.58 km²) and ST15 (189.46 km²) is due to the territory's initial exploration. The too-high area occupancy of ST13, as shown in Nov and Dec 2016 is expected to its straying outside the tiger reserve in the adjoining degraded forest of Rajgarh. After settling in their respective territories, ST13 in the north of STR and ST 15 in the south, their average area occupancies (home ranges) decreased to 61.37 km² and 47.67 km². The observed larger mean home ranges (based on MCP method) of ST4 (85.40 km²) and ST6 (79.94 km²) as compared to young ST13 (61.369 km²), ST11 (57.63 km²), and ST15 (47.67 km²) may be due to the reason of early occupancy (occupancy seniority) of the respective areas by already settled old tigers. The same logic can be attributed to an overlap of the home ranges ST4 and ST6 with those of the maximum number of tigresses in reserve. Our findings for ST4 and ST6 are consistent with a polygynous mating system in that male home ranges overlapped those of 8-9 and 7 females. Other studies of Bengal tigers in Nepal were polygynous, with one male siring offspring with seven females (Smith & McDougal, 1991).

Similarly, spacing patterns that suggested polygyny (Yudakov & Nikolaev, 1987) were also found in Amur tigers. Dobson (1982) hypothesized that in polygamous species, selecting outbreeding should result in sub-adult males dispersing farther than females. However, given that male home ranges are generally more extensive in solitary species, dispersing males would have to move farther than females to emigrate from their father's home range. In the past studies, two males have been observed to maximize their home ranges to include as many breeding females as possible (Lott, 1991; Minta, 1993; Powell, 1979; Sandell, 1989). Smith (1984) confirmed this pattern for Bengal tigers in Nepal.

The significant observation variation in home ranges (100% MCP) and mean of monthly home ranges for all individual male tigers (Table 1) may be attributed to high displacement (Table 4) as well as expansion-contraction (Table 2) of the area occupancies. This may suggest a very high dynamism of home ranges of tigers in human-dominated landscapes. The observed high mean monthly displacement of the home range of ST15 *viz*. 4.23 km can be attributed to its dispersal from its natal area (home range of mother ST9) to south of STR post-Sep 2017. Exploring the southern part of the reserve (October 17 to April 18) and settling in a smaller area (11.73-43.55 km²) with minimum displacement of monthly home ranges (May 18 to Aug 2018) can be stated as the second justification (Fig 6).

Although studies attempted to monitor the changes in home-range occupancy in the vacated area after the mortality of tigers by other tigers (Goodrich et al., 2010) and demonstrated that adjacent tigers took over the vacancies created by the death of two male tigers. The observation of non-expansion of the home ranges of any of the remaining four male tigers (ST4, 6, 13, and 15) after the killing of the ST11 male tiger in STR suggests non-exploratory behavior of already settled male tigers.

Conclusion

The role of tiger monitoring based on radio-telemetry in human-dominated landscapes, especially in habitats like STR needs to be taken as a priority by the wildlife managers to know the movement pattern of tigers, especially regarding dispersing young tigers. Such managerial inputs will help in averting human-carnivore conflicts when expanding their home ranges to explore maximum and use modern technology to relocate them back if the situation demands.

Acknowledgment

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References

Anderson, J. (1982). The home range. A new non-parametric estimation technique. Ecology 63, 103-112.

Southwood, T.R.E. (1996). Ecological methods. Methuen, London, U.K.

Burt, W. H. (1943). Territoriality and home range concepts as applied to mammals. Journal of mammalogy 24, 346–352.

Chundawat, R.S. (2001). Tiger conservation in dry tropical forests of India. Report: Jan 2000 to June 2001, submitted to Centre for Wildlife Studies, Bangalore, India

Deat, A., Mauget, R., Maurel, D. & Sempere, A. (1980). The automatic, continuous fixed audio tracking system of the Chize forest, In C.J. Amlaner & D.W. Macdonald, (Eds.), A Hand Book on Biotelemetry and Radio-Tracking. Permagon Press, Oxford

Dobson, F.S. (1982). Competition for mates and predominant juvenile male dispersal in mammals. Animal Behaviour, 30, 1183–1192.

Eric, M., Gese, E.M, Rongstad, O.J. & Mytton, W.R. (2008). Home range and habitat use of coyotes in southeastern Colorado, Journal of Wildlife Management, 52 (4), 640-646.

Goodrich, J. M., Kerley, L.L., Schleyer, B.O., Quigley, K.S., Miquelle, D., Smirnov,Y.N., Nikolaev, I.G., Quigley, H. & Hornocker, M.G. (2001). Capture and chemical anesthesia of Amur tigers. Wildlife Society Bulletin, 29, 533–542.

Goodrich, J.M., Kerley, L.L., Miquelle, D.G., Smirnov, E.N., Quigley, H.B. & Hornocker, M.G. (2005). The social structure of Amur tigers on Sikhote–Alin Biosphere Zapovednik. In D.G. Miquelle, E.N. Smirnov, & J.M. Goodrich, (Eds.), Tigers of Sikhote–Alin Zapovednik: Ecology and Conservation, PSP, Vladivostok, Russia (in Russian), pp. 50–60.

Goodrich, J.M., Miquelle, D.G., Smirnov, E.N., Kerley, L.L., Quigley, H.B. & Hornocker, M.G. (2010). Spatial structure of Amur (Siberian) tigers (Panthera tigris altaica) on Sikhote–Alin Biosphere Zapovednik, Russia, Journal of Mammalogy, 91(3), 737–748.

Harestad, A. S. & Bunnell, F. L. (1979). Home range and body weight – a reevaluation. Ecology, 60, 389–402

Jhala, Y.V., Mukherjee, S., Shah, N, Chauhan, K.S., Dave, C.V., Meena, V. & Banerjee, K. (2009). Home range and habitat preference of female lions (*Panthera leo persica*) in Gir forests India. Biodiversity Conservation, 18, 3383–3394.

Kelly, M.J., Noss, A.J., Bitetti, M.S., Maffei, L., Arispe, R.L., Paviolo, A., De Angelo, C, .D. & DiBlanco, Y.E. (2008). Estimating puma density from camera trapping across three study sites: Bolivia, Argentina, and Belize. Journal of Mammalogy, 89, 408–418

Kerley, L. L., Goodrich, J.M., Miquelle, D.G., Smirnov, E.N., Quigley, H.B., Hornocker & M.G. (2003). Reproductive parameters of wild female Amur (Siberian) tigers (*Panthera tigris altaica*). Journal of Mammalogy, 84, 288–298.

Lott, D. F. (1991). Intraspecific variation in the social systems of wild vertebrates. Cambridge University Press, Cambridge, United Kingdom.

Macdonald, D.W. & Amlaner, C.J. (1980). A practical guide to radio-tracking, In C.J. Amlaner & D.W. Macdonald (Eds.), A hand book on biotelemetry and radio-tracking. Pergamon Press, Oxford.

Macdonald, D.W. (1983). The ecology of carnivore social behaviour. Nature, 301, 379–384.

Mcdougal, C. (1977) . The face of the tiger. Rivington Books, London, United Kingdom

Minta, S.C. (1993). Use of spatio-temporal interaction statistics on badgers to test predictions of territorial polygyny theory. Oecologia, 96, 402–409.

Miquelle, D.G., Smirnov, E.N., Merrill, W.T., Myslenkov, A.E., Quigley, H.B., Hornocker, M.G. & Schleyer, B. (1999). A habitat protection plan for the Amur tiger, In Seidensticker, J., Christie, S. & Jackson, P (Eds.), Riding the tiger: meeting the needs of people and wildlife in Asia. Cambridge: Cambridge University Press, pp. 273– 295.

Mohr, C.O. (1947). Table of equivalent populations of North American small mammals. American Midland Naturalist, 37, 223-249.

Nikolaeve, I. G. & Yudin, V.G. (1993). Conficts between man and tiger in the Russian Far East. Bulletin Moscovsky Obschestva Ispytateley Prirody, 98, 23–36.

Powell, R.A. (1979). Mustelid spacing patterns: variation on a theme by Mustela. Zeitschrift fu¨r Tierpsychologie, 50, 153–165.

Quigley, H.B., Koehler, G.M. & Hornocker, M.G. (1989). Dynamics of a mountain lion population in central Idaho over a 20–year period, In R.H. Smith(Eds.), Proceedings of the 3rd mountain lion workshop. The Wildlife Society, Arizona Chapter, Phoenix, p. 54.

Sandell, M. (1989). The mating tactics and spacing patterns of solitary carnivores, In J.L. Gittleman (Eds.), Carnivore behavior, ecology and evolution. Cornell University Press, Ithaca, New York, pp. 164–182

Sanderson, G.C. (1966). The study of mammal movements – a review. Journal of Wildlife Management, 52, 316– 320

Sankar, K., Goyal, S.P. & Qureshi, Q. (2005). Assessment of status of tiger in Sariska Tiger Reserve Rajasthan. A Report submitted to the Project Tiger, Ministry of Environment and Forests, Government of India, New Delhi.

Sankar, K., Qureshi, Q., Mondal, K., Worah, D., Srivastava, T., Gupta, S. & Basu, S. (2009). Ecological studies in Sariska Tiger Reserve, Rajasthan. Final Report. Wildlife Institute of India, Dehra Dun, p. 145.

Sankar, K., Qureshi, Q., Nigam, P., Malik, PK., Sinha, PR., Mehrotra, RN., Gopal, R., Bhattacharjee, S., Mondal, K. & Gupta, S. (2010). Monitoring of reintroduced tigers in Sariska Tiger Reserve, Western India: Preliminary findings on home range, prey selection and food habits. Journal of Tropical Conservation Science, 3(3), 301-318

Schaller, G.B. (1967). The deer and the tiger: a study of wildlife in India. Chicago, IL, University of Chicago Press

Smith, J.L.D. (1984). Dispersal, communication, and conservation strategies for the tiger (*Panthera tigris*) in Royal Chitawan National Park, Nepal. Ph.D. dissertation, University of Minnesota, Minneapolis.

Smith, J.L.D., McDougal, C. & Sunquist, M.E. (1987a). Female land tenure system in tigers, In R.L. Tilson & U.S. Seal (Eds.), Tigers of the world: the biology, biopolitics, management and conservation of an endangered species. Noyes Publications, Park Ridge, New Jersey, USA, pp. 97–109

Smith, J.L.D. Wemmer, C. & Mishra, H. R. (1987b). A tiger geographic information system: the first step in a global conservation strategy, In R.L. Tilson. & U.S. Seal (Eds.), Tigers of the world: the biology, biopolitics, management and conservation of an endangered species. Noyes Publications, Park Ridge, New Jersey, USA, pp. 464–474.

Smith, J.L.D. & Mcdougal, C. (1991). The contribution of variance in lifetime reproduction to effective population size in tigers. Conservation Biology, 5, 484–490

Smith, J.L.D. (1993). The role of dispersal in structuring the Chitwan tiger population. Animal Behaviour, 124, 165–195

Swihart, R.K. & Slade, N.A. (1985). Influence of sampling interval on estimates of home-range size. Journal of Wildlife Management, 49, 1019-1025.

Seidensticker, J. (1976). On the ecological separation between tigers and leopards. Biotropica, 8(4), 225-234

Sunquist, M. E. (1981). The social organization of tigers (*Panthera tigris*) in Royal Chitwan National Park. Smithsonian Contributions to Zoology, 336, 1–98.

Sunquist, M.E, Karanth, U.K. & Sunquist, F. (1999). Ecology, behavior, and resilience of the tiger and its conservation needs, In J. Seidensticker, S. Christie, & P. Jackson (Eds.), Riding the

tiger: tiger conservation in human-dominated landscapes Cambridge University Press, Cambridge, United Kingdom. Pp. 5–18

Trent, T.T. & Rongstad, O.J. (1974). Home range and survival of cottontail rabbits in Southwestern Wisconsin. Journal of Wildlife Management, 38, 459–472

Yudakov, A. G. & Ikolaev, I.G. (1987). Ecology of the Amur tiger. Winter long-term observations in the western part of the middle Sikhote-Alin, 1970–1973. Nauka Press, Moscow, Russia (in Russian).

White, G. C. & Garrot, R. A. (1990). Analysis of radio-tracking data. Academic Press.