Ecology of leopard (*Panthera pardus*) in Sariska Tiger Reserve, Rajasthan

Final Report

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

June 2013

Ecology of leopard (*Panthera pardus*) in Sariska Tiger Reserve, Rajasthan

Final Report

JUNE 2013

Investigators: ***Dr. K. Sankar***

Sh. Qamar Qureshi

Dr. Y. V. Jhala

Reserchers: ***Krishnendu Mondal***

Shilpi Gupta

Pooja Chourasia

Citation

Sankar K., Qureshi, Q., Jhala Y.V., Mondal, K., Gupta, S. and Chourasia, P. 2013. Ecology of leopard (*Panthera pardus*) in Sariska Tiger Reserve, Rajasthan. Final Report. Wildlife Institute of India, Dehra Dun. 113 Pp.

I. Title of the project: **Ecology of leopard in Sariska Tiger Reserve, Rajasthan**

II. Duration of the project: **5.09.2007 to 31.03.2013**

III. Name of the investigator(s): **Dr. K. Sankar**
Sh. Qamar Qureshi
Dr. Y. V. Jhala

IV. Name of the research fellow(s): **Krishnendu Mondal, SRF**
Shilpi Gupta, SRF
Pooja Chourasia, SRF

V. Total cost of the project: **Rs. 67,64,450.00** ***(Rupees Sixty Seven Lakhs Sixty Four Thousand Four Hundred and Fifty only)***

VI. Name of the funding agency: **NA**

VII. Name of the collaborator(s): **NA**

VIII. Date of submission of final report: **25.06.2013**

IX. **List of M.Sc. Dissertations awarded:**

a. Zaara Kidwai. 2009. Abundance and habitat utilization by Galliformes in the Sariska Tiger Reserve, Rajasthan, India. Submitted to Aligarh Muslim University, Aligarh, 2002.

b. Salvadore Lyngdoh. 2008. Vegetation mapping and change detection of land use/land cover in Sariska Tiger Reserve, Rajasthan. Submitted to Forest Research Institute University. FRI, Dehradun, 2008.

X. **List of Ph.D. thesis awarded/submitted/under submission.**

a) Gupta Shilpi. 2010. Ecology of medium and small sized Carnivores in Sariska Tiger Reserve, Rajasthan, India. Ph.D., Thesis awarded by Saurashtra University, Rajkot.

b) Mondal Krishnendu, 2011. Ecology of leopards (*Panthera pardus*) in Sariska Tiger Reserve, Rajasthan. Ph.D., Thesis awarded by Saurashtra University, Rajkot.

XI. **A copy of all publications and related materials should be appended in the final report.**

a) Krishnendu Mondal, S. Gupta, S. Bhattacharjee, Q. Qureshi and K. Sankar. 2012. Response of leopards to re-introduced tigers in Sariska Tiger Reserve, Western India. *International Journal of Biodiversity and Conservation* Vol. 4(5), pp. 228-236.

b) Krishnendu Mondal, K. Sankar, Qamar Qureshi, Shilpi Gupta and Pooja Chourasia. 2012. Estimation of population and survivorship of leopard *Panthera pardus* through photographic capture-recapture sampling in Western India. *World Journal of Zoology*. 7(1): 30-39.

c) Krishnendu Mondal, Shilpi Gupta, K. Sankar, Qamar Qureshi. 2011. Prey selection and food habits of leopard in Sariska Tiger Reserve, Rajasthan, India. *Mammalia 75: 201-205.*

d) Pooja Chourasia, Krishnendu Mondal, K. Sankar and QamarQureshi. 2012. Food Habits of Golden Jackal (*Canis aureus*) and Striped Hyena (*Hyaena hyaena*) in Sariska Tiger Reserve, Western India. *World Journal of Zoology*. 7 (2): 106-112.

e) Shilpi Gupta, Krishnendu Mondal, K. Sankar and Qamar Qureshi. 2009. Estimation of striped hyena *Hyaena hyaena* polulation using camera traps in Sariska Tiger Reserve, Rajasthan, India*. JBNHS. 106 (3).*284-288*.*

f) Shilpi Gupta, Krishenndu Mondal, K. Sankar and Qamar Qureshi. 2009. Record of desert cat (*Felis silvestri ornata*) in Sariska Tiger Reserve, Rajasthan. *The Indian Forester. Vol. 135.No.10.*

g) S. Gupta, K. Mondal, K. Sankar and Q Qureshi. 2012. Abundance and Habitat Suitability Model for Ratel (*Melivora Capensis*) in Sariska Tiger Reserve, Western India. Wildl. Biol.Pract. 8(1):13-21.

h) Krishnendu Mondal, K.Sankar and Qamar Qureshi. 2010. A spot of trouble. Sanctuary Asia. Vol.XXX No. 4. August. Pp 36 to 39.

Contents

Western India. *World Journal of Zoology*. 7(1): 30-39.	
Mondal, K., Gupta, S., Qureshi, Q. and Sankar, K. 2011. Prey selection and food habits of leopard (*Panthera pardus fusca*) in Sariska Tiger Reserve, Rajasthan, India. Mammalia, 75 (2011): 201–205.	
Krishnendu Mondal, S. Gupta, S. Bhattacharjee, Q. Qureshi and K. Sankar. 2012. Response of leopards to re-introduced tigers in Sariska Tiger Reserve, Western India. *International Journal of Biodiversity and Conservation* Vol. 4(5), pp. 228-236.	
Pooja Chourasia, Krishnendu Mondal, K. Sankar and Qamar Qureshi. 2012. Food Habits of Golden Jackal (*Canis aureus*) and Striped Hyena (*Hyaena hyaena*) in Sariska Tiger Reserve, Western India. *World Journal of Zoology*. 7 (2): 106-112.	

List of Figures

List of Tables

Acknowledgments

We are grateful to Sh. P. R. Sinha, Director, Wildlife Institute of India (WII) for his support and encouragement for the 'Ecology of leopard' project. We are equally thankful to Dr. V. B. Mathur, Dean, FWS, WII for his support and guidance extended to the project.

We sincerely thank Sh. R. N. Mehrotra (former PCCF, Rajasthan) and Sh. P. S. Somasekar (CCF, Wildlife, Rajasthan) for giving permission to work in Sariska. We are thankful to Sh. Rajesh Gupta (former DCF, Sariska TR), Sh. Sunayan Sharma (former DCF, Sariska TR) and Sh. V. Praveen (former DCF, Sariska TR), Sh. R. S. Shekawat (former Field Director) and Sh. Mahendra Sharma, DFO, Sariska for their extended support and co-operation required for the smooth conduct of field work in Sariska. We are thankful to all the Range Officers specially Sh. Arvind Jha, Sh. Daulat Singh Shekawat, Sh. Vidyadhar Singh, Sh. Udairam and Sh. Rajesh Phagna for their support and hospitality extended during the field work.

In WII, we are highly grateful to Dr. Parag Nigam, Dr. P. K. Malik, Dr. S. P. Goyal, Dr. G. S. Rawat, Dr. K. Ramesh, Sh. G. S. Bharadawaj and Dr. S. A. Hussain for their guidance, support and valuable suggestions extended at different stages of the project execution.

We acknowledge the support and assistance of following staff and Section Officers of Administrative, Finance, Library and Computer Sections at WII: Sh. P.K. Aggarwal, Sh. A.K. Dubey, Sh. Kharak Singh, Sh. Naveen, Sh. Y. S. Verma, Sh. Rajesh Thapa, Sh. Sukumar, Dr. Manoj Agarwal, Dr. Panna Lal, Sh. Veerappan, Sh. Virendra Sharma. Special thanks to Mr. Vinod Thakur for his help in leopard scat analysis in Research Laboratory and Mr. Gyanesh Chibber and Mr. Kishan are thanked for their immense help in project administrative work.

We are thankful to our field assistants and drivers Jairam, Ramesh, Omi, Chhotelal Khagesh and Mamaraj for their assistance in field data collection. At Sariska base camp, the following researchers and students provided technical support to the project: Subhadeep Bhattacharjee, Rahul Rana, Manjari Malvia and Zaara Kidwai. We are thankful to many ways to WII researchers for their help in data analysis and comments on our research articles: Santanu, Kausik, Tapojit, Swati, Sutirtha, Aniruddha, Abesh, Angshuman, Indronil and Sudip.

Executive Summary

The leopard is found in almost every kind of habitat, from the rainforests of the tropics to desert and temperate regions. Leopard is found throughout sub-Saharan Africa and Southern Asia with scattered population in China and North Africa. The Indian race, *Panthera pardus fusca*, is distributed all over the country, being absent only in the arid deserts and above the timber line in the Himalayas. The leopard is the most adaptable among all the big cats. This species is known for its use of habitat edges and its ability to live in close to human habitation. Leopard shows plasticity in changing behavior as conditions changes. Leopard's ability to feed on a broad spectrum of prey makes them most successful predator among big cats and its size gives the ability to feed on a variety of prey species ranging in size from a young buffalo to smallest rodent.

Although it is the most common of the big cats, Myers (1976), recommended that it remains on Appendix 1 of CITES because extensive hunting had depressed their populations in several parts of Africa. In India it figures in the Schedule I of the Indian Wildlife (Protection) Act, 1972. It has been feared that leopard populations will decline across most of its range because of habitat destruction and poaching. In India too, habitat destruction, loss of wild prey, poaching for skins, bones and claws, and poisoning carcasses of livestock killed by leopards are significant threats to the animal. The reduction in tiger populations has also meant that increasing poaching pressure may be brought upon on the leopard to meet the demands of the skin and bone trade. The conflict originating due to loss of livestock and people is one of the major causes of leopard persecution. The increasing human population, changing land use practices, soaring demands from our urban population and more recently fast expanding economic activity have started straining the delicate balance at which leopard survive. Inadequate size of the protected areas, leopard being a large territorial animal require large spaces and in small and isolated protected areas they frequently venture out and come in direct conflict and experience high mortality. Fragmentation and loss of habitat and its quality usually result in loss of prey availability. Inadequate prey base affect leopard’s reproductive success

and its survival. More recently poaching for commercial use is a serious threat to leopard population.

To study various ecological aspects of leopard such as, ranging patterns, population density, habitat use and food habits a study was conducted on 'Ecology of leopard in Sariska Tiger Reserve, Rajasthan'. The Sariska Tiger Reserve (Sariska TR) is one of the important protected areas in the semi-arid tracts of Western India. The total area of Sariska TR is 881 km^2, of which 273.8 km^2 areas was notified as `National Park' in 1982. There are 31 villages located inside Sariska TR including 10 of them are in National Park area and they are due for relocation since 1984. The reported population of leopard in Sariska ranged from 52 to 72 between 2002 and 2005 and 24 leopards were reported poached during 2002 to 2005. Before initiation of the current research project, Sankar *et al.* (2009) estimated the leopard density in the Sariska TR. They found that after the local extermination of tiger from Sariska TR, due to poaching, leopard took over the best available habitat and the estimated density of leopard (10.7/100 km^2) was comparatively higher than the other protected areas in India. Hence it was imperative to study the population trend of leopard, home ranges and factors influencing its ranging pattern in areas where tiger had used intensively before they were exterminated due to poaching in Sariska TR. The present study documented the population and survival rates of leopard between 2007 and 2012 and also the ranging pattern and resource selection of leopard in the study area. An earlier study revealed that leopard in Sariska largely preyed upon small rodents. Hence it was also interesting to study the food habits of leopard in the absence of tiger and after tiger re-introduction in Sariska in 2008. This study documented the available prey base (wild and domestic) for leopard in the intensive study area as well the food habits and prey selection of leopard between 2008 and 2012. Altogether, the present research project addressed the following objectives: (1) To study the ranging patterns and resource selection of leopard, (2) to study prey selection and food habits of leopard and (3) to study the population structure, survivorship and dispersal patterns of leopards. The project duration was from 5.09.2007 to 31.03.2013.

The study area was Sariska Tiger Reserve (Sariska TR) which is situated in Aravalli hills in Alwar district of Indian state of Rajasthan between Longitude: 79°17' to 76°34'N and Latitude: 27° 5'

to 27° 33' E. The total area of Tiger reserve is 881 km^2, with 274 km^2 as a notified National Park. Sariska TR is characterized by rugged terrain, valleys and plateau with the altitudinal variation from 540 m to 777 m. The two main plateaus are Kankawari (524 m above mean sea level) and Kiraska (592 m above the mean sea level).

Radio-telemetry technique was followed to estimate the home range of leopards as this technique is found to be the most updated and useful practice to gather information on home range, daily and seasonal movement pattern of big cats. To capture leopard in the study area a couple of iron double door trap cage was deployed using goat, domestic dog, meat and chicken as bait in the cage. Rotten meat (cat-lure), eggs and fresh blood were also used to lure leopard inside the cage. The dimension of the trap cage was 9 ft X 2.5 ft X 3 ft including the bait cage. A number of 148 trap nights in 2009 and 115 trap nights in 2010 were deployed in different locations in the study area following leopards' signs and trails. Despite of these efforts, no forest leopard (adults) could be trapped in trap cages. On two occasions, a leopard cub was trapped inside the trap cages and they were released. To understand the ranging pattern of leopard, two male leopards were captured from conflicted areas outside Sariska TR and released in the study area.

The first male leopard (SP1) was captured from a village near Shahpura 50 km away from Sariska TR. The second male leopard (SP2) was rescued from a 96 ft deep dry well of Madhogarh fort around 100 km away from Sariska TR. Subsequently, the animals were released inside the Tiger Reserve. Radio-locations of each collared animal were determined by ground tracking through VHF signal following 'homing in' and 'triangulation' techniques. Four to six locations every week per collared animal were recorded in different time of day. The first male leopard (SP1) was monitored from 27th March 2009 to 18th December 2009 (266 days) till the animal died due to liver and lungs congestion. In total, 148 locations were collected from the first male leopard (SP1). The second male leopard (SP2) was monitored from 28th October 2009 to 18th August 2010 (292 days) till the animal was lost. In total, 268 locations were collected from the second male leopard. For the first male leopard (SP1), in total 74 locations were recorded in summer, 36 locations in monsoon and 38 locations in winter. For the second male leopard (SP2), in total 98 locations were recorded in summer, 54 locations in monsoon and 116

locations in winter. In the present study, 3rd order resource selection (resource selection of individual leopard within its home range) of trans-located leopards was estimated (Johnson 1980) through Generalized Linear Mixed effect Model (GLMM).

The estimated home range of SP1 male leopard with 100 % MCP was 84.3 km^2 and that of SP2 male leopard was 63.2 km^2. With 90% Kernel, the estimated home range of SP1 was 72.4 km^2 and that of SP2 was 25.9 km^2. The home range estimate with 50% Kernel, which was the core-area within home range, was 12.2 km^2 for SP1 and 4.1 km^2 for SP2. It was found that *Zizyphus* mixed forest influenced most positively amongst the habitat variables explaining trans-located leopard's resource use followed by *Acacia* mixed forest. *Anogeissus* dominated forest and scrubland had negative influence in explaining trans-located leopard's resource use in the study area. These two leopards significantly used more habitats with higher encounter rate of nilgai and wild pig and less used habitats with higher encounter rate of chital and common langur. Encounter rate of tiger had a negative correlation with resource use of trans-located leopards, but it was not found significant.

Prey species abundance in the study area was estimated by line transect method under distance sampling technique. In total, 32 line transects varying in length from 1.6 km to 2 km were laid covering 160 km^2 area in the intensive study area. These transects were walked three times in early morning hours for five successive years from 2008 to 2012. The total transects length of 60.4 km were walked three times in early morning resulting in total effort of 181.2 km. Scat analysis method was chosen to estimate the proportion of different prey species consumed by leopard, the method being widely used and cost and time effective. In total, a number of 145 leopard kills were recorded during the study period to understand their predation pattern. A number of 171 scats were collected in 2008, 90 scats in 2009, 82 scats in 2010, 110 scats in 2011 and 130 scats in 2012.

In the study area (Sariska National Park), peafowl was the most abundant prey species throughout the study period. The density of peafowl varied from 121.43/ km^2 in 2008 to 100.73/ km^2 in 2009, 113.77/ km^2 in 2010, 103.53/ km^2 in 2011 and 235.12/ km^2 in 2012. Amongst the wild prey species, chital was most abundant (44.30 / km^2) in 2008 followed by sambar (25.23 / km^2), nilgai (18.91 / km^2) and wild pig (14.95 / km^2). In 2009, chital (40.40 /

km^2) was the most abundant wild ungulate prey species followed by nilgai (22.73 / km^2), sambar (16.37 / km^2) and wild pig (6.67 / km^2). In 2010, nilgai (13.53 / km^2) was the most abundant wild ungulate prey species followed by chital (12.55 / km^2), sambar (8.27 / km^2) and wild pig (4.06 / km^2). In 2011, nilgai (19.98 / km^2) was the most abundant wild ungulate prey species followed by chital (18.10 / km^2), sambar (16.01 / km^2) and wild pig (6.99/ km^2). In 2012, nilgai (36.62/km^2) was the most abundant wild ungulate prey species in the study area followed by, chital (37.12/km^2), wild pig (20.51 / km^2) and sambar (15.82/km^2). The density of common langur in the study area varied from 22.06/ km^2 in 2008 to 11.42/ km^2 in 2009, 4.28/ km^2 in 2010, 23.40/ km^2 in 2011 and 40.27/km^2 in 2012. Since there are ten villages inside the Sariska National Park area, the abundance of livestock was comparatively high in the study area. The density of goat in the study area was recorded as 54.1/ km^2 in 2008, 60.9/ km^2 in 2009, 58.9/ km^2 in 2010, 45.69/ km^2 in 2011 and 8.65/km^2 in 2012.

From the scat analysis, it was found that sambar contributed maximum (40.4%) in leopard diet in 2008 followed by chital (22.4%), nilgai (11.5%), common langur (10.4%), hare (4.4%), cattle (3.8%), porcupine (2.7%), wild pig (2.2%), peafowl (1.6%) and domestic dog (0.5%). In 2009, sambar contributed the most (45.5%) in the diet of leopard, followed by chital (15.2%), nilgai (8.9%), cattle (7.1%), common langur (6.3%), peafowl (6.3%), porcupine (5.4%), hare (2.7%) and wild pig (2.7%). In 2010, sambar contributed maximum (33.7%) in leopard diet followed by chital (20.8%), cattle (11.9%), common langur (10.9%), peafowl (8.9%), nilgai (5.0.5%), rodent (4.0%), wild pig (2.0%), porcupine (2.0%) and hare (1.0%). In 2011, sambar contributed maximum (31.4%) followed by chital (16.1%), common langur (12.4%), cattle (9.5%), peafowl (8.0%), rodent (7.3%), nilgai (6.6%), wild pig (3.6%), hare (3.6%) and goat (1.5%). In 2012, chital contributed maximum (38.6%) in leopard diet followed by sambar (19.3%), nilgai (18.7%), rodent (12.7%), peafowl (9.6%), common langur (7.8%), cattle (4.8%), buffalo (1.2%), and wild pig (0.6%). Data on utilization (from scat analysis) and availability (from distance sampling analysis) of prey species was compared and an index of selection of each species was obtained (Ivlev's index). It was found that, in 2008, sambar ($P<0.01$) and chital ($P<0.01$) were preyed more than their availability, while nilgai ($P<0.01$), cattle ($P<0.01$) and peafowl were preyed less than their availability. Common langur was preyed in proportion to its availability ($P>0.05$). In

2009, sambar (P<0.01) was preyed more than their availability, while cattle (P<0.01) and peafowl were preyed less than their availability. Nilgai, chital and common langur were preyed in proportion to its availability (P>0.05). In the year 2010, sambar (P<0.01), chital (P<0.01) and common langur (P<0.01) were preyed more than their availability, while nilgai (P<0.01) and peafowl were preyed less than their availability. Cattle was preyed in proportion to its availability (P>0.05). In 2011, sambar (P<0.01), chital (P<0.01) and common langur (P<0.01) were preyed more than their availability, while nilgai (P<0.01), cattle (P<0.01) and peafowl (P<0.01) were preyed less than their availability. In 2012, sambar (P<0.01), chital (P<0.01) and common langur (P<0.01) were preyed more than their availabilities, while nilgai (P<0.01) was preyed less than their availability. Cattle and peafowl were preyed in proportion to its availability (P>0.05). In total 145 kills of leopard were recorded in the study area during the study period. As per the kill records, sambar and nilgai contributed maximum (12.6% and 11.1% respectively) to the leopard's diet followed by peafowl (6.3%), chital (5.9%), wild pig (2%) and common langur (1%) in terms of wild prey species. Where as in terms of livestock, cattle contributed maximum (36.4 %) in leopard's diet followed by goat (21.6%) and buffalo (3.1%). The high records of livestock kills were mainly from the peripheral areas of the Sariska Tiger Reserve. Compared with previous study in the present study area, it was found that, leopard largely used to prey upon rodents when there was an established population of 20-24 tigers in Sariska TR. During the study period, leopard largely preyed on sambar and chital. Leopard shifted their diet from lesser prey species (rodents) to large ungulates after tiger extermination from Sariska TR.

Camera trapping method under mark-recapture framework was used to estimate the population structure of leopard in the study area between 2008 and 2012. The entire study area was divided into two 80 km^2 blocks and each block was subdivided into 20 grids of 2x2 km^2. One pair of camera was placed in each 2x2 km^2 grid. At each grid, a pair of passive infrared analog or digital camera traps (DeerCam® or StealtCam or SpyPoint/ Moultrie/ Cuddeback) was placed opposite each other between 5 and 8 m from the center of the trail so as to photograph both flanks of leopard.

The camera trapping resulted in a total of 64 photographs of 17 individuals in 2008, 61 photographs of 14 individuals was recorded in 2009, 34 photographs of 8 individuals in 2010, 42 photographs of 14 individuals in 2011 and 76 photographs of 38 individuals in 2012. The 40 trapping locations covered minimum convex polygon area of 118.7 $km^2$and an effective trapping area (ETA) of 223.8 km^2, 223.1 km^2, 250.5 km^2, 231.5 km^2 and 223.4 km^2 with a buffer of half mean maximum distance moved model (1/2 MMDM) in 2008, 2009, 2010, 2011 and 2012 respectively. The estimated population (*N*) of leopard in the study area with Mh Jacknife estimator was 17.9 ± 3.0 in 2008, 16.3 ± 3.3 in 2009, 9.0 ± 1.5 in 2010, 16.9 ± 3.4 in 2011 and 40.0 ± 1.7 in 2012. For estimation of density of leopard in the study area, half normal detection function fitted the best and the densities arrived using multiple likelihood model (MLDens) were 9.3 ± 2.2 individuals/ 100 km^2 in 2007, 7.7 ± 1.9 individuals/ 100 km^2 in 2008, 5.3 ± 1.4 individuals/ 100 km^2 in 2009, 3.1 ± 0.4 individuals/ 100 km^2 in 2010, 7.1 ± 2.0 individuals/ 100 km^2 in 2011 and 16.8 ± 2.2 individuals/ 100 km^2 in 2012. The overall survival rate of leopard in the study area was estimated as 0.72 ± 0.14 between 2007 and 2008, 0.59 ± 0.13 between 2008 and 2009, 0.94 ± 0.16 between 2009 and 2010, 0.58 ± 0.08 between 2010 and 2011 and 1.00 ± 0.11 between 2011 and 2012. The overall survival rate of leopard population in the entire sampling period was estimated to be 0.79 ± 0.04. Overall, the geometric mean rate of population change was estimated as λ_t = 1.32 ± 0.38 (estimated mean ± SE), representing an approximate 4% increase in population during 2007-2012.

As observed, in the present study the estimated population of leopard in the study area declined from 16.3 ± 3.3 in 2009 to 9.0 ± 1.5 in 2010; which may be attributed to temporary emigration due to tiger re-introduction in the study area. After the extermination of tiger in Sariska, leopard took over the entire tiger habitat, which was the best habitat available in Sariska and became the top predator. The density estimates for leopard in 2007 and 2008 were comparatively higher, when there was no tiger in the study area. Six tigers were re-introduced in the study area between 2008 and 2010 and after that density of leopard declined significantly (from 6.2 ± 0.8 in 2009 to 3.1 ± in 2010) in the study area. But, after tiger established their home ranges in Sariska, the abundance of leopard again went up to 40.0 ± 1.7 in 2012 and density raised to 16.8 ± 2.2. In regions of high tiger density, for example, tigers are

known to out-compete leopards. Radio-tracking studies on tiger and leopard movements indicate that leopards avoid areas frequented by tigers. In the present study, site utilization of both the species was estimated with site-wise capture records. It was found that the site utilization of leopard and tiger were 0.55 and 0.53 respectively in absence of either species, while that of both leopard and tiger together was 0.51. The detection probability of leopard was 36% in the absence of tiger and it was 6% when tiger was present.

The overall survival rate of leopard in the study area was 79 %, and the rest 21% represented the deaths and emigration of leopard from the study area. In total eleven leopard deaths were recorded in the study area. After analyzing the cause specific mortality model, it was found that more than 13% leopard deaths were due to road accidents and poisoning. A proportion of 7% leopard deaths were due to inter-guild fight with tigers, which can be considered as the natural cause obeying the theory of carnivore competition. In the present scenario, if the anthropogenic causes for leopard deaths are decreased and habitat continuity is maintained with adjoining forest areas in north with Alwar Forest Division and in south Jamwa Ramgarh Wildlife Sanctuary, thus encompassing a total area of 2388 km^2, the existing leopard population in Sariska TR will survive for more than 100 years (probability of extinction 0.06). Considering the adaptive capability of leopard throughout its range, the leopard population in Sariska may survive, for longer period with better habitat management, forest protection and closing of State Highways for vehicular traffic during the night hours.

The Critical Tiger Habitat (CTH) of Sariska is 881.4 km^2. A buffer area of 322.23 km^2 around CTH 322.23 km^2 has been recently notified. Hence the effective total area of Tiger Reserve is 1203.63 km^2 which can ensure the long term survival of tigers and leopards in semi-arid landscape of Aravalli Hills, provided the anthropogenic activities are reduced in these areas and habitat management efforts are undertaken to improve the prey base for large carnivores.

At present nine villages are located in National Park area which are due for relocation since 1984. Johnsingh *et. al.,* (1997) reported that part of National Park (ca.120 km^2) could sustain a high density of prey species and a reasonable population of tigers. It would be an endeavor of the Park Management to relocate remaining nine villages by the new relocation package provided by National Tiger Conservation Authority and to nullify the disturbance in the National

Park area to provide a disturbance-free and "inviolate space" to the reintroduced tigers and existing leopard population. There are two state highways: Alwar-Thanagazi-Jaipur and Sariska-Kalighati-Tehla, which are over 44 km in length and traverse through the National Park. The vehicular traffic results in enormous disturbance to wildlife. These two State Highways (SH-13 & SH-29 A) passing through the National Park should be completely closed to prevent road accidents of large carnivores and their prey base. Eco-development efforts should be taken up involving the primary stakeholders in the protection of the PA to reduce chances of tiger/leopard-human conflict and retaliatory killing. The traffic of pilgrims heading for Pandupole temple during Tuesdays and Saturdays via Sariska–Kalighati-Pandupole metallic road should be regulated to reduce vehicular disturbance in National Park area.

The present wild prey density and biomass in Sariska was high and comparable with other tiger reserves such as Ranthambhore, Pench, Nagarhole, Bandipur, and Mudumalai. The nine villages from the notified National Park, once relocated, may make a 274 km^2 area available free from biotic interference which can support at least 15 adult tigers and the existing population of leopards (40.0 ± 1.7). The estimated mean livestock grazing distance from different villages of the National Park and the Sanctuary was 3.3 km and 3.1 km, respectively, thus leaving only 15% of the area in the whole tiger reserve as undisturbed wildlife habitat. The future of Sariska lies in successful relocation of the remaining 9 villages from the National Park (Haripura, Kiraska, Sukola, Dabli, Deori, Kankawari, Lilunda, Rekhamala and Dhuarmala). The successful relocation of *Bhagani, Umri and Rotkala* villages can set as an example to expedite the entire relocation process. In contrast, the relocation of National Park villages, though not easy and even if accomplished in a given time span, does not provide Sariska with a safe and undisturbed wildlife habitat all alone, since the Sanctuary villages are much more populated than those of the National Park and will continue to exploit the forest resources. To achieve success in making people less dependent on forest resources, implementation of eco-development programs in and around the tiger reserve with the involvement of Non-Governmental Organizations (NGOs) is recommended. Till these villages are relocated, the anthropogenic activities such as wood cutting, lopping and grazing should be restricted for the future survival of leopards in Sariska.