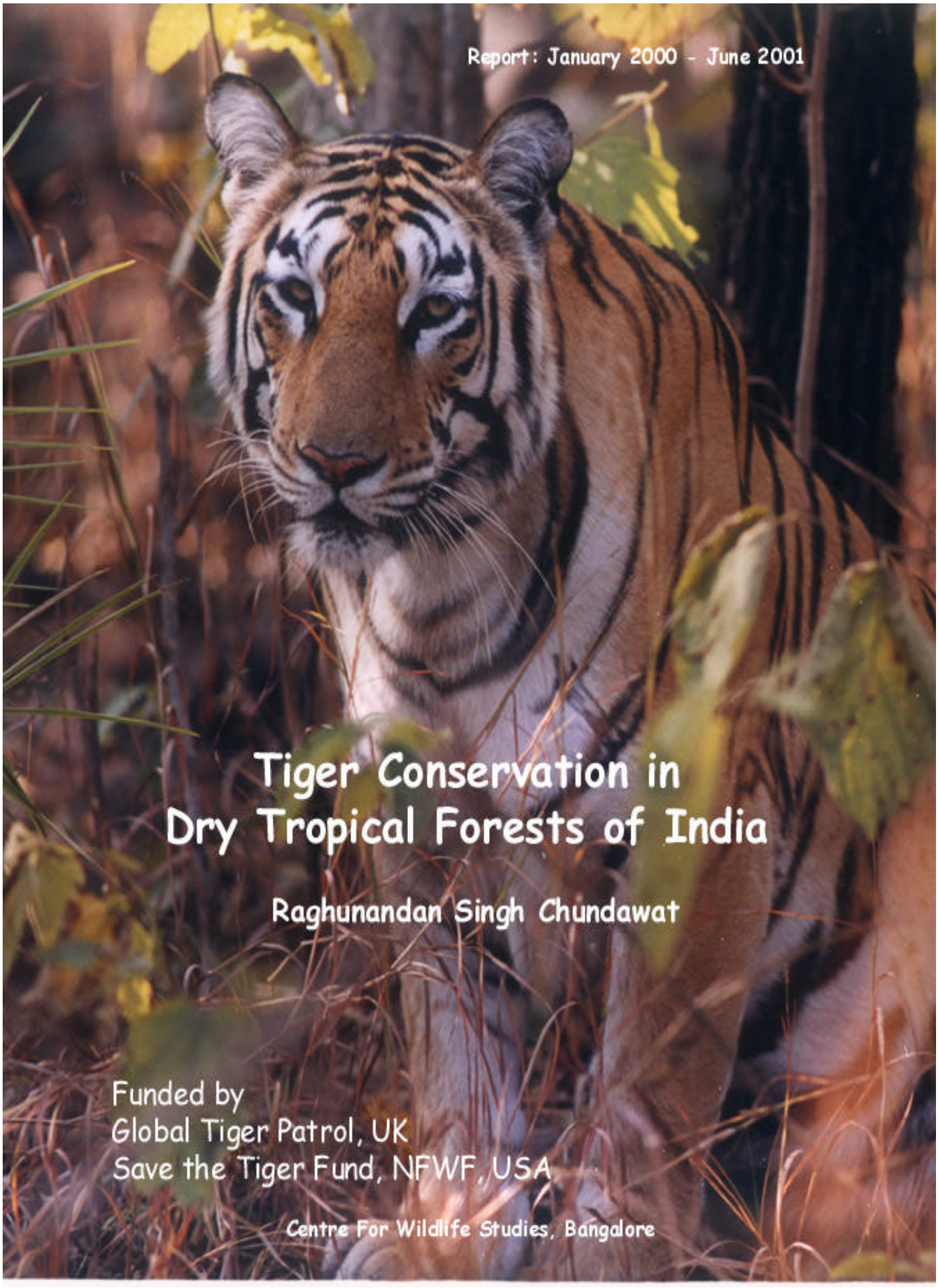

Report: January 2000 - June 2001

Tiger Conservation in Dry Tropical Forests of India

Raghunandan Singh Chundawat

Funded by
Global Tiger Patrol, UK
Save the Tiger Fund, NFWF, USA

Centre For Wildlife Studies, Bangalore

Report for the Period: January 2000- June 2001

TITLE OF THE PROJECT: **Strengthening Tiger Conservation through Understanding Predator-Prey Relationships in Dry Tropical Forests of India.**

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Sponsors : **Global Tiger Patrol, UK**
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INTRODUCTION

The tiger occupies an array of habitats in the sub-continent, ranging from coastal mangrove forests in the Sunderbans to tropical montane forests in Bhutan (Wikramanayake et al, 1999; Sunquist and Karanth, 1999; Miquelle, et al, 1999). Its response varies according to the habitat it occupies. It achieves its highest densities in the productive alluvial plains of the terai and other moist tropical forest habitats (Sunquist, 1981; Karanth and Nichols, 1998). It is in these habitats that tiger has been studied most (Schaller, 1967; Sunquist, 1981; Smith; 1984; Tamang, 1982; Karanth and Sunquist, 2000). The dry forest areas, which form the largest tiger habitat, has been studied little (Chundawat, et al, 1999). It is in these ecosystems that tiger is finding it hardest to survive. Looking at the past fifty years' presence and absence of tiger in protected habitats, reveals that local extinction is highest in this dry habitat. Tiger has already become locally extinct from 70% of semi-arid and from 35% of dry deciduous forest areas (Chundawat and Gogate, 2001).

Tiger in dry forests survive in extremely small isolated populations. The average size of protected areas in this habitat is less than 350 km^2 and the average size of the tiger populations within them is less than ten. Studies indicate that a demographically viable tiger population can be managed within such smaller protected areas provided that their prey base is managed intensively (Karanth and Stith, 1999). For this intensive management a better understanding of the system and of the predator-prey relationship is required in order to manage prey in densities that can support a demographically viable tiger population.

Because tiger is a specialised hunter (Sunquist and Sunquist, 1989), its breeding success, social organisation and land tenure system are affected by the availability, composition and distribution (temporally and spatially) of suitable prey. Therefore, emphasis is placed on understanding the predator prey relationship. It is also important to study how the tiger responds to the variable environment.

In view of this, the study proposes to generate information to determine the predator's (tiger's) functional responses to the varying densities, composition and distribution of major prey and to different habitat conditions. In this report information on home range, habitat use, prey abundance and the food habits of tiger are discussed.

OBJECTIVES

The study has the following objectives:

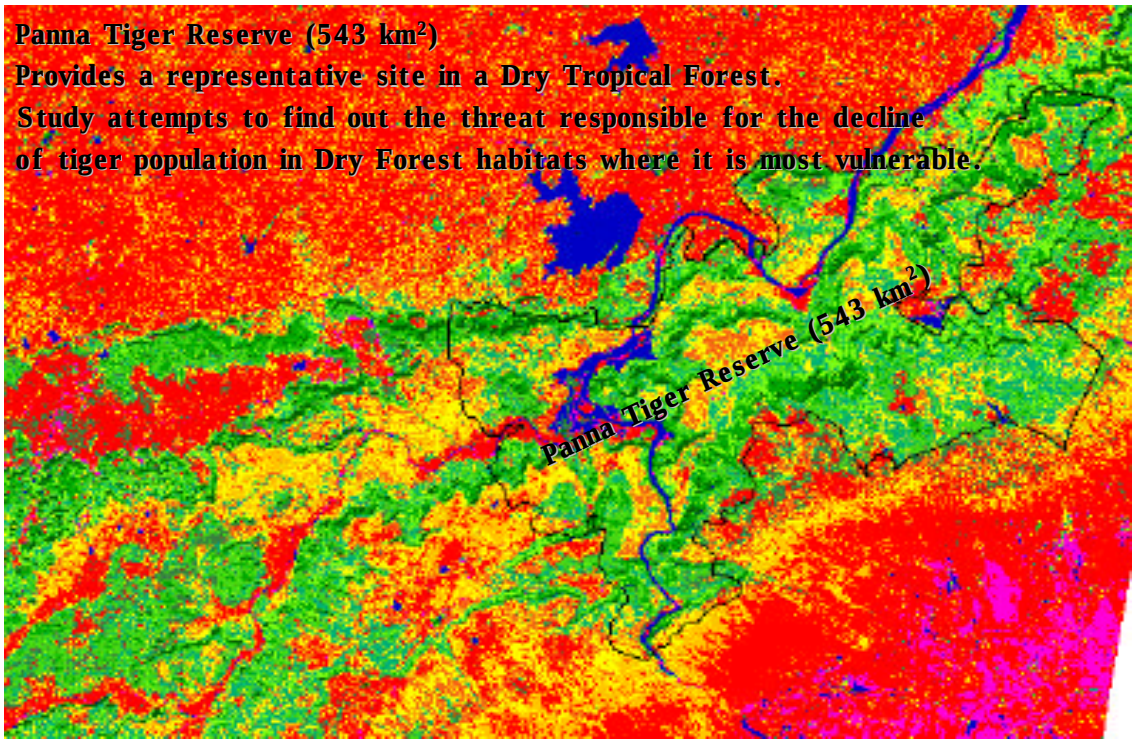
1. To determine the prey base requirement for a minimum demographically viable tiger populations in a Dry Tropical Forest.

2. To evaluate tiger habitat suitability with special emphasis on its prey.

3. To develop an understanding of the predator-prey relationship and to assess prey availability and the distribution pattern of tiger's major prey species.

4. To suggest management strategies for the management of a demographically viable tiger population and the management of its major prey species in Dry Tropical Forest habitats.

Figure 1.. Map of Panna NP and its adjoining area.



STUDY SITE

Intensive study

The intensive fieldwork under this project is being carried out in Panna Tiger Reserve in Madhya Pradesh where the ongoing study on the ecology of tigers is being undertaken (Figure 1). Under the ongoing project, several tigers are collared and their movements are monitored regularly to gather information on their home ranges, land tenure system, social organization and food habits.

The Panna National Park was declared as a National Park in 1981 and in the recent past as Tiger Reserve encompassing an area of 543 km^2. Extensive plateaux and gorges characterize the terrain of the area. The Ken River, a tributary of the Yamuna, passes through the National Park and is the major perennial source of water. The dominating vegetation type is “Miscellaneous dry deciduous” forest interspersed with grassland. Other major forest types are riverine, open grasslands, open woodlands with tall grasses, closed woodlands with short and tall grasses, and thorny woodlands.

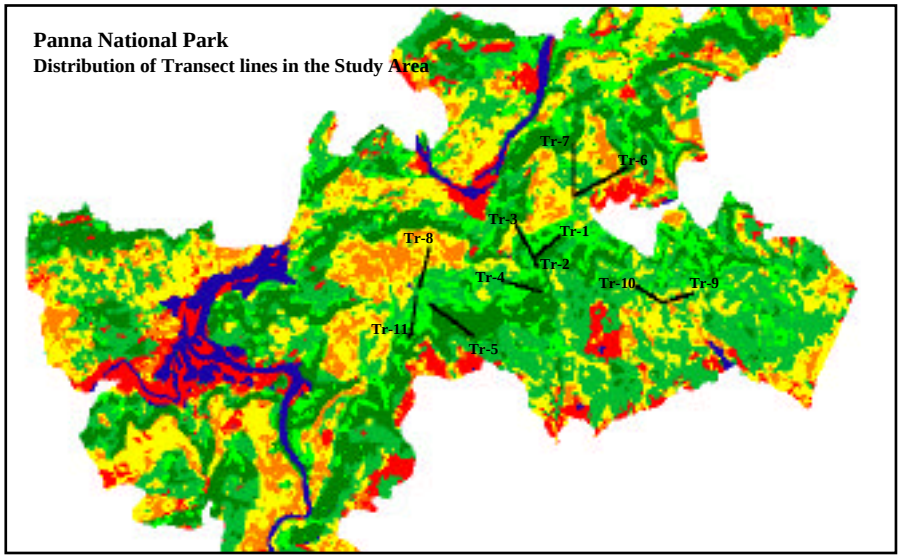
The park supports a diverse fauna. Among the large predators found in the area are tiger (Panthera tigris tigris), leopard (Panthera pardus), sloth bear (Melursus ursinus), wild dogs (Cuon alpinus) and wolf (Canis lupus). The herbivores includes sambar (Cervus unicolor), cheetal (Axis axis), nilgai (Boselaphus tragocamelus), chinkara (Gazella bennettii) and chausinga (Tetraceros quadricornis). Other mammalian species commonly found are Hanuman langur (Presbytes entellus), striped hyaena (Hyaena hyaena), Jungle cat (Felis chaus), wild boar (Sus scrofa), Indian fox (Vulpes bengalensis), and Indian tree shrew (Anathana ellioti).

METHODS

Estimation of tiger's major prey

Abundance of tiger's major prey species was estimated using line transect methods (Buckland, et al, 1993; Burnham, et al, 1980; Karanth and Sunquist, 1992)). Ten lines transects were selected randomly covering the entire intensive study area for estimation of prey Figure 2). These lines were 1.5 to 2.3 km long. Two to three persons walked each of these lines every morning and evening for over two weeks in early March2001. Local youths were trained and joined the research team with other trained volunteers for the count. All lines were cleared for easy and silent walking and distances were marked. During the transect run, the team walked slowly and quietly to ensure that most of the animal from the line were spotted. Whenever an animal was sighted, a compass bearing of the spot where the animal was first seen was recorded. Later with the help of a range finder the radial distance of the spot from the line was noted down. In addition to this information on species, group size, time and distance was noted down on the data sheet. This data was later analysed using the computer software DISTANCE (Laake et al, 1993).

Figure 2.. Park of the Panna NP map showing transect lines



Radio-collaring and monitoring of animals

In order to collect information on home range, movement, habitat use, activity of tigers and their major prey, permission for six tigers and five individuals of sambar, chital and nilgai was obtained.

Chemical Restraints of Tigers

For radio-collaring purposes tigers were chemically restrained. The targeted tiger was first located and later the research team, which included a veterinary expert, cautiously approached the animal on elephant back. In the case of already collared animals only one elephant was used, but in the case of a new individual or when replacing a non-functional collar, two elephants were used and a few observers were place on a tree at two to three vantage points to keep an eye on the tiger's movement. After locating the tiger, the elephant with the veterinary doctor approached the animal within 25-30 metres and waited until the animal pro-

vided a good view for darting.

The research team used Teleinject equipment for darting the animal. Meditomedine (trade name: Zalopine) in combination with Ketamin was used to capture the animal and "Antisedan" was used to reverse the effect of the tranquilization. On one occasion the research team also used Rompun and Ketamin combination for chemical capture. It was ensured that pressure on the projectile was kept at the minimum required in order to minimize the impact of the dart as it hit the animal. This is important so that the animal does not get disturbed and move away too far. By doing so the effect of the dart's impact wasreduced to a degree where the tiger did not move more then thirty to forty metres and in some cases less then ten metres. This allowed the research team and the veterinary doctor to monitor the animal throughout the induction time of the drug. After ten to twelve minutes, when the animal's head was rested on the ground, it was approached from behind. The animal's reflexes were first tested with the help of a long stick and later the tail was touched to assess the effect of the drug on the animal. Once the tiger's status was properly assessed, the research team quickly moved in with a couple of people to fix the radio-collar on the animal and take the morphometric measurements. This on average took less then twenty minutes and as soon as the collar was placed and measurement recorded, a few pictures of the head from the front were taken for identification purposes. After the research team moved away from the animal, a dose of antidote was given intra-muscularly at two to three places. The recovery of the tranquilized animal was monitored from elephant back. Recovery of tiger usually took ten to fifteen minutes when using Meditomedine and longer when the combination of Xylezine and Ketamine was used. Recovery in the case of Meditomedine was smooth and quick and the animal walked with coordination within twenty minutes after the antidote was given. The research team, later continued to monitor the animal intermittently for the next eight to ten hours.

Figure 3. Research team radio-collaring a male sambar

Chemical Restraint of Prey Species

Tiger's major prey, sambar and chital, were captured using the same drugs and equipment, which was used for tiger (Figure 3). Animals were approach from an open vehicle and darted from a distance of 25-30 metres and also from hides. After the darting, the animal was observed from a distance and its activities were monitored with the help of binoculars. On average the darted animal moved 50-60 metres from the site it was

darted and it took 6-8 minutes for it to go down. Once the animal went down the research team waited for twelve to fifteen minutes before approaching the animal cautiously from behind. From ten metres the animal's status was assessed and later it was approached carefully and touched. Immediately a dark cloth was used to cover the eyes and a radio-collar was attached. After the antidote was given, recovery of the animal was observed from 20-30-metres distance. The animals took fifteen to twenty minutes to be able to walk properly. These animals were monitored closely by the research team for the next 24 hours to minimize predation.

Monitoring of Radio-collared Animals

Radio-collared animals are tracked on a systematic schedule to obtain the locations of the animal. The locations are determined by triangulation method. For this all roads are marked at every 500m and in some places every 250 m. UTM coordinates for each of these points are recorded with the help of a GPS. In addition to these, several other vantage locations have been noted down. Once the radio-collared animal is contacted, compass bearings are taken and recorded from these known points with the help of directional antenna. This is repeated from three to four known points. Later with the help of a computer software "LOCATE" the animal's location is determined using the UTM coordinates and compass bearings. These locations of the animal are used for determining home ranges, movement pattern and habitat use by the animal.

Locations for every animal are obtained twice or thrice a week to determine the home ranges and habitat use pattern over the seasons. These animals are also monitored continuously for twenty-four hours once a month, to gather information about the daily movement and habitat use on a daily basis. For the twenty-four hours monitoring, locations are obtained every hour for tiger and every two hours for prey species and activity is recorded every fifteen minutes.

Habitat use

With the help of remote sensing data a detailed forest cover and habitat map was prepared for the National Park and its adjoining areas. This map was used to determine habitat use by tigers and their major prey species by plotting their location on the map and calculating the frequency of occurrence in different habitat types. Using this habitat map and other layers such as grazing pressure, village locations, water distribution, and other anthropogenic pressures, predictive models for the distribution of major prey species of tiger, sambar, chital and nilgai were prepared. These maps were then used to determine tiger distribution in relation to the availability of its major prey species.

In addition, to supplement this information, throughout the intensive study areas, 'control plots' were established on a grid basis every one-minute. These plots were later monitored at the end of every season for tree and shrub density, canopy and grass cover, stalking and hiding cover, grass height, disturbance, abundance of tiger prey by indirect evidences and a temperature data logger was placed at se-

lected plots to record the temperature every hour. This provided information on the availability of resources for the animals. Use of these resources by these animals was determined by visiting the locations obtained through radio-trakking of animals and conducting similar habitat evaluations for the locations of each radio-collared animal. To minimize the workload, in stead of visiting all the locations, only 40% of the locations were selected, randomly, to determine the habitat use by these animals.

Food habits of tigers

To determine the food habits of tiger, scats were collected every month. These scats were later dried and washed through a fine sieve. The prey remains which included hairs, pieces of bones, hooves etc. were collected for identification of prey eaten by tigers. Micro-histological analysis of hair helped identify the prey species eaten. Whenever a scat was collected, date and locality was noted down. The research team was also able to identify the scats of an individual tiger with the help of the radio monitoring of tigers. In such cases the individual identification number of the tiger was also noted down. In addition to this, monitoring of radio-collared tiger also helped in locating kills made by them.

RESULTS

Group size and population structure of tiger prey

Tigers' major prey species in Panna NP are sambar, chital, nilgai, four horned antelope, wild pig, chinkara and langur. Information on the population structure and group size is collected while walking line transects and also from random and opportunistic observations during the course of the study. Because of time limitations data for all the prey species has yet to be analysed. Only the line transect information collected on three major prey species - chital, sambar and nilgai - is discussed in this report.

Male to female ratio was found to be more biased towards females in these three populations of sympatric ungulate species. It was 100:41 for chital, 100:31 for sambar and 100:36 for nilgai. the number of young per hundred females seen was low in the case of chital and the number of yearlings was low in chital and also in sambar populations (Table 1).

The information indicates that the mean group size for chital, sambar and nilgai is 3.96, 2.2 and 2.8 respectively. Information on other species and other details are provided in Table 2. During the line transects, sambar, nilgai, four horned antelope and chinkara were seen mostly singly or in family groups. The family groups usually comprised of mother, fawn and yearling. Chital and nilgai were seen more often in larger groups than other ungulates, ranging from 1-44 in chital population and 1-17 in nilgai population.

Table 1. Population structure of the three major prey spcies in Panna NP.

Species	Female	Young male	Adult male	Yearling	Fawn
Chital	100	8.04	32.86	13.28	24.12
Sambar	100	9.92	20.6	15.2	42.9
Nilgai	100	7.34	28.19	21.32	36.01

Estimation of prey species

Table2. Details of group size of the prey species observed.

Species	Animal sighted	Mean group size	Range	Percent occurrence in group size class			
				1	2-3	4-10	>10
Sambar	577	2.2	1-10	39.1	43.0	17.7	0
Chital	963	3.96	1-44	29.6	35.3	27.9	6.9
Nilgai	909	2.8	1-17	35.1	40.4	21.9	2.4
Fourhorn	144	1.2	1-4	89.0	17.9	0	0
Wild pig	143	3.4	1-12	60.9	2.4	0	0
Chinkara	88	1.6	1-4	61.8	38.1	0	0
Langur	1197	8.0	1-50	9.4	0	59.7	30.8

The abundance of the prey was estimated once in 2001 between 5th to 18th of March. In addition to this, the same transect lines were also monitor regularly every month in the year 2000. Data from these monthly monitoring will be summarized in the final report. A preliminary analysis has been done on the March 2001 count-data and the result of this analysis is used for discussion in this technical report.

A total of eleven lines were walked covering a total length of 532.34 km^2. Detailed information on these transect lines is provided in Appendix-I. These transect lines represent an area of over 200 km^2 of the middle and upper plateaux of the study area. The result of this exercise refers only to the area sampled and therefore cannot be extrapolated for the entire Panna National Park (543 km^2) in its present form.

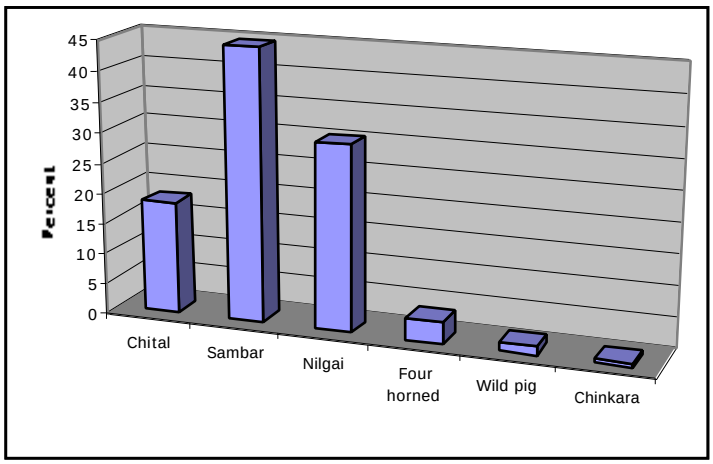
Animal abundance estimated is 32 prey/km^2 in the area, excluding langur. Detailed information on densities and other related parameters is described in Table 3. Efforts were made to lay the line to represent the entire sampled area in proportion to its availability. But due to logistic reasons it was not possible, therefore some of the habitats are more represented then others. The sampling is more intensive in the undisturbed high ungulate density areas, which covers approximately 70% of the entire sampled area. A high level of precision (coefficient of variation of Density < 15%) was achieved for most species by conducting the exercise for a short window of time, which reduced the temporal variation in the population distribution and detection probability. Also by conducting the exercise intensively, it is possible to reach the minimum sample size of 40 groups criteria for all the target species (Burnham, at al, 1980; Karanth and Sunquist, 1992). Habitat wise analysis for calculating densities has yet to be conducted and therefore ecological densities for different

Table 3. Estimates of density paramenter for the prey species in Panna National Park

Species	Density	Density Cv %	95% Confidence Lcl	Ucl	Enct rate	Density Group	Cv Group Density
sambar	9.16	10	7.5	11.19	0.47	4.14	0.09
Chital	10.8	10	8.85	13.18	0.45	3.14	0.08
Nilgai	6.02	7	5.16	7.03	0.6	2.55	0
Fourhorn	4.03	11	3.24	5.01	0.22	3.37	0.1
Wildpig	1.29	30	0.72	2.32	0.07	0.58	0.23
Chinkara	0.92	17	0.65	1.32	0.1	0.68	0.16
Langur	22.9	13	17.5	29.9	0.28	2.5	0.1

habitat are not calculated and discussed in this report.

Figure 4. Biomass contribution (in %) by the major prey species in Panna



In this sampled area chital, sambar and nilgai are the most abundant wild ungulates, butoverall in sheer numbers langur is the most abundant prey species. Among the ungulates chital is the most abundant prey species in the area followed by sambar and nilgai. Wild pig density was found to be low (1.29/km^2). Although chital was the most abundant prey species in the area in number, sambar and nilgai contribute most to the prey biomass available in the sampled areas. In terms of biomass, sambar and nilgai together contributed over 75% to the available prey biomass of the area and sambar alone contributed almost half the total prey biomass. Chital contributed very little in the availability of prey biomass for tiger and contribution from other smaller prey species was found to be minimal in the area (Figure 4).

Home ranges

Some prey species of tiger have also been radio-collared and monitored to study the tiger ecology in detail. These radio-collared animals are monitored on a regular schedule as described in the methods. In this report information only on home ranges of tiger, sambar and chital and the habitat use by tiger is included for discussion. Home ranges are estimated using a software program "CALHOME" (Kite, at al, 1994). Although information on the activity and movement patterns for all the radio-collared animals and habitats use by the prey species is recorded, the data has yet to be analysed. These aspects of the radio-collared animals are therefore not discussed in the report.

Radio-collared Tigers

Female-118

During the course of the study five radio-collared tigers are being monitored; these include four females and one male. One of the females, '118', who was radio-collared in 1997 was captured again and her non-functional collar was replaced with a new collar. Female 118 is raising her third litter of three cubs comprising of two males and one female. She was first collared in January 1997, when she was raising a litter of three 7-8 month-old female cubs. Unfortunately the radio-collar stopped functioning after eleven months but the research team have been able to monitor her intermittently since then. Later I was able to radio-tag the three females of her first litter after they became independent and had established their own territories. In between the two litters mentioned above,female-118 had a second litter of two male cubs, which, like her first litter, survived to adulthood and dispersed. Her third litter

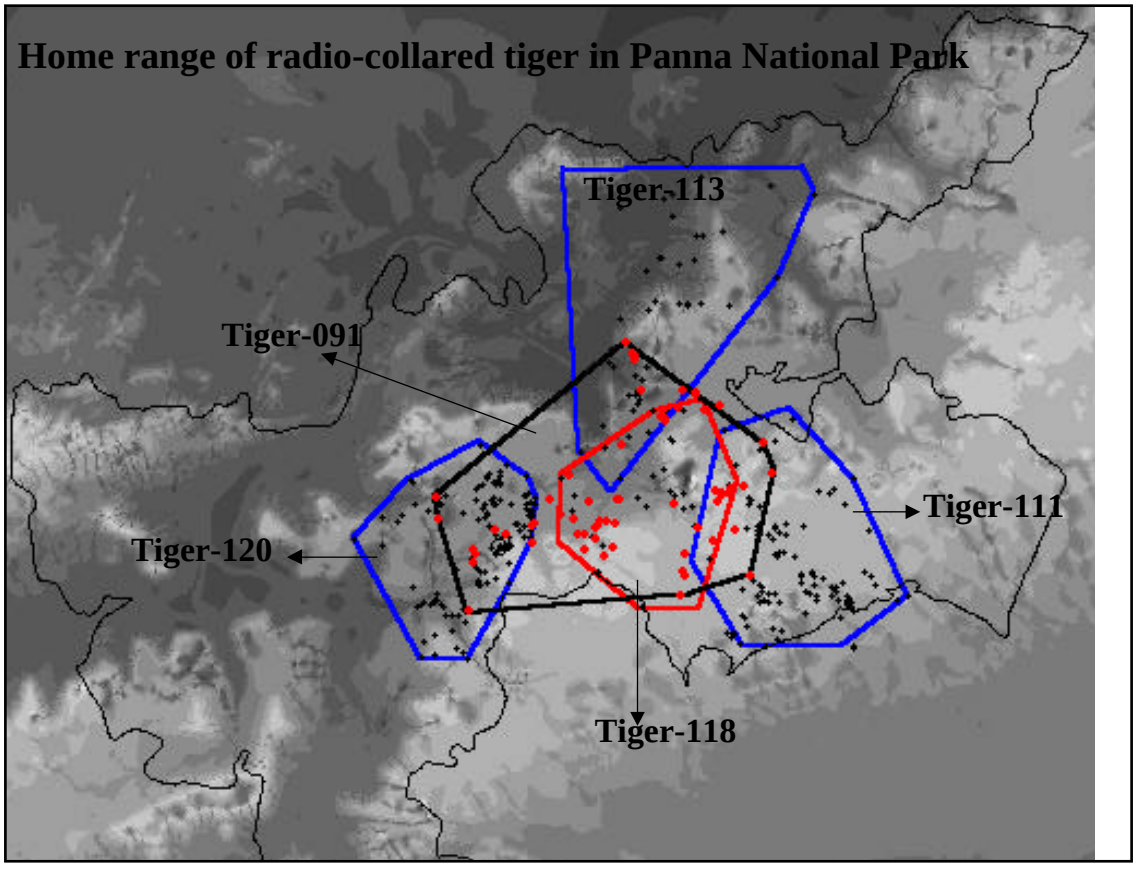
is now over 22-23 months old and is ready to disperse. It is expected that female-118 will deliver her fourth litter in the next few months. Female-118 occupies an undisturbed high prey density habitat in the core area of the Park.

The estimated home range (MCP 100%) of 118 is 31 km^2 with the core area of her activity - where she spends over 70% of the time - calculated to be close to 10 km^2 (Harmonic mean, 70%). Her range overlaps with that of her daughters, female-111 and female-113 (Figure 5). However, we have not seen any association of the daughters with the mother after they became independent and established their territories. 118 had a larger range prior to her first litter establishing their territories. Subsequently it seems that part of her range is now taken over by her daughters and as a result her range has reduced considerably - by 10 km^2.

Female - 111

Female-111 is one of the dughters of female-118, and was first radio-collared in April 1998, when she was in the process of dispersing. Initially she used part of the mother's territory. After 6-7 months making forays into the surrounding areas, she established her own territory in an adjoining area immediately southeast of her mother with some overlap. Her territory extends beyond the Park boundary by three to four kilometres into the neighbouring territorial forests of South Panna Forest Division. She

Figure 5 . Map of radio-collar tigers with locations in Panna NP



had her first litter of two cubs - one male and one female - at the age of approximately 36 months in May 1999. She had her second litter in March 2001 twenty-two months later. The second litter comprises of three cubs but the research team has not been able to identify the sex of these cubs yet. Female-111 occupies an area close to the periphery of the National Park and her territory includes areas surrounding one village situated inside the Park. She also partially uses areas of another two villages that are located at the periphery but outside the Park boundary.

'111' patrols a large area of 50km^2 (100% MCP)and most of her activity is restricted within 37 km^2 of her range on the upper plateaux (Table 4). The area used by her has low prey abundance but very high cattle presence and most of her kills are cattle. Moreover, during the hot summer months there is no water available within her territory on the upper plateau inside the Park. She either has to come to the base of the escarpmentson the middle plateau in search of cool resting-places and water or has to visit a water hole more then 3 km away from the Park boundary (Figure 5). This brings the tiger into direct conflict with local human populations, whenever she kills livestock in this unprotected forest habitat.

Female - 120

Female-120 was radio-collared in January 1999, when she was 34 months old. She has established her territory in the area west of her mother's territory which she occupied by displacing an old territorial female from the area. She was able to displace the territorial female with the help of her third sibling, who lived and moved in coalition with her for eight to nine months before they separated and established their respective territories. At the time of her collaring she was seen accompanied by her sibling and she remained in association with her for another couple of months after this. She gave birth to her first litter at the age of around 42 months in December 1999. This litter comprised of one male and one female cub who are now nineteen months old and in the process of dispersing. Like her mother she also occupies a prey-rich, undisturbed forest habitat on the middle plateau. But her range extends up to the Park boundary and includes areas adjoining the territorial forest and villages at the southern periphery of the Park.

She covers an area of 35 km^2 (MCP 100%) and most of her activity is restricted to small areas of less then ten square kilometres (Table 4).

Female - 113

The third daughter of the mother - female-118 - was radio-collared in December 2000. Like her other two siblings, she also has established a territory in an area adjoining the mother's territory and par-

tially occupying it. Hers is to the north of her natal area. At the time of her collaring in December 2000, she was raising a litter of two cubs - also one male and one female - 15-16 months old. She occupies an area immediately south of the River Ken in the valley and part of her range includes areas north of the river. Her range also touches the periphery of the Park onthe northern boundary of her territory.

She covers a very large territory (67 km^2, MCP 100%) but spends most her time in a much smaller area (10.6 km^2, Harmonic mean 70%) which is more of a similar size to that of the other tigresses (except female-111; (Table 4). She occupies a very narrow belt of tiger habitat along the river Ken, which includes several villages.

Male-091

The male was radio-collared in April 1996 and the collar was replaced in October 1998. The second collar continued for the next three years and finally due to battery exhaustion stopped functioning in October 2000. At its peak, the male's range covered an area of 277 km^2, which is more then 50% of the entire Park area, but it included only two female territories. This large area encompassed the two territories of female-118 and the other female who was later ousted by female-120. Later his territory encompassed 118's daughters, female-120 and female-111. With these females he fathered six litters and two from the female ousted by female-120. These eight litters fathered by him amount to seventeen cubs of which thirteen of them have survived to adulthood in the last five and a half years. Over the years he has lost a considerable part of his territory to other males after several battles. His territorial behaviour has been discussed earlier in the report and other publications (Chundawat et al, 1999) The collared males's range is now reduced to a mere 98.25 km^2 and only partially covers the three female territories he once occupied (Figure 5).

Radio-collared Sambar and Chital

A total of five sambars and one chital

Table 4. Home range size (in km^2) of radio-collared tigers in Panna National Park.

Home range size	Tiger F-111	Tiger F-113	Tiger F-118	Tiger F-120	Tiger M-91
100% Mnimum Convex Polygon	50.9	67.5	31.3	35.7	98.25
Harmonic mean 70%	36.9	10.6	9.8	9.6	11.4
Avg. Distance Traveled	1.3	2.8	1.7	1.4	2.2

are radio-collared for monitoring their activities. Radio-collared sambar include two large males and three females and the chital is an adult female. All the radio-collared females are associated with young. The average size of male and female sambar homes ranges are similar and range from 8.6 to 15.8 km^2 (Figure 6). But male sambar covered on average larger distances than the females (Table 5). Core areas of activities for female sambar are much smaller than those of the males. Females are using less than 1.5 km^2 for 70% of their activities, whereas males' activities are spread over 3-5 km^2. The chital home range is much smaller than those of the sambar; she ranges over an area less than four square kilometres. But her movement and area of most activity (70%) is almost as big as the female sambar.. During the summer months, the centre of activities of all the radio-collared sambar and chital was in the same area associated with a perennial water hole. This changed dramatically soon after the first shower at the end of summer, suggesting strongly their close association with water availability.

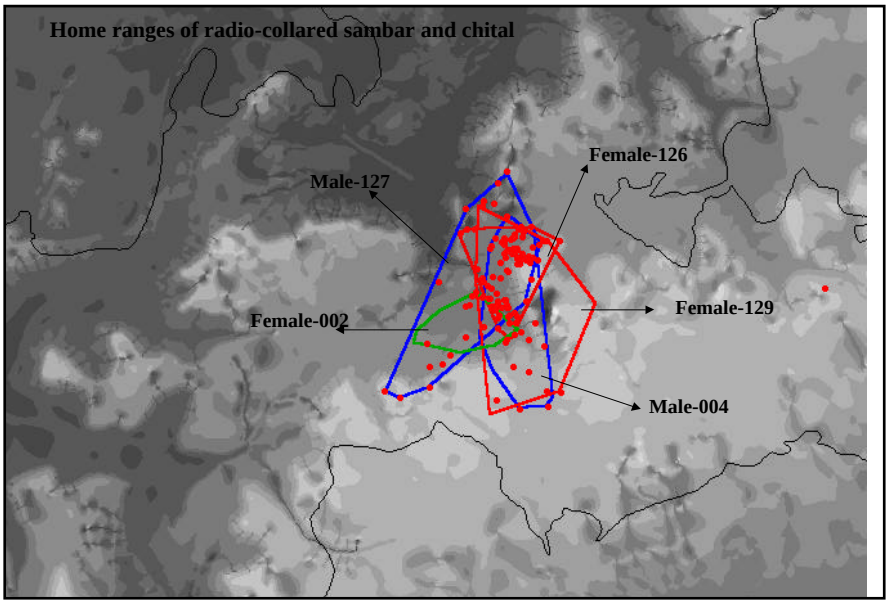
Table 5. Home range size (in km^2) of radio-collared sambar and chital in Panna National Park.

Home range size	Sambar 004 M	Sambar 127 M	Sambar 126 F	Sambar 129 F	Chital 002 F
Minimum convax polygon	9.2	15.8	8.6	15.8	3.7
Harmonic mean 70%	3.6	5.4	1.1	1.8	1.5
Avg. Distance travelled	1.2	1	0.9	0.9	0.7

Habitat use by tiger and relation to its prey

All tiger locations are pooled and used to determine habitat use by tiger. A detailed map of different habitat types is prepared from satellite data and from this map, availability of each habitat is calculated for tigers. On average tigers used the densely forested areas more then other habitats and of these, dense Mixed Forest along the base of the escarpment was used most (> 40%). When the same data is looked at in more detail with information segregated for the summer and winter seasons, it is noticed that open habitats are used relatively more (8-15%) in

Figure 6. Map of home ranges of sambar and chital in Panna NP



winter. However, overall, distribution of tiger during the winter months is more widely spread across the habitats with higher use of dense forest (< 25%). During the summer months it is the Mixed Forest habitats along the escarpment that are used most. These forest habitats along the escarpments provide special micro habitats with dense cover, water and caves for shelter, where the tiger finds cool places to escape from the intense heat of the hot summer days.

The study aims to find out whether the distribution of tiger is related to its prey and if it is then which prey species it is more closely related to? A distribution map of densities for major prey species (these include only sambar, chital and nilgai) was developed with the help of field data and GIS. These models were then taken into the field for ground truthing. After verification of these distribution models, tiger locations were used to determine the use of an area by tiger according to the availability and abundance of its major prey. Details of the distribution of the prey species are given in Table 6. Nilgai has a very widespread and more or less even distribution in all density classes. However chital was found to have a very restricted distribution; only < 20% of the area had high chital density. Sambar distribution is also similar to that of chital, in over 50% of the area they are not found or found at extremely low (< 1 animal/km^2) density.

When tiger distribution is seen in relation to pooled animal density for these ungulates, it is observed that tiger distribution is closely related to high prey density areas (Figure 7). When tiger distribution was seen in relation to each of its prey species separately it is observed that tiger distribution was not related to high nilgai density areas. But tiger used the high density chital and sambar areas more then other areas, even though in terms of space these areas are highly restricted. This indicates that tiger distribution is related to high prey availability but it is the chital and sambar availability which is affecting the tigers' use of habitat more than other prey species in Panna National Park.

In a dry environment like Panna, water plays a key role and it was noticed that during the summer months not only was prey species distribution related to its availability, but tiger distribution was also very closely related to water (Figure 8).

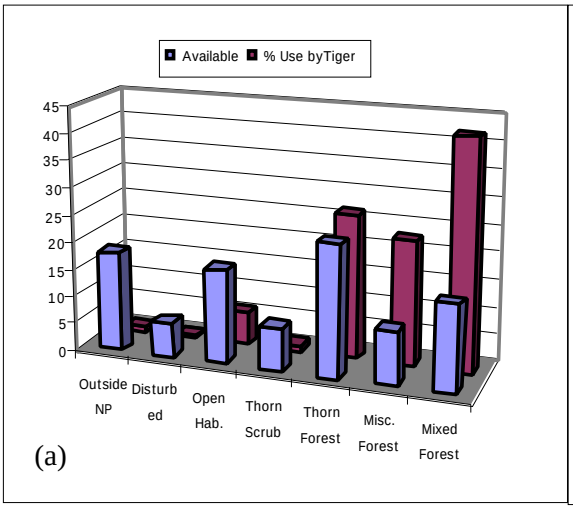
Food habits of tiger

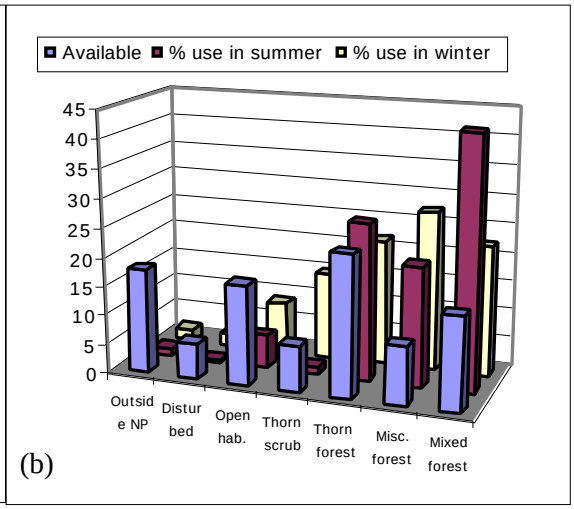
The food habits of tigers of Panna were determined by identifying the prey remains in the scats of the tiger. In this report results from a preliminary analysis conducted and data already published as part of this study earlier (Chundawat et. al., 1999) is used to discuss the food habits of tigers in Panna. Sambar, chital, nilgai and cattle are the major prey species in the diet of tigers. Contribution by mammals less than 40 kg was over 30%. High occurrence of cattle remains indicated higher predation on livestock.

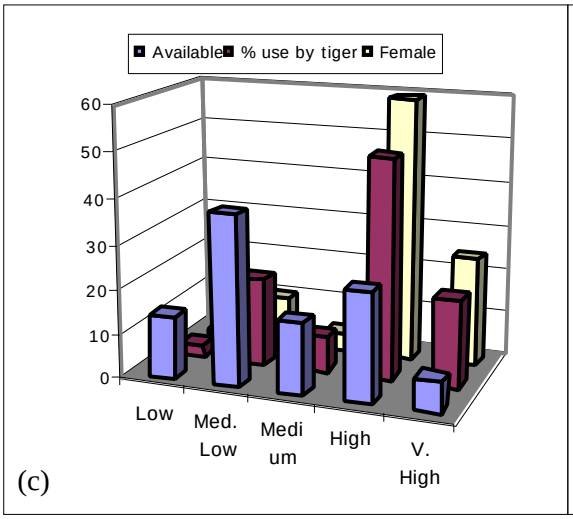
Table 6. Distribution of ecological density of chital, sambar and nilgai in Panna NP.

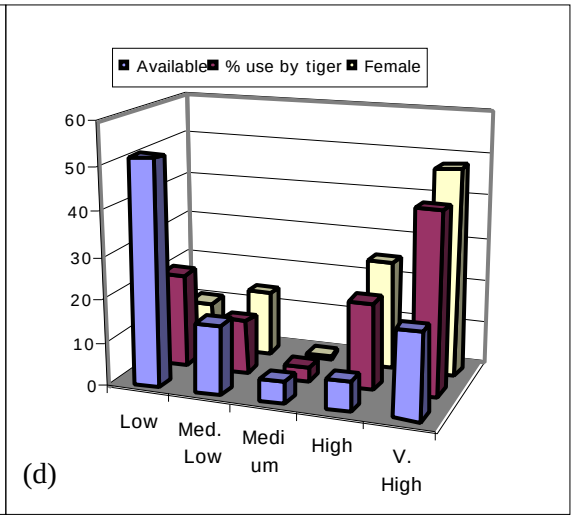
Density	Nilgai	Sambar	Chital
Low	7.6	52	59.7
Med. Low	19.7	16.3	20.9
Medium	18.6	5	12.4
High	34.2	7	7
V. High	20	19.7	0

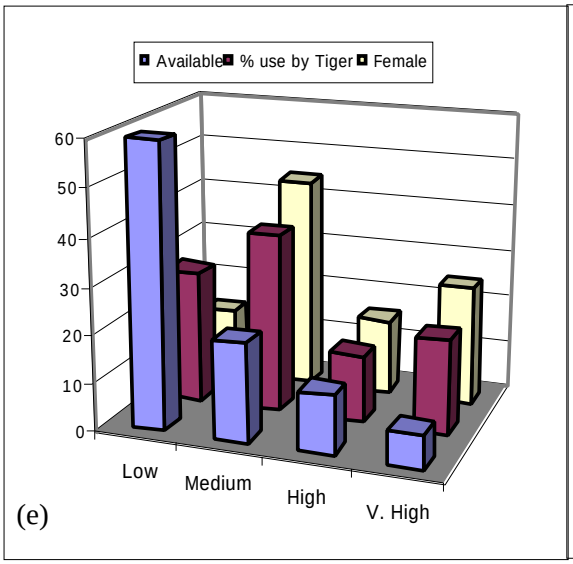
Figure 7. Habitat use by tiger; (a) annual, (b) winter and summer and in relation to availability its prey in dufferent density, (c) all ungulates, (d) sambar, (e)chital and (f)nilgai

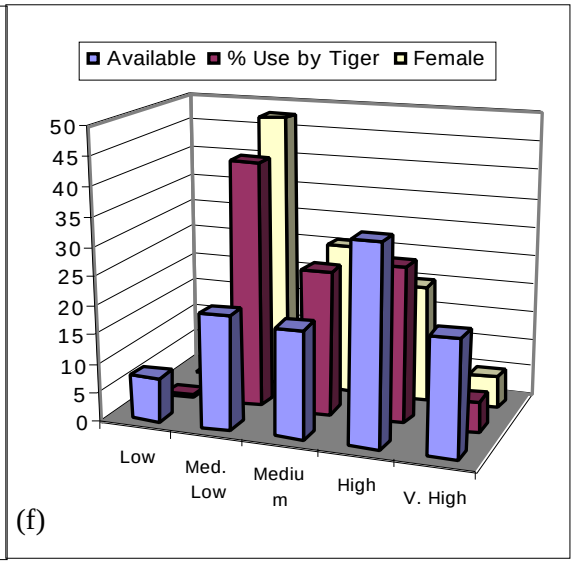










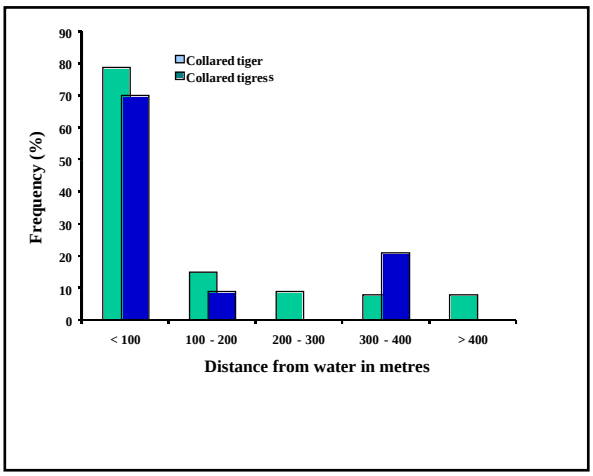


DISCUSSION

In Panna, the indication from preliminary analysis is that group sizes of wild ungulates are smaller than at other sites (Karanth and Sunquist, 1992; Kumar, 2000), especially in the chital population. This needs further investigation to find out the factors affecting the group size.

Group size could be an indicator of poor resource availability and lack of habitat suitability, which could also have a negative effect on the reproductive success of the population (Jarman, 1974). It is also observed that in the chital population the number of fawns per 100 females are low, when compare to other populations in the subcontinent (Mishra, 1982; Karanth, 1993; Khan et al, 1989; Kumar, 2000). Furthermore, it is also noticed that survival of this population into the next age class of yearling is also very low. This indicates poor reproduction in chital population and later high mortality in the yearling age class. A similar high mortality from 43 fawns every hundred female to 15 yearlings is observed in sambar yearling class. Sambar, four horned antelope and chinkara are seen mostly singly or in family groups, which include mother with a fawn and yearling. This information is also further supplemented from monitoring the association of the radio-collared sambar. Males are solitary most of the time, except during the rut when they associate with female groups or join other males temporarily after the rut. Females are seen mostly with their fawns and yearlings and occasionally associate with other family groups for a short time at their favourite feeding places. Chital and nilgai were seen more frequently in larger associations, indicating their social nature.

Figure 8. Association of radio locations of tigers with water during summer months.



A density of 32 prey/km^2 is relatively low compared to other high tiger density areas (Karanth and Nichols, 2000), including similar dry forests of Ranthambore and Sasan Gir (Karanth and Nichols, 2000; Khan, 1989; Kumar, 2000). A comparison of prey abundance in six protected areas which include Pench, Kanha, Kaziranga, Nagarahole, Ranthambore (Karanth and Nichols, 2000) and Panna NPs reveal that medium (52.7%) and large prey (46.4%) contribute most and almost equally in term of prey biomass availability. But the interesting aspect is that the medium sized prey (which here include chital, hog deer and wild pig) contribute, on average, more than 70% in terms of number of prey available in these systems (Table 7). But in contrast to this in Panna, contribution by medium size prey is low in terms of both prey biomass (20%) and number of animals (32.2%). Availability of prey biomass in Kanha is comparable to Panna but the only difference is

once again in the availability of chital population. In Kanha chital contribution is 78% in term of biomass (18.5% in Panna) and over 86% in number (Karanth and Nicholas, 2000) (33% in Panna). It is significant that chital or medium size prey is limited in Panna and this could be an important factor affecting the tiger ecology.

Home ranges of tiger in Panna are larger than other tiger populations studied in the subcontinent (Sunquist, 1981; Smith, 1984; Karanth and Sunquist, 2000), especially that of the breeding females. Female territories are mostly resource oriented (Sunquist and Sunquist, 1989). In Panna their larger range could well be largely due to low prey abundance and availability, high human disturbance and sparse water distribution in summer. Furthermore the heterogeneous distribution of resources over time and space makes resource availability unpredictable. Therefore Panna supports a smaller population currently then it could otherwise (Karanth and Nicholas, 2000). One of the important management aspects (other than biological but relevant for the conservation of tigers in Panna) related to their larger ranges is that the tiger home ranges either extend beyond the Park boundaries or touch the periphery. This exposes them to external pressures and brings them into direct conflict with local human populations.

Table 7. Percent biomass and number of tiger prey in different Protected Areas

Protected Area	Biomass Large prey	Biomass Medium prey	Number Medium Prey
Pench NP	41.08	58.91	81.66
Kanha NP	18.76	80.81	91.09
Kajir. NP	69.85	30.14	70.91
Nagarh. NP	56.13	44.13	73.91
Ranth. NP	54.76	44.59	69.3
Panna NP	75.62	20.03	37.57
average	52.7	46.435	70.74

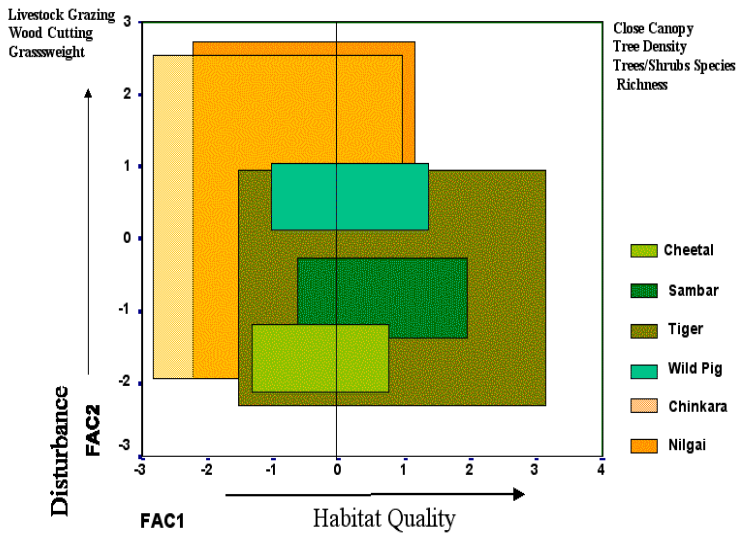


Figure 9. Distribution of tiger and its prey species in relation to habitat quality and disturbance. (modified from Mathai, 1999)

The distribution of tigers in Panna is closely related to high prey density areas, as has been found in other areas (Sunquist and Karanth, 1999). It is clear from the results of the study that tiger distribution is more closely related to two prey species of deer - chital and sambar - and not to nilgai, a large bodied antelope, an otherwise ideal prey in terms of size and abundance. The Dry Forest habitat of Panna is

an area occupied by two different kinds of ungulate populations which have evolved in different environments - one in open habitats and the other in forest. Nilgai and chinkara represent a prey population which prefer open habitats, whereas chital and sambar are forest-edge habitat dwellers. From Figure 8, it is clear that although the nilgai and chinkara population occupy a much larger area, most of it is outside the tiger distribution. Because tiger has evolved as a specialized forest-edge predator following the cervid radiation in Asia (Sunquist and Karanth, 1999), its survival and hunting strategies are more cued to cervids than prey found in open habitat. Tiger is not avoiding nilgai consciously but only a part of the population of nilgai is predated - that which occupies forest-edge habitat. Moreover, nilgai is less likely to achieve their optimal densities in these forest habitats. Therefore, in habitats such as Panna, which form over 40% of the tiger habitat in the subcontinent, prey such as nilgai and chinkara may be playing a limited role in the ecology of tigers. Cervid and bovid populations achieve maximum densities in a mosaic of forest habitat and in Asia and it is from these habitats that higher tiger densities are reported.

CONCLUSIONS

From the above results and discussions, the following conclusions have been derived:

1. A density of 32 prey/km^2 is estimated for Panna National Park, which is low in comparison to other high tiger density areas.
2. Contribution by medium-sized prey is small (20%) in terms of biomass i the system.
3. A low ratio of fawn and yearlings per female is observed in the chital population, indicating poor productivity of the population.
4. The home ranges of female tigers are larger than those in other tiger habitats studied.
5. The home ranges of all the tigers either extend beyond the Park boundary or touch the periphery, exposing breeding individuals to external pressures.
6. Distribution tiger and its prey species, sambar and chital, are closely related to water availability in summer.
7. Tiger distribution is closely related to high density chital and sambar areas and not as strongly with nilgai.
8. Chital, sambar and nilgai are major prey species of tiger in Panna.
9. Cattle and smaller prey contribution in tiger are high.
10. Medium-sized prey, which is a limited resource in Panna National Park, is important in the ecology of tiger. In Panna medium-sized prey includes chital and the wild pig populations.
11. It is also observed that distribution and abundance of chital population is restricted and limited in number.
12. Though nilgai contribute over 30% in the availability of prey biomass, it plays a limited role in the distribution of tiger in Panna.
13. Chital and sambar are the prey species found to be more important for tiger in Panna then nilgai and chinkara.

SUGGESTED MANAGEMENT STRATEGIES

1. **Wild life management beyond the National Park boundaries.**

The study very clearly reveals that none of the breeding territories are fully protected within the National Park boundaries. They extend beyond into adjoining forest habitat controlled by territorial forest divisions, where wildlife management is not the priority. It is in these areas, where the tigers predate on livestock, that they come into direct conflict with local populations. But since these tiger habitats are not under direct control of the Park management, there is little it can do to provide protection to these individuals. Moreover some of these areas also harbour important microhabitats used by some of the breeding individuals. It is therefore suggested that the adjoining forest habitats should be transferred immediately from the territorial division to come under direct control of the Field Director and Con-

servator of Forest (Wildlife) to providefull protection to the breeding population of the Park. It is very important because unlike other Tiger Reserves of the State, Panna has no buffer area as has been recommended in the Project Tiger guidelines.

Action suggested:

A. From immediate effect, part of the Gangau Wildlife Sanctuary which was not included in the National Park but lies outside must be put under Tiger Reserve Management.

The proposal for creation of buffer areas under the guidelines of the Project Tiger must be implemented and these forest areas should be brought under the Tiger Reserve's jurisdiction for management and administration. A copy of the map of the proposed buffer and proposal developed by the Park authority is included as Appendix-II for reference. The research findings strongly endorse this proposal for its implementation.

2. **Regime for grazing facilitation to help chital population**

In more than one way, the results of the study indicate that chital plays an important role in the ecology tiger in the Park, but it needs managerial inputs to help the population recover over its suitable habitat. Two aspects of its ecology are important for consideration. Firstly, poor production of fawns and secondly, restricted distribution of chital, despite extensive forest-edge availability in the Park. The chital population has increased in the Park mainly in an area where water is available and a small population of feral cattle help chital in "grazing facilitation", The cattle open up the habitat making it suitable for chital to exploit when it is required most, prior to its peak rutting activity in March to April. Since such grazing facilitation is not possible over the entire area, management intervention is required and a well-planned grazing regime of controlled burning should be established, keeping in mind the nutrition requirement for the only grazing community of the Park - the chital. This early burning will also help in controlling unwanted dry season fires so the proposed plan can also be seen as a fire protection measure. Grasslandswill be classified according to moisture availability and suggestons given for burning in the areas that keep moisture for a longer period of time. Burning could start from as early as December in some areas to the end of January in others. This will allow new nutritious forage availability for the chital population for their physiological buildup just prior to their peak rut in March/April.

Action suggested:

B. A detailed plan on the map must be created, delineating areas clearly and time and rotation for burning and monitoring scheme for four to five years.

C. The principle investigator of the research project after consultation with sev-

eral scientists and personnel who hved worked with fire management will develop a plan. This plan will be presented at the Chief Wildlife Life Warden's office and will be critically reviewed by invited guests and mangers of Tiger Reserves of the State. After the review the plan should be implemented so that it could be placed at the start of the working season. The research project will establish a monitoring programme for this experimentation for “grazing facilitation” for chital population to help save wild tigers in the Dry Forest habitat of Panna National Park.

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