Understanding Tiger Ecology in the Tropical Dry Forest of Panna Tiger Reserve

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Introduction

Among all wild animals, the tiger has received a considerable amount of attention the world over. Despite such favourable notice, tiger populations are declining at a faster rate than at any time in their history. Many local isolated populations are being pushed towards extinction. The recent loss of tigers from Sariska is one such example that highlights the extreme vulnerability of tiger populations in the Indian sub-continent. The decline in tiger numbers is mainly due to increasing human pressure on tiger habitats throughout its range; mounting demand on natural resources is destroying the tigers' habitat and increased man-wildlife conflicts create an environment unsuitable for the survival of a large predator like tiger. In these habitats used by humans, the tigers' survival is precarious and in most places, it is on the verge of local extinction. The situation is worse outside the protected areas.

Since enacting the Indian Wildlife (Protection) Act, 1972 and the inception of "Project Tiger" in April 1973 in India, considerable effort has been made towards the conservation of tigers in India (Panwar, 1982, 1987). The repeated occurrence of tiger crises indicates that not enough has been done and the efforts may have been imperfectly directed; certainly much more needs to be done to save wild tigers in India. A network of protected areas, as Tiger Reserves, supposedly safeguards extensive wilderness especially for the tiger. Yet, the tiger population within these protected areas can also be affected by several ecological factors in addition to the existing human induced biotic pressures and developmental activities such as large dams. Like all large carnivores, the tiger requires adequate space, substantial prey base, cover and protection from human caused mortality (Schaller, 1972; Gittleman and Harvey, 1982; Mills, 1991; Caro and Durrant, 1995).

Tiger populations, in most of the protected areas in India, face the following several conservation problems (Panwar, 1982, 1987; Wemmer et al, 1987, Karanth, 1991; Johnsingh et al, 1991):

a) Inadequate size of protected areas.
b) Fragmentation and loss of habitat, as well as an increasing rate of habitat degradation resulting in a decrease in habitat quality.
c) Inadequate prey base.
d) Mounting demands for forest based resources, thereby increasing man-wildlife conflicts.
e) More recently, poaching for commercial use.

As a result, the tiger only survives in small and isolated populations (Johnsingh et al, 1991). Such small populations are vulnerable to normally operating demographic and environmental stochasticity (Caughley, 1994). This vulnerability, in addition to the factors mentioned above, make such populations very unstable (Soule 1986); a slightest perturbation in the ecosystem can have a pronounced effect on the stability and in turn on the viability of these populations. Therefore, the overall survival of tigers will depend upon the stability and viability of local populations.

Problem Statement

To maintain a demographically viable population of tigers, the size of the protected area is the critical issue for management (Woodroffe and Ginsberg, 2000). The rate of extinction for any larger mammal species is rapid, and is more pronounced in the case of a large carnivore population in small and isolated protected areas. There are no defined methods to determine what should be the minimum size of a protected area (May, 1975; Terbough, 1976; Simberloff and Abele, 1976). Yet management of a protected area should strive to conserve the species for which it has been created (Smith, 1984). It would, therefore, be appropriate to consider tiger as an indicator species to address the issue of size of protected areas and other ecological problems that exist in its habitat.

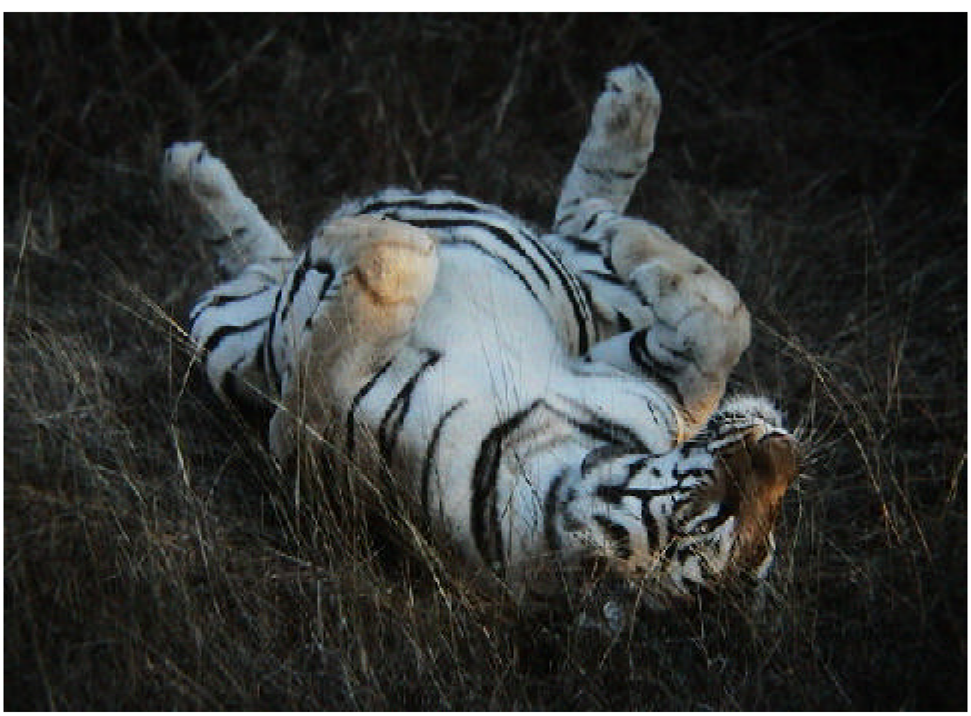
In India, most of the protected areas that have tigers, are small and isolated units, either due to their physical fragmentation or because of managerial differentials (Panwar, 1987; Johnsingh et al, 1991). Approximately 80% of the protected areas in India are less than 400 km2 in size (Rodgers and Panwar, 1988). In such a situation, it is important for management to determine the potential of PAs in conserving tiger populations. In other words, based on the animal's ecological requirements, it is important to consider approximately how many tigers a PA can support. Rather than simply plotting the tiger population growth chart, such an approach would be more meaningful for the conservation of this endangered species. A field-oriented approach of this type would eventually give a realistic projection of the requirements needed to maintain demographically viable populations. In effect, it would improve our scientific understanding for managing protected areas for the conservation of tiger populations.

The pertinent question that Management needs to ask is: 'are the present protected areas capable of sustaining a prey base, which can support a demographically viable tiger population?'

How does Management go about answering this question?

a. Like most other carnivores, tigers specialize in their feeding habits; their predatory strategies and have evolved through a rigorous natural selection process to maximize their energy intake (Sunquist and Sunquist, 1989). Therefore, the ecology, social organization and movement pattern of tigers are likely to be governed by several ecological factors such as availability of prey, its temporal and spatial distribution, its size and anti-predatory behaviour. It, therefore, becomes necessary to collect information on tiger feeding ecology, ranging and movement pattern to find answers to the question asked earlier.

b. Animals occupy an array of habitats, and their demography varies with the different habitats type they occupy. The reproductive success of a population largely depends on the proportion of suitable habitat available for breeding. In "source" habitats, where surplus individuals are produced, any loss or alteration to these habitats due to natural or anthropogenic reasons will have a drastic effect on the stability and survival of the population (Pulliam, 1988; Pulliam and Danielson, 1991). Therefore management needs to know - how are these "source" habitats utilized by tigers? What are the characteristics of such habitats? How do we identify and manage these habitats to maximize the reproductive success of tigers? These are a few of the important management questions that need immediate answers and that will benefit management in achieving its goal of tiger conservation.



c. Another important issue that needs to be addressed is that of the dispersal patterns of juvenile tigers and their survival. Dispersal not only regulates the population but also maximizes mating success and plays a major role in genetic flow and social organization (Dobson, 1982; Smith, 1984). Populations in a "source habitat" (resource rich) produce excess individuals, which then have to disperse from their natal areas into neighbouring "sinks" (sub-optimal habitat). The management of dispersing individuals in these sinks is extremely important and small PAs as "source" habitat need to be linked to the neighbouring "sinks", so that tiger populations can be conserved as a meta-population (Pulliam, 1988). A study of such dispersal dynamics would provide scientific guidelines for the management of meta-populations, which in India is long overdue.

The issues discussed above are considered pertinent for this study and it attempts to answer following questions:

1. What is the food requirement for tiger?
2. What is the minimum size of protected area required to sustain a demographically viable population of tigers?
3. Does tiger prey regulate its social system, ranging pattern and habitat requirement?
4. What are the "source" habitats and how are they utilized?
5. What happens to the individuals that disperse?
6. How do tigers react to human interference in "sink" habitats?
7. What would be the best conservation strategy for managing large carnivore populations in small isolated protected areas?

Need for the study

Over 60% of the world's tiger population survives within the Indian subcontinent. The tiger occupies a wide range of habitats in India but very few protected area are large enough to protect a large viable population (Rodgers and Panwar, 1988). Although, in the past a few studies have been conducted on tiger (Schaller, 1967, Seidensticker, 1976, Sankhala 1977, McDougal, 1977, Panwar, 1979, Sunquist, 1981, Tamang, 1982, Smith, 1984), most of them were in its optimal habitat. Thus most of the knowledge available on tiger ecology is from moist and productive habitats.

On the other hand the tiger census figures of 1993 report that about 50% of the Indian tiger population is living outside the Protected Areas, which are sub-optimal habitats for tigers. The average tiger population in these PAs is less than10 tigers. At present about 45% of the remaining tiger habitat in the Indian subcontinent, is in Tropical Dry Forests (Wikramanayake et al 1999). Extreme temperatures, seasonality, low productivity and high human pressure characterize these habitats. The tiger has suffered mostly in these habitats. About 35% and 70% of the tiger population has become locally extinct from Dry Deciduous Forests and Semi-arid Forest habitats respectively. Such large-scale local extinctions of tiger population in Dry Forest habitats highlight the vulnerability of tiger populations in its largest habitat in India. Therefore, this study was conducted in a DRY FOREST HABITAT, which represents a typical scenario, where tigers experience all the problems discussed above. The Panna National Park/Tiger Reserve of Madhya Pradesh was selected for the study.

OBJECTIVES OF THE STUDY were to:

* evaluate habitat suitability for tigers and assess the availability and distribution of its major prey;
* estimate and study the home ranges and movement patterns, land tenure patterns, socialorganization and habitat use by tigers;
* determine food habits and food preferences of tigers;
* develop a model to suggest management measures to protect tiger populations in Dry Tropical Forests.

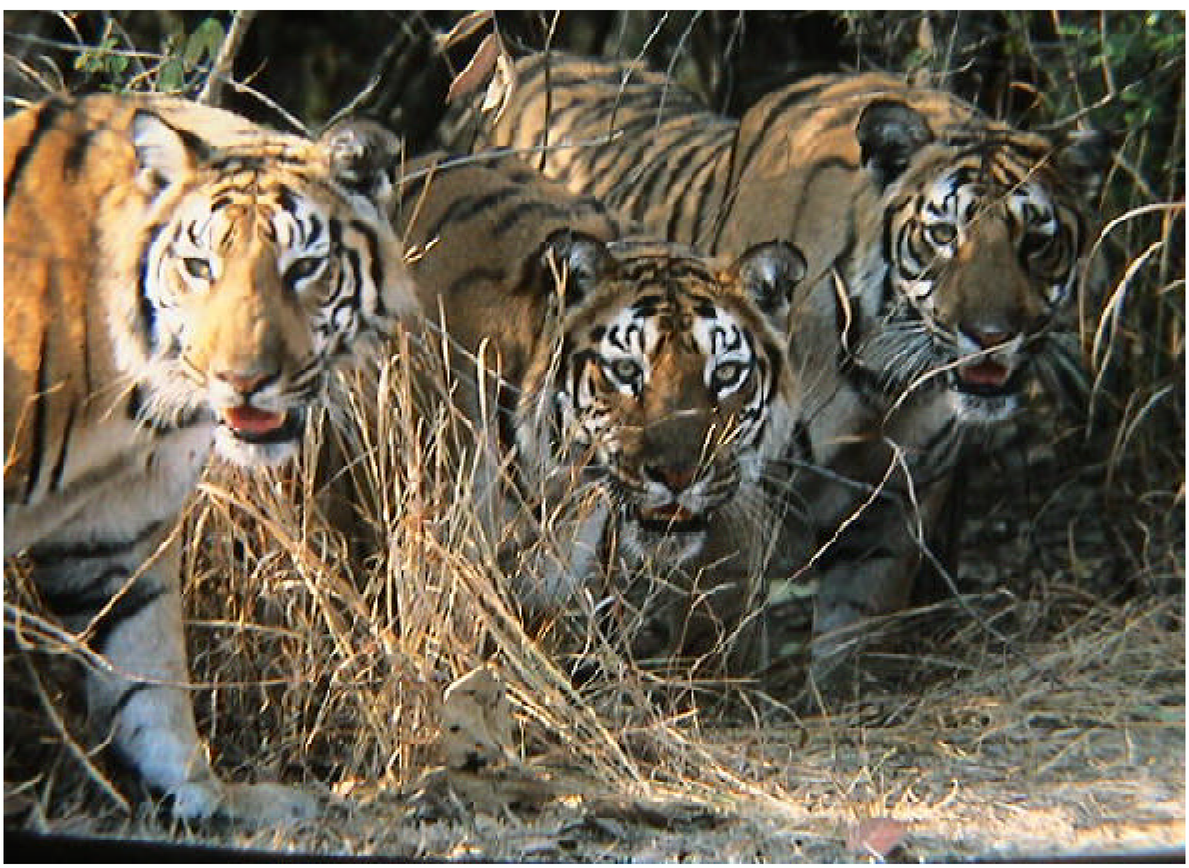
The Study Area: Panna Tiger Reserve

Panna National Park, in the central Indian highlands, represents one of the important tiger habitats of the Tropical Dry Forest (Chawdhry 1997; Chundawat et.al 1997; Gogate and Chundawat 1997; Pabla, 1984). Panna National Park along with the surrounding territorial forest areas is the only large tiger habitat remaining in north Madhya Pradesh (M.P.). These forests were the private game reserve of the erstwhile princely states of Bijawar, Chattarpur and Panna. Apart from the conservation values, these forests are also home to several rock paintings and temples dating back 2000 to 4000 years (Chaudhary, 1996).

The Panna National Park attained the legal status of Protected Forest in 1948. Part of these forests was declared National Park in 1981; this included a major part of the existing Gangau Wildlife Sanctuary. The M.P. State Government, issued a notification dated 17-10-1981, to declare this area as National Park; this was published in the State Gazette of 1.1.1982 (M.P. Gazette, 1985); the final notification under section 34(4)(A) of the Act is still awaited. Subsequently, in 1994, Panna National Park was identified as an important tiger habitat and declared a Project Tiger area. The total area of the park is 542.66 km2. For administrative purposes, the park is divided into four management units ? ranges, viz: Panna, Hinouta, Madla and Chandranagar. The Park headquarters are situated at Panna town.

Panna National Park is situated in the northern extension of the Vindhyan ranges bordering UP in the north (Chaudhary 1996). It spreads over two of M.P.'s districts: Panna and Chhattarpur (Figure 1). Biogeographically and floristically, this area forms part of the Indo-Malayan Region, whereas zoo-geographically, it is a part of the Oriental Region (Mackinon, 199XX). It lies in Zone 6 E, i.e., 'Deccan Peninsula - Central Highlands' (Panwar and Rogers, 1988). The location of the National Park is also important because it is situated at a point where the continuity of the forest belt gives way to the extensive Gangetic Plains (Pabla, 1984).

The topography of the area is characterized by step tablelands with two distinct plateaux



above the Ken river valley. Altitude varies from 220m at the river bank to 540m. The fall between upper and middle plateau and middle plateau and the Ken river valley is steep, forming 10-80m high escarpments. This distinctive landscape gives rise to many gorges, cliffs, and overhangs. A large number of caves and rock shelters, springs and patches of thick forest cover are also spread over the area, creating unique microhabitats for different animals and birds.

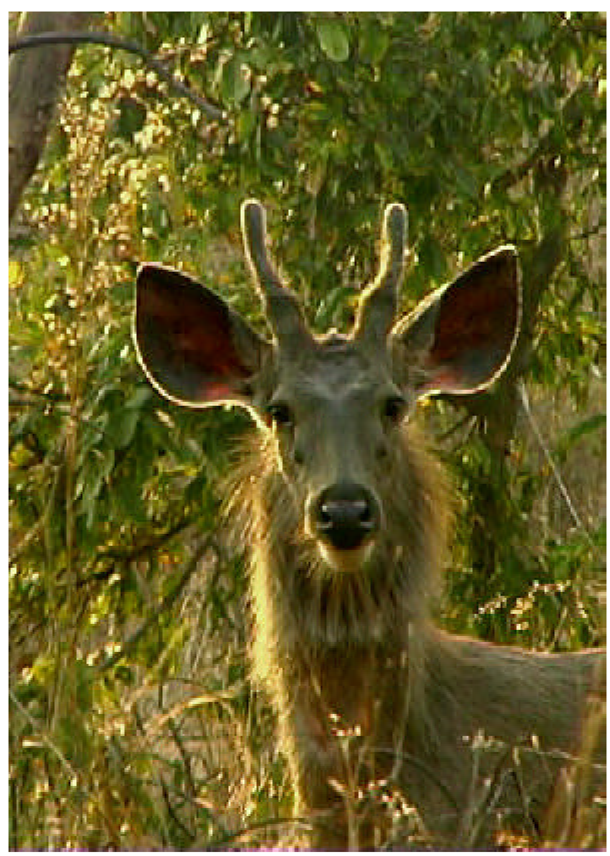
The Vindhyan strata in this region are known for their poor water retaining capacity due to the large number of fractures and faults. As a result, most of the surface water percolates down very fast, leaving streams, nallahs and pools dry soon after the monsoon. Streams in the National Park are seasonal; the Ken river is the only perennial river. It flows for about 55 km through the park, before joining the Yamuna river in Banda district of U.P.

The climate of the area can be described as typically dry tropical with three distinct seasons. The summer begins in March and lasts until the first shower of the monsoon in June. May is the hottest month of the year and temperatures often rise as high as 48 ° C. The annual rainfall averages about 1100 mm and most of it ? over 70% ? falls during July and August only. Consequently, a long dry spell follows the monsoon. Winter is short, but temperatures can regularly go below 5 ° C and frost is a common feature in open habitat areas.

According to Champion and Seth (1968), this area is classified as Northern Dry Deciduous Teak Forest (5 B C/2). The dominating vegetation type is Miscellaneous type interspersed with grassland areas. Other major forest types are riverine, open grasslands, open woodlands with short grasses, closed woodlands with short and tall grasses, and thorny woodlands (Chundawat et al, 1997). The characteristic floral species of this area includes tree species such as Tectona grandis, Diospyros melanoxylon, Madhuca indica, Buchnania latifolia, Anogeissus latifolia, A. pendula, Lannea coromandelica, Boswelia serrata, etc. Major shrub species include Lantana camera, Grewia sp., Nyctanthus arbortristis, Ixora sp., Zyziphus mauritiana, Z. oenoplea, etc. The dominant grass species are Apluda mutica, Themeda quadrivalvis, Heteropogon contortus, Aristida sp., Eragrostis sp., etc.

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 laniger*). The herbivores include, sambar (*Cervus unicolor*), chital (*Axis axis*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella gazella*) and chausinga (*Tetraceros quadricornis*). Other mammalian species commonly found are hyaena (*Hyaena hyaena*), jungle cat (*Felis chuas*), wild pig (*Sus scrofa*), Hanuman langur (*Semnopithecus entellus*), jackal (*Canis aureius*), Indian fox (*Vulpes bengalensis*) and Indian tree shrew (*Anathana ellioti*). The avifauna of the park is rich and is represented by over 200 species of birds.

There are 13 villages inside the National Park with a total human and cattle population of approximately 2,500 and 9,500 respectively. The main occupation of people residing inside the park is agriculture and cattle rearing.



General Methods

A preliminary survey was carried out towards the end of 1995 in Panna National Park to determine the suitability of the area for conducting a radio-telemetry project. Fieldwork began in October 1996, during which research activities such as the recording of tiger movement with the help of radio telemetry, estimation of tiger prey abundance, habitat evaluation, collection of scats to determine the food habits of tiger and determination of biotic pressures on the tiger and its prey were undertaken. The study's research worked continued until December 2004.

Estimation of Prey Population

Prey abundance was estimated by distance sampling (Burnham et al. 1980; Buckland et al. 1993). Distance sampling through line transect surveys has been used very widely and successfully in tropical forests of the sub-continent (Karanth and Sunquist, 1992;Khan et al., 1996; Biswas and Sanker, 2002; Jathanna et. al. 2002; Karanth et. al., 2002; and Bagchi et al., 2003). For this purpose, eleven straight transect lines were established in different strata identified within the intensive study area and marked at regular intervals(Figure 2). These transect lines were maintained every year and walked regularly to gather information on group size and population structure and to estimate the abundance of tiger prey species.

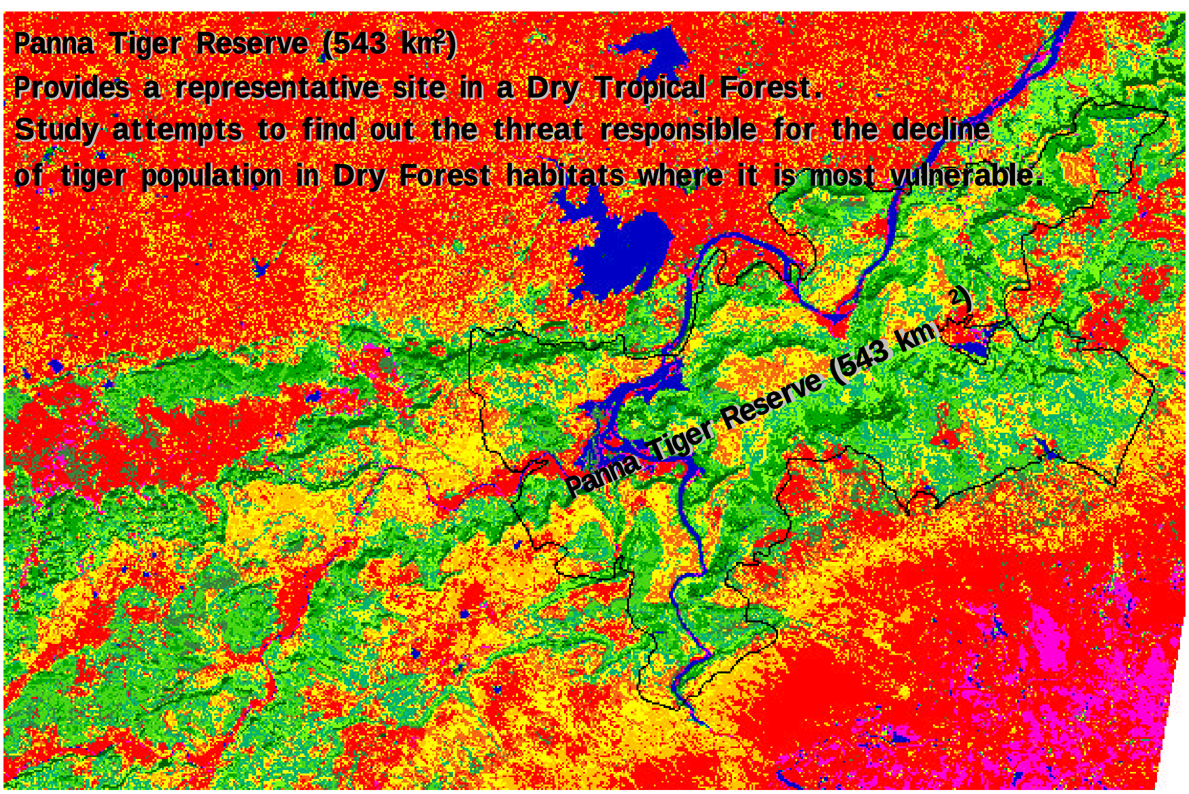
A similar exercise was also conducted using vehicles and the roads were used as lines; these were monitored regularly, twice or thrice every month. Information on abundance, distribution, herd size and population structure of ungulates over a larger area of the Park was collected from this field exercise. For this method, the existing road network of the Park was used. 'Distance' (Laake et al. 1994), a computer software programme, was used for the analysis of the above data.

Home Range and Movement Pattern

Radio-collaring and monitoring of animals

In order to collect information on home range the movement, habitat use and activity of tigers and their major prey, several animals were radio-collared. Permission for chemical capture and radio-collaring of tigers and their

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



prey ? sambar, chital and nilgai ? was obtained from the Government of Madhya Pradesh and the Ministry of Environment and Forests, Government of India. In all, seven tigers (several of the tigers were collared more than once over the years), five sambar and two chital were chemically immobilized and radio-collared. All the chemical restraint operations were conducted by professional veterinary experts who came from the Wildlife Institute of India, from the University of Hissar (anaesthesia specialist) and from the Veterinary college, Jabalpur.

Chemical Restraints of Tigers

For radio-collaring purposes it is necessary to chemically restrain the tigers. First the targeted tiger was located by the research team; then a team of veterinary professionals, which included a wildlife veterinary expert, anaesthesia expert and another veterinary doctor, cautiously approached the animal on elephant back. In the case of collared animals (for replacing the old functional collar) 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 movements after the drug was injected. After locating the tiger, the elephant with the veterinary doctor approached the animal within 25-30 metres and waited until the animal provided a good view for darting.

The research team used Teleinject equipment for darting the animal. A new but very effective and safe drug called 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 the combination Rompun and Ketamin 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 to reduce trauma otherwise caused by the impact of the dart on the animal. We were able to reduce the impact of the dart to its bare minimum so that on most occasions the tigers did not move more then thirty to forty metres after contact. In some cases the tiger moved even less then ten metres after it had been darted.

This allowed the research team and the veterinary doctors 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, two or three members of the research team quickly moved in to fix the radio-collar on the animal and take the morphometric measurements. On average, this took less then twenty minutes. As soon as the collar was placed and measurements recorded, some photographs 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 away with coordinated steps within twenty minutes after the antidote was injected. The research team continued to monitor the animal intermittently for the next eight to ten hours.

Chemical Restraint of Prey Species

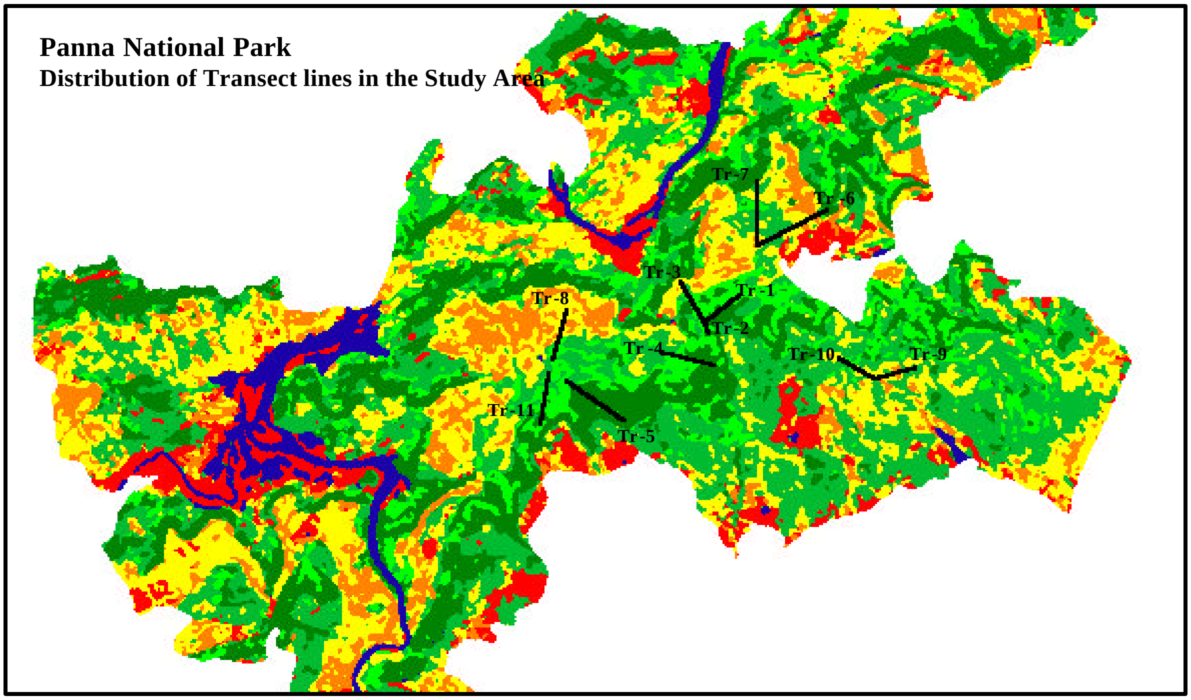
Tiger's major prey, sambar and chital, were captured using the same drugs and equipment, that were used for tiger. Animals were approached from an open vehicle and darted from a distance of 25-30 metres and also from hides. After the darting, the animal was observed from a distance and its activities 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 cautiously approaching it. From ten metres, the animal's status was again assessed before it was approached carefully and touched. Immediately a dark cloth was used to cover the eyes and a radio-collar was attached. After recording the measurements, the antidote was given and 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 the possibility of the predation.

Monitoring of Radio-collared Animals

Radio-collared animals were tracked on a systematic schedule to obtain the locations of the animal. The locations are determined by triangulation method (Tester and Sniff 1957, Heezen and Tester 1967 & Springer 1979) and wherever possible by homing technique (Mech 1983). For this all roads were marked at 500m intervals and in some places every 250m. UTM coordinates for each of these points were recorded with the help of a GPS. In addition to these, coordinates of several vantage locations were 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 exercise was repeated from three to four known points. Later with the help of the computer software "LOAS" 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 radio-collared animals.

Locations for every animal were obtained twice or thrice a week to determine the

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



home ranges and habitat use pattern over the seasons. These animals were also monitored continuously for a twenty-four hour period once a month, to gather information on 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 by Tiger

A detailed habitat map was prepared using satellite LISS-III data. Seven major habitat classes were identified. This habitat classification was verified and modified after ground truthing. Based on this information, a detailed habitat map was prepared for the Panna National Park and its adjoining tiger habitats (Figure 1). The final map was used to determine habitat use by the tigers and their prey species by plotting their locations on the map and calculating the frequency of occurrence in different habitat types. This exercise was repeated for different seasons to determine seasonal habitat use.

Using this habitat map of Panna Tiger Reserve and other layers such as grazing pressures, village locations, water distribution and other anthropogenic pressures and density estimation of major prey species in different habitats, predictive models for the distribution of major prey species of tiger, sambar, chital and nilgai were developed using GIS. These maps were used to determine the distribution of tiger 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

Figure 3. Research team radio-collaring a male sambar

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 (Muller-Dombois & Ellenberg 1974) and a temperature data logger was placed at selected 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-tracking of animals and conducting similar habitat evaluations for the locations of each radio-collared animal. To minimize the workload, instead of visiting all the locations, 40% of the locations were selected, randomly, to determine the habitat use by these animals.

Food Habits and Predation by Tigers

Food habits of tiger are determined by identifying the prey remains in scats and information collected from kill sites (Schaller 1967, Johnsingh 1983, Karanth 1993, Chellam 1993). In the field it is not always possible to find each and every kill made by the tiger. Therefore, using only found kills leads to unavoidably biased information and under-represents the utilization of smaller prey species, which are consumed relatively fast (Sunquist 1981, Johnsingh 1983, Karanth & Sunquist 1995). Therefore, to have a reliable picture of food habits of tigers, scats were collected from the study area and analyzed. Prey remains in the scats of the carnivores are mostly the hairs and pieces of bones: these remain undigested while passing through the gut (Sunquist 1981; Karanth & Sunquist 1995; Mukherjee et al. 1994). Through microhistological study of bone and hair, prey species were identified (Koppikar and Sabnis ???).

TIGER PREY-I: Group dynamics, population structure and estimation of animal and biomass density.

Tiger has a very wide distribution in Asia and occupies variety of habitats throughout its range (Sunquist et al., 1999). Here it predates mainly on large ungulates of tropical and temperate forests (Schaller, 1967; Sunquist, 1981; Johnsingh, 1983; Seidensticker and McDougal, 1993; Karanth and Sunquist, 1995; Biswas and Sanker, 2002, Bagchi et. al., 2003). Like other large carnivores, its abundance is governed by the availability of its prey (Sunquist and Sunquist, 1989). Tiger has evolved as a specialist predator of large deer, wild cattle and pigs and its present distribution is limited to habitats where populations of its major prey still survive in abundance (Sunquist et al., 1999). Recent studies indicate that loss of prey is one of the major factors affecting the viability of the tiger populations (Karanth and Stith, 1999) and indicate that a demographically viable tiger population can be protected provided that their prey base is managed intensively. Therefore, in order to save wild tigers, effective management of large herbivore populations is an important conservation issue in tiger habitats. Despite the conservation significance of Tropical Dry Forests for tiger and other co-predators, very little quantitative information is available from this ecosystem. This largest tiger habitat is highly fragmented (Wikramanayake, et al., 1998) and suffers from forest fires, poaching, competition with livestock and loss of habitat and habitat quality (Panwar, 1987; Karanth 1991; Deb Roy, 1996; Seidensticker, 1997, Chundawat and Gogate, 2001). For effective conservation measures to save tigers in Dry Forests, intensive management of prey populations require strategies to manage prey in densities that can support a demographically viable tiger population. Basic quantitative information on prey availability for tigers is required for this.

Methods

Population structure and Group size

The prey population of Panna Tiger Reserve was monitored regularly on a very systematic schedule by counting animals from the vehicle. The intensive study area included most of the forests of the three ranges of Panna, Hinauta and Madla. The forest roads of the Reserve in these ranges were used as transect lines and monitored twice or thrice every month throughout the year. This was not possible during the monsoon months, due to heavy rain and bad road conditions, but even then the road transects were conducted at least once a month. Whenever an animal was seen, information on the species, number, group size, age and sex and the perpendicular distance from the road was recorded, in addition to the date and time, activity and transect number. From this data set, information on demographic parameters of the prey population is generated.

Estimation prey population

In this study we used distance sampling by line transect to estimate abundance of tiger prey in the Tropical Dry Forest of Panna Tiger Reserve. Line transect surveys were conducted in years: 2000, 2001 and 2003. For these surveys, nine line transects of variable length, ranging from 1.93-2.85 km, were marked. They were also prepared for better view on the line and more silent walk.

In 2000, these nine lines were walked in the morning twice every month from October to June. Later this approach was modified and in 2001, all the lines were walked simultaneously every morning and evening for fifteen days in March. Further modification was made in the 2003 survey: only three lines were walked simultaneously morning and evening and these were repeated every fourth day in February and March. Thus in total 24 (12 days x 2 times a day) temporal replicate surveys for each line were conducted. Data from these three surveys are used here to discuss the best design approaches and appropriate season for surveys in tropical forests where visibility changes considerably with the season and can thereby affect density estimates. These data sets are also analyzed to determine the efficiency of the survey without compromising on most of the assumptions. We seek to use the results to help in designing future surveys that will achieve the desired objectives most effectively.

Densities and biomass densities of tiger prey species were calculated from the data obtained from the most recent, 2003, survey; this is used for comparisons with estimates obtained from other habitats of the Indian sub-continent. For every group sighting, information on species, the number of individuals, radial distance (with help of laser range finder) and radial angle were recorded. For analysis of data, the computer program DISTANCE 4.0 (Thomas et al., 2002-b) was used.

Analysis

For density estimates and related analyses concerning variance, the nine transect lines were considered as spatial replicates and all the temporal replications on particular transect lines were pooled. We followed the standard procedures for analysis detailed in Buckland et al. (2001) and Thomas et al. (2002b). Cluster sizes were estimated using size bias regression method by regressing the natural log of cluster size against estimated probability of detection at distance x, g(x). Whenever the regression was not found significant at alpha level of 0.15, mean of cluster sizes was used. Both manual as well as automatic pooling functions were used in Distance 4.0 to fit the curve at the lowest possible value of ?? (Chi-square)

To compare seasonal and morning-evening estimates obtained by distance software, one factor ANOVA was used with available estimates and respective standard deviations (Zar, 1984). Changes in other parameters like seasonal group size and radial distance were tested using one factor ANOVA. Trends were tested for accuracy with the help of maximum R2 value and with student's t-test for testing the significance of a regression.

Results

Population structure and Group size

In this report information on population structure and group size of tiger prey is reported from the most recent 2003 monthly surveys. Prey species include sambar, chital, nilgai, four-horned antelope, chinkara and wild pig. A total of 4,434 animals were sighted of which 3,332 animals were aged and sexed. These included 252 chinkara, 1,278 chital, 125 four-horned antelope, 1,409 nilgai, 794 sambar and 134 wild pig. The average group size observed during the study is: sambar 3 (SE ± 0.14), chital 5 (SE ± 0.41), nilgai 2.8 (SE ± 0.11), four-horned antelope 1.3 (SE ± 0.06), chinkara 1.68 (SE ± 0.07) and wild pig 4.2 (SE ± 0.4). Except for chital and wild pig, no significant difference in group size is observed for the different seasons in most prey species (Figure 4). Both chital and wild pigs are seen in larger groups during the monsoon months than in summer and winter. Group size range observed is 1-20 for sambar, 1-64 for chital, 1-19 for nilgai, 1-5 for four-horned antelope, 1-6 for chinkara and 1-14 for wild pig.

Details of population structure for prey species is given in figure 6. No change in the population structure (age and sex ratio) is observed from the previously reported data (Chundawat, 2001). Chital to fawn ratio remains low at 24 fawns for every 100 females. In the case of wild pig, high female to young ratio was seen and it was 100:100, but low female to yearling ratio 100:22.9 indicates high mortality at an early age. Male to female ratio remained biased towards female in all the prey species observed (Table 1).

Line transect sampling

In this report, data from 2000, 2001 and 2003 surveys is analyzed and reported. In the monthly survey of 2000, the total length walked was 233.6 km and 339 groups of animal were sighted. In the 2001 and 2003 surveys, the total length walked was 520.7 km and 466.06 km respectively. The total number of animal groups seen was 1,014 during the 2001 survey and 1,023 groups in the 2003 survey. We pooled the 2000 distance sampling data bi-monthly to analyze and detect changes in encounter rates, group sizes and sighting distances and their likely effect on density estimates. Encounter rates of all the prey species varied significantly between the two months groups (Chital2000: $F=3.538$, $p<0.05$; Nilgai2000: $F=7.494$, $p<0.001$; Sambar2000: $F=5.049$, $p<0.005$). The cumulative encounter rates of the prey species of tigers found in Panna Tiger Reserve reach highest during the months of February and March (Figure 5). Ungulate density varied significantly (Chital2000: $F=3.066$, $p<0.05$; Nilgai2000: $F=2.87$; $p<0.05$; Sambar2000: $F=4.031$, $p<0.01$).

The subsequent two surveys were conducted during February and March. During the 2001 and 2003 surveys, a larger distance was covered in a relatively short duration by walking all the transect lines, simultaneously, every day in the morning and evening. The surveys in February and March resulted in a larger detection of animal groups for all the species than observed in the previous monthly surveys.

Mean group size for most of the species did not vary significantly during the 2001 (fifteen days) and 2003 (forty five days) surveys. Radial distances of chital changed significantly in 2001 ($F=6.68$, $p=0.005$) as well as in 2003 ($F=5.284$, $p=0.000$). This was primarily due to fire on the transect lines towards the end of both the surveys. These fires opened the habitat and this increase in the visibility may be the major affecting factor that brought the significant changes in radial distances encountered. But, during these surveys no significant change in the encounter rate was observed for most of the prey species except for nilgai, where it showed a gradual increase from 0.3 to 0.9 per km in the 2003 survey.

Encounter rates for most species in the morning and evening surveys of 2001 and 2003 differed significantly (Sambar2003: $F=5.59$ $p=0.05$; Nilgai2003: $F=11.35$, $p=0.005$; Sambar2001: $F=9.24$, $p=0.01$) and these rates were consistently lower in the evening for all the species. Thus there is a significant effect on the density estimate for a few of the species when the morning and evening data is pooled. (one tailed tests Nilgai2003: $F = 16.63$, $p=0.001$; Sambar2001: $F=11.03$, $p=0.005$). In the 2003 survey, we walked these lines in the morning and evening every fourth day to examine the effect of disturbance from repeated walking but the results were similar with a lower encounter rate in the evening walks.

It was also noticed that generally for all the species except sambar the encounter rate, in morning and evening, gradually declined with the length of time spent in walking the transect length. In the case of chital and nilgai it declined significantly. There was a significant negative trend in case of chital in both years where the encounter rate dropped on the morning ($R^2_{2001}=0.73$; $t_{2001}=3.28$, $p=0.05$, $R^2_{2003}=0.76$; $t_{2003}=4.33$, $p=0.005$) as well as evening ($R^2_{2001}=0.88$; $t_{2001}=5.43$, $p=0.01$; $R^2_{2003}=0.88$; $t_{2003}=6.53$, $p=0.001$) transects. Similarly for nilgai it showed a significant declining trend in year 2003 (R^2_{2001}=0.48; t_{2001}=1.91, p=0.2; R^2_{2003}=0.58; t_{2003}=2.87, p=0.05) in the morning and in the evening in 2001 (R^2_{2001}=0.93; t=7.18, p=0.002; R^2_{2003}=0.26; t=1.47, p=0.2). However, although the sambar encounter rate declined similarly in the morning, on the evening transect the encounter rates marginally increased close to dusk (Figure 7). This can be explained by the activity pattern determined from the radio-collared animals (Figure 8).

Density and Biomass estimation

Density of tiger prey is estimated from the most recent count conducted in 2003. The pooled prey abundance is estimated to be 46.32 prey/km2, (excluding langur). Details of the estimated prey densities and other relevant parameters are described in Table 3. As in most of the tiger habitats of the subcontinent, chital, nilgai and sambar dominate the wild tiger prey population in Panna Tiger Reserve. In terms of number of animals per square kilometre, chital is the most abundant animal. In the Reserve the contribution of smaller prey (<25 kg and including langur) is 30%, medium sized prey (25 - <55kg), which includes chital and wild pig is 38% and large prey (>55 kg), which includes sambar and nilgai, is 31%. Most frequently encountered prey in the Reserve is nilgai followed by sambar and chital.

The ungulate prey biomass density estimated for the Tropical Dry Forest of Panna Tiger Reserve (4,057 kg/km2) is on the high side for the subcontinent. But, unusually for the sub-continent, most of the biomass (over 70%) is contributed by two prey species, nilgai and sambar. The contribution of chital, the tiger's most common and major prey throughout the subcontinent, is only 19.69%. Contribution from other smaller prey species is minimal (< 7%).

Discussion

Group size and Population structure

It is observed in Panna Tiger Reserve that group size of most of the prey species is relatively small (Karanth and Sunquist, 1992; Khan et al., 1996; Biswas and Sanker, 2002; Jathanna et. al. 2002; Karanth et. al., 2002; and Bagchi et al., 2003). It is more pronounced in chital population, though a comparison of group size between 2001 and 2003 counts shows a marginal increase in group sizes of chital to a mean of 5 (± 0.41) from a mean group size of 3. Group size could be an important indicator of poor resource availability and quality and habitat suitability limiting the reproductive success of the population (Jarman, 1974). Smaller group size in tiger prey population is an important finding for Tropical Forest, which is the largest tiger habitat in the sub-continent and needs further investigation to ascertain the factor responsible for affecting the group size in this type of habitat.

Most of the prey species, other than chital and wild pig, did not formed larger groups in different seasons. In the chital and wild pig populations, group size was larger during the monsoon months, when forage is abundant. Smaller groups were seen in winter, amongst the sambar, chital and wild pig. We observed no change across the seasons in the sex and age ratio of all the prey populations.

It is also observed that the female to fawn ratio in chital is very low in comparison to other chital populations from different but more productive tiger habitats (Mishra, 1982; Karanth, 1993; Khan et al., 1989, Kumar, 2000). It is also noticeable that the survival of this population of fawns into the next age class of yearling is also very low. This indicates poor reproduction in the chital population and high mortality in the yearling age class. Panna, which is characterised as Dry Tropical Forest, has extensive open miscellaneous forest with dense grass cover. This does provide suitable habitats for chital with high abundance of graze. Grass growth stops soon after it flowers and seeds, as a result of the long dry spell soon after the monsoon. After December, the dead, above-ground biomass of grass provides very poor quality forage in terms of nutrition. This is at a time when the chital population requires quality nutrition prior to their readiness for rut in March and April. This could be one of the reasons for low fawn ratio in Panna.

A similar high mortality is also noticed in the sambar population from a healthy >40 fawns/100 females to <20. This, as mentioned in the earlier reports, is an important aspect

Species	Female	Male	Yearling	Fawn
Chital	100	41	10.75	24.27
Sambar	100	33.89	16.94	41.4
Nilgai	100	51	20.79	35.98
4horn	100	45.7	2.8	30
Chinkara	100	72	2.8	9.4
Wildpig	100	56.25	22.9	100

Table 1. Sex ratios of tiger prey described animals per hundred females in Panna Tiger Reserve.

for the management to look into for the better management of prey population especially sambar which is a preferred prey species of tiger in the subcontinent (Biswas and Sanker, 2002; Karanth et. al., 2002; and Bagchi et al., 2003). A high female to young ratio was observed in the wild pig population but its female to yearling ratio is low, suggesting high mortality at this age category. This could be due to high predation on piglets by predators such tiger, leopard and jackal.

Sambar, four horned antelope, and chinkara are mostly seen singly or in small family groups, which are comprised of mother, fawn and yearling. This information is further supplemented by the observations made on the radio-collared females of sambar. Males are usually solitary except during the rut, when they associate with female groups or join other males temporarily after the rut is over. Female family groups occasionally associate with other such groups for a short time at their favourite feeding places. In contrast to these observations made on the three prey species above, chital and nilgai are more frequently seen in larger groups or associations, indicating their social nature.

Estimation prey population

The density estimate of 46.32 preys/km2 in Panna Tiger Reserve is fairly high for a Tropical Dry Forest of the subcontinent (Karanth and Sunquist, 1992; Khan et al., 1996; Biswas and Sanker, 2002; Bagchi et al., 2003). Because mega-herbivores such as wild buffaloes (Bubalus bubalis), rhinos (Rhinoceros unicornis) and elephants (Elaphus maximus), which contribute very little to the diet of tiger, are absent from a large part of the Tropical Dry Forest, they are excluded for comparison of the prey populations from important tiger habitats. Biomass densities from these tiger habitats indicate that, on average, medium sized prey (46.64 %) and large prey (52.27 %) contribute almost equally to the prey availability. But interestingly, in terms of number of animals, medium sized prey - such as chital, wild pig and hog deer – contribute, on average, over 70 % of prey availability (Table 4). In contrast to these protected habitats, in the Panna Tiger Reserve, the contribution by chital and other medium prey to the prey population is small, both in term of biomass density (21.26 %) and the number of animals (39.24%).

The low abundance of chital, one of the tiger's major prey species, could be an important factor to the tiger ecology in Panna. Being the only grazing wild herbivore (Eisenberg and Seidensticker, 1976; Putman, 1988, Khan et al., 1996), chital is particularly and highly susceptible to grazing pressure of domestic livestock populations (Khan, 1996, Jathana et al., 2003). A large population of over 9000 domestic cattle within Panna Tiger Reserve and extensive accidental fires in the past could be the reasons that limit the chital population here. Despite their low nutritive value, chital prefer grasses even during the dry summer months (Khan et al., 1996). Dry season fires are devastating in Panna, completely eradicating grasses from the burnt areas. In the recent past, rehabilitation of three villages and intensive fire protection measures have created extensive grasslands and restored them as suitable

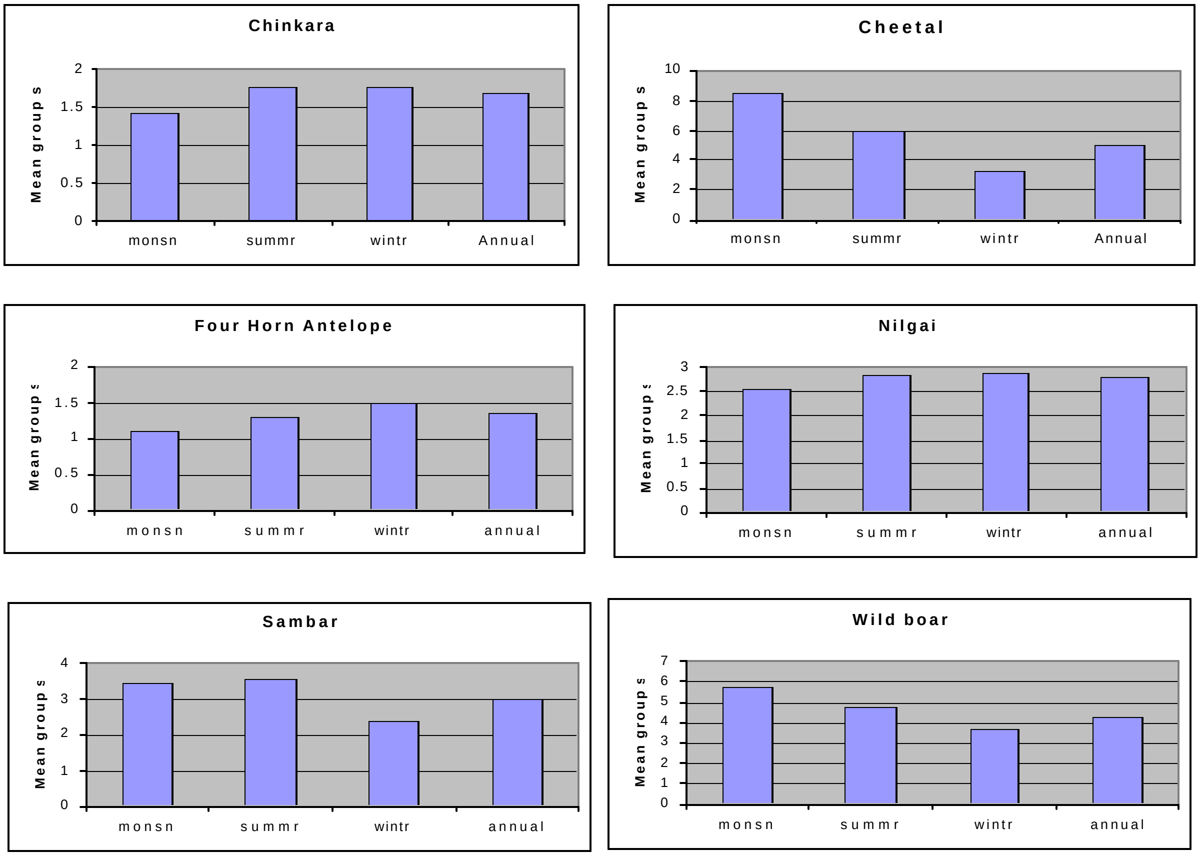


Figure 4. Mean group size of prey species in Panna Tiger Reserve

habitats for chital. As a result the chital population is recovering, mainly in areas recently made free from human pressure, as has been documented in other protected forests of the subcontinent (Karanth and Sunquist, 1992; Khan et al., 1996).

Density estimates of tiger prey from Pench National, Ranthambhore National Park, the Gir forest of Gujarat and Panna Tiger Reserve indicate that Tropical Dry Forests - the largest tiger habitat in India (Wikramanayake, et al., 1999) - can support fairly high prey biomass, provided the habitat is adequately protected (Eisenberg and Seidensticker, 1976; Karanth and Sunquist, 1992; Khan et al., 1996; Karanth and Nicholas, 1998; Biswas and Sanker, 2002). The Dry forests of Panna support ungulate populations which have evolved in different

Species	Animal Sighted	Mean Group size	Range	Percent occurrence in size class size			
				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**

Table 2. Mean group sizes, range and frequency of group size of tiger prey in Panna Tiger Reserve.

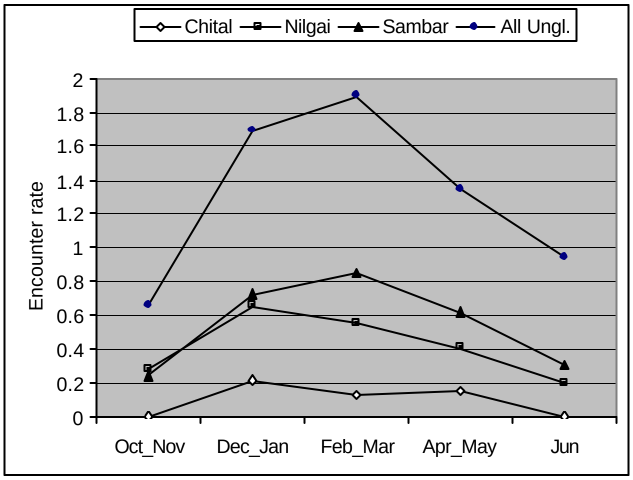


Figure 5. Bi-monthly (pooled) encounter rates of major prey species of tiger during the 2000 survey in PNP

environments – one in open habitats and the other in forest mosaic. Nilgai and chinkara represent a prey population partial to open habitats, whereas chital and sambar are forest and forest-edge dwellers ((Schaller, 1967; Prater, 1988; Eisenberg and Seidensticker, 1977). Because tiger has evolved as a specialized forest-edge predator following the cervid radiation in Asia (Sunquist, et. al., 1999), its survival and hunting strategies are more cued to cervids than other prey species occupying the open habitats such as nilgai. Therefore in Dry Forests, despite high abundance of prey such as nilgai in open habitats, this does not necessarily translate entirely into tiger prey availability.

In tropical forests of the subcontinent, ecological conditions change drastically over time and space and this can affect animal distribution and detection (Thomas et al., 2002). Soon after the monsoon, visibility in forest habitats gradually increases with loss of foliage as the long dry season progresses. Loss of foliage not only makes it easier to detect animals but they can now be sighted from longer distances, significantly increasing the radial distances. In addition to this, the significant change in group size over the seasons, not only affects the number of animals encountered but can affect the encounter rate of the groups. Moreover, during peak summer months when water is available only at a few sites, most of the ungulates congregate near these habitats. In these changing ecological circumstances, monthly surveys do not provide a reliable way to estimate ungulate densities in a Tropical Dry Forest such as the Panna Tiger Reserve. Pooling data from the surveys conducted over an extended period time of several months are therefore likely to be prone to limitations such as those encountered during the monthly surveys of 2000 in Panna TR.

It is clear from the monthly surveys in 2000 that the highest encounter rates of detection for most ungulate prey are obtained during February and March. Moreover, group sizes during these months are also closer to the mean estimated for the year. Therefore, for estimation of wild herbivore populations in a Tropical Dry Forest, February/March appears to be the most suitable time. Walking transect lines simultaneously and repeatedly every morning and evening maximized the efficiency of the surveys (Karanth and Nicholas, 1998). By conducting these surveys within a short time span (ranging from 15 to 40 days), the error associated with varying encounter rates, change in group sizes and effect of visibility on radial distance and ESW, is minimized effectively in this study.

But the problem of low encounter rates during the evening count on the same line affects the density estimation. One of the likely reasons for low density estimates in the evening could be the fact that during these intensive surveys, all the lines were walked repeatedly in the morning and evening every day. It is speculated that this may have caused enough disturbance for the animals to move away from the area and affect the low evening encounter rates.

Another factor could be the activity pattern of prey species. It is generally assumed that most of the animals are active during the early morning and evening (Karanth and Sunquist, 1992). The radio telemetry study of sambar and chital in Panna indicates that the activity pattern of herbivores is a likely factor resulting in the low detection and density estimate in the evening. The first half of the morning surveys coincide with the peak activity period, which declines gradually. Similarly, increasing encounter rates in the case of sambar towards the end of the evening coincide with its increase in activity. But decreasing encounter rates towards the evening for chital and nilgai is difficult to explain with the existing data set. The effect of repeated

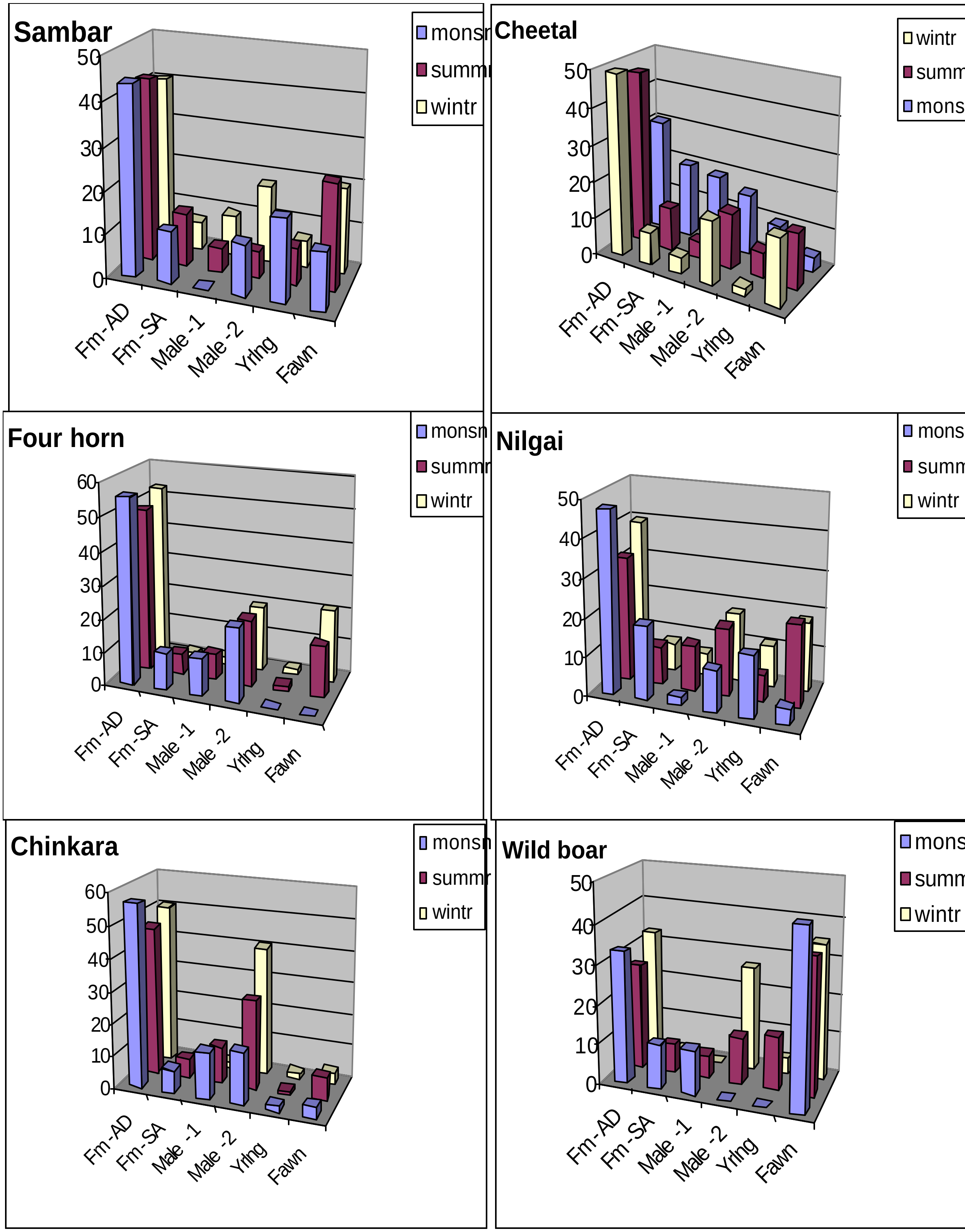


Figure 6. Population structure of prey species (in percentage) found in PNP.

walks on the encounter rate can be tested by conducting a similar experimental exercise where lines are walked once only in a day to see the effect of disturbance caused by the previous walk. In the present data set this variation in the evening and morning count has possibly caused under estimation of prey population.

These trends were consistent during all the surveys and highlight an additional point that counting animals for more then two hours can have a significant effect on the density estimate because of the shift in activity pattern. This

Species	Year	N	D	D CV %	95% CL		Encnt. Rate	Cluster size	Dg	Dg CV%	Wt in kg	Biomass density
					LCL	UCL						
Chital	2000	29	4.692	62.1	1.23	17.87	0.12	3.48	1.34	60.9	47	220.52
	2001	125	10.95	52.9	3.65	32.78	0.45	3.92	3.09	52.5		514.79
	2003	241	16.67	51.9	5.46	50.89	0.49	6	3.09	51.3		783.53
Sambar	2000	147	18.73	34.9	8.45	41.52	0.6	2.61	7.18	34.2	134	2510.89
	2001	234	8.77	37.2	3.96	19.41	0.47	2.3	3.97	36.9		1175.58
	2003	223	10.35	34.1	4.87	22.00	0.45	2.62	3.95	33.7		1387.57
Nilgai	2000	107	11.37	29.1	6.14	21.06	0.44	3.14	3.62	26	125	1421.75
	2001	126	6.30	37.2	2.83	13.99	0.6	2.72	2.67	37		787.62
	2003	333	13.11	26	7.44	23.09	0.68	2.98	4.40	24.5		1639
4H Antelope	2000	31	2.97	31.9	1.5	5.71	0.13	1.61	1.84	29.5	21	62.475
	2001	96	3.95	19.2	2.62	5.95	0.21	1.23	3.32	19		82.99
	2003	82	2.70	20.6	1.73	4.19	0.17	1.22	2.21	20.2		56.742
Wild pig	2000	6	*Dataset too small to estimate density*								20	*NA*
	2001	29	1.36	46.5	0.54	3.44	0.08	3.28	0.58	42.6		27.34
	2003	20	1.51	57.8	0.49	4.62	0.04	4.05	0.37	52.1		30.22
Chinkara	2000	25	2.30	50.3	0.76	6.94	0.1	1.88	1.22	49.4	32	73.63
	2001	44	0.91	42.1	0.38	2.18	0.1	1.62	0.72	41.6		29.21
	2003	85	1.97	45.5	0.73	5.32	0.17	1.81	1.09	45.1		63.32
Langur	2000		25.31	37.8	10.9	58.57	0.17	11.23	2.25	36.4	9	227.8
	2001	130	20.68	26.7	11.7	36.41	0.28	8.22	2.51	25.6		186.20
	2003	65	13.90	0.18	9.47	20.41	0.13	11.55	1.20	16.6		125.18

Table 3. Animal and biomass density (kg/km^2) estimates of tiger prey in Panna Tiger Reserve. (n= number of detection; D= density of animals/ km^2; D cv= coefficient of variation density; 95% CL= 95% confidence interval; Encnt. R.= encounter rate; Dg= group density/km^2; Dg cv= coefficient of variation of group density; wt in kg= average wt of the species).

potentially limits the length of transects, which will largely depend on length, visibility, terrain and number of detection. To minimize the error encountered in morning and evening counts in the shorter, intensive 2001 surveys of fifteen days and the increase in group size and encounter rate during the relatively extended 2003 survey, a new survey design is needed. A sampling period (as short as possible) with more lines, which are walked once a day and repeated after three to four days, can minimize the errors encountered during the surveys.

Figure 7. Encounter rates (animal groups (or sighting)/hour) pooled for every 15 minute time interval of three major species of tiger during the walk on the line in the morning (between 6.45 and 8.30 am) and evening (between 16.30 to 18.15 pm), in Panna Tiger Reserve. Straight dotted lines indicate trend for evening and continuous line is for morning trend. (a) chital; (b) sambar and (c) nilgai. (a) chital

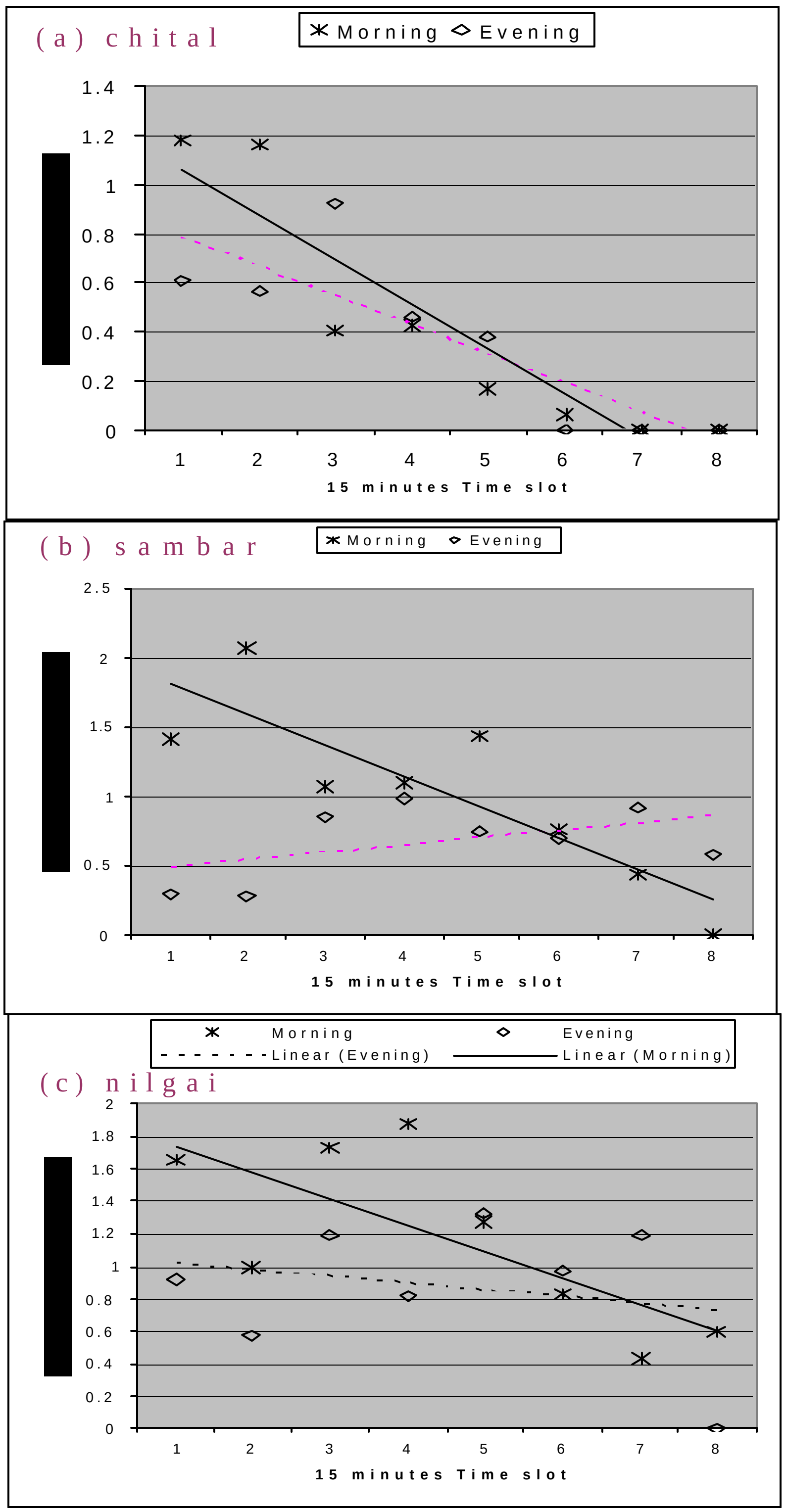
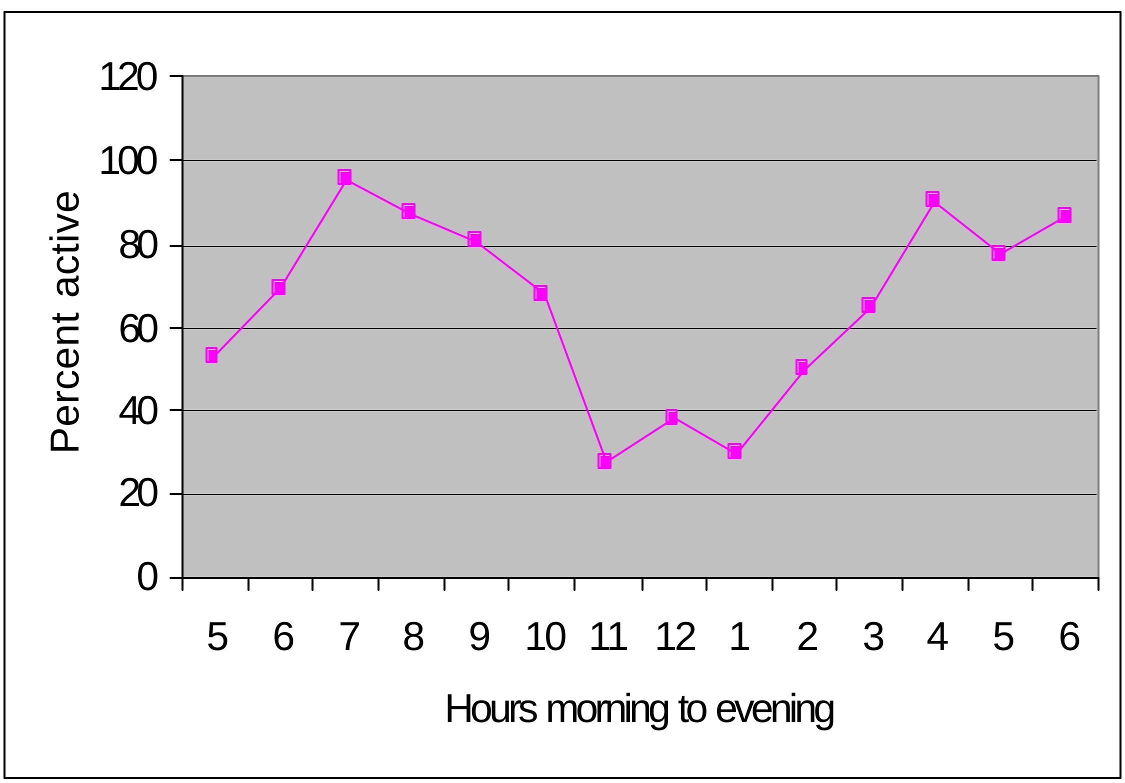


Table 4. Biomass density and density of medium and large tiger prey in different Protected Areas of the Indian sub-continent, (figure in percent).

Important tiger habitat	Biomass Density in Percent		Animal density Medium prey
	Large prey	Medium prey	
Pench NP	41.08	58.91	81.66
Kanha NP	18.76	80.81	91.09
Kajiranga NP	69.85	30.14	70.91
Nagarahole NP	56.13	44.13	73.91
Ranthambhore NP	54.76	44.59	69.3
Panna NP	73.08	21.26	39.24
Average	52.27	46.64	71.02

Figure 8. Percent activity of radio-collared sambar during February and March months in Panna Tiger Reserve.



TIGER PREY-II: Home range and movement, habitat use and activity pattern of sambar and chital

The home range of an animal is the area traversed by an individual in its normal activities of food gathering, mating and caring for the young (Burt, 1943). Animals often rank resources, and home range can be envisioned as an integration of contour maps of these resources, which include escape cover, travel routes and known home ranges of members of other sex (Ellner and Real, 1989; Pyke, 1984; Pyke et. al. 1977). If the sum of daily costs of maintaining, monitoring, defending, developing and remembering the critical resources exceed the benefits gained from the home range it will reflect in the animals' nomadic nature and it will not exhibit site fidelity. Site fidelity is usually an indicator of whether an animal has established a home range (Powell, 2000).

We have used Minimum Convex Polygon method which is the most commonly used method of estimating home ranges (Jennrich and Turner, 1969). This method is sensitive to extreme data points as it incorporates areas that are not used by the animal. The Harmonic Mean Estimator is used to explain the pattern of use or centre of activity based on the harmonic mean distances (Dixon and Chapman, 1980). Harmonic Mean Estimator may accurately show multiple centres of activity, but each estimated utility distribution is unique to the position and spacing of the underlying grid.

Animal ecology pivots around two important resource concerns: forage and partner as mate. Food is a critical resource, important for all animals. Females who have the added responsibilities of nurturing young ones are expected to consider forage as a prime resource (Putman, 1980). Males, on the other hand carry the responsibility of passing over their genes and making sure that they get the best opportunities to mate with females in oestrous. Since forage and oestrous mate are both resources with seasonal availability, movement patterns across different seasons is expected to reflect the availability of these resources. Seasonal and annual average of distance covered within 24 hours provides a clear picture of resource availability and energy spent on these resources by different individuals.

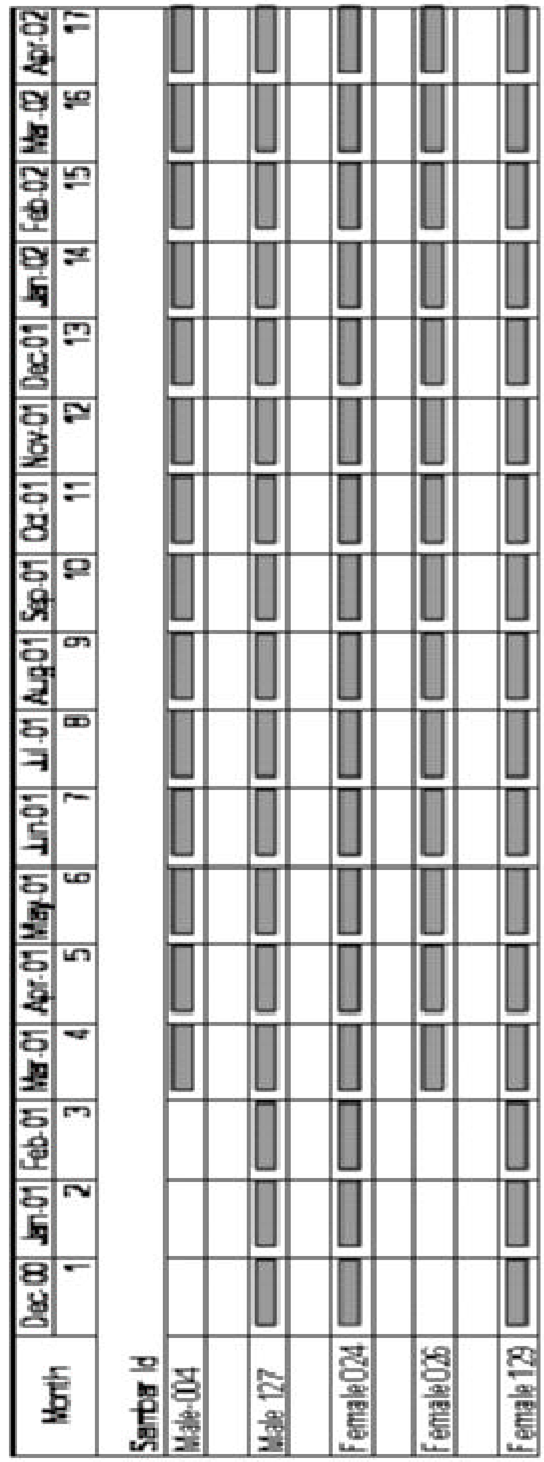


Table 5. Radio-tracking of five radio-collared sambar in PNP.

Methods

Five sambar and two chital individuals were radio-collared for the purpose of this study. These comprised of two adult sambar males (Msam-004, Msam-127) and one adult chital male (Mch-05) and three females sambar

(Fsam-024, Fsam-026, Fsam-129) and one female chital (Fch-02). These animals were monitored on a regular schedule in different seasons. Radio-collared animals were radio-tracked for 14 to 17 months in the year 2001 and 2002. Details of tracking effort are provided in table 5. No mortalities of any radio-collared animals are observed within the study period. Detailed description of techniques for determining locations of radio-collared animals is given in the Chapter-III "methods". We used Minimum Convex Polygons (MCP, Jennrich and Turner, 1969) for evaluating the home ranges of sambar and Harmonic Mean (HM) estimator (Dixon and Chapman, 1980) for determining the centre of activity. In addition to calculation of annual home ranges, seasonal home ranges are also calculated for monsoon, winter and summer seasons.

Animals make occasional forays into areas beyond their regular home range. Locations of these forays lead to overestimation of home range sizes. Since such forays do not represent actual home ranges, such locations are excluded from the home range analyses. This problem is addressed by calculating home ranges with 95% of the total radio-locations. The outer most 5% locations and observations on these locations are described separately. For triangulation and calculation of home ranges we used LOASTM and BIOTASTM software (Ecological Software SolutionTM, © 1998-2001). The distance between two locations of successive days is used to determine the distance covered by a radio-collared animal in 24 hours. These distances are calculated using custom made macros in an MS EXCELTM spreadsheet.

Results

The average annual home range size of male chital and sambar is larger (male sambar=13.185 km2, n=2; male chital=XX) than that of females (female sambar= .46 km2, n=3; female chital= XX). Detailed results with seasonal and annual home ranges (MCP) and centres of activity (HM) are given in table XX. Figure XX provides a comparable graph of annual and seasonal home ranges of all the five radio-collared sambar and two chital.

Home ranges

Male-004

Sambar-004 was tracked for 14 months between March 2001 and April 2002. The average seasonal home range size estimated for sambar-004 is 9.01 km2, which is similar in size to its annual home range (11.49 km2, n= 151; figure 6.2). This sambar ranged over larger areas during all seasons and its home range sizes in summer (9.08 km2, n=39), monsoon (10.02 km2, n=41) and winter (7.77 km2, n=71) show only marginal variation (Figure 9).

Two centres of activity are observed within its annual range and the total area is estimated at 4.99 km2 (80% HM, Figure 9). The smaller of the two centres of activity is located around its rutting activities. It spent most of its time on the upper Talgaon plateau, far away from the rutting ground.

Male-127

Sambar-127 was tracked for 17 months. Unlike sambar-004, its average seasonal home range size (6.13 km2) is less than half (41%) of its annual range (14.88 km2, n=226, figure 6.4).

Male-004		**Area (km^2)**	
Period	**n**	***MCP***	***HM***
Annual	**151**	**11.49**	**4.99**
Monsoon	**41**	**10.02**	
Summer	**39**	**9.08**	
Winter	**71**	**7.77**	

Monsoon (3.04 km2) and winter (2.32 km2) ranges are small. It ranged over much a larger area during the summer months (13.03 km2, figure 8).

Only one centre of activity (5.77 km2, 80% HM) is observed within its annual range (Figure 8), which overlapped almost entirely with the home range of its rutting season i.e. winter, and also with its monsoon home range. Its centre of activity is similar in size to that of sambar-004.

Female-024

Female-024 was radio-tracked for 17 months. Its average seasonal home range size is small, only 43 % in size in comparison to its annual home range (8.2 km2, n=198; figure 12). Winter (2.22 km2, n=65) and monsoon (0.44

Male-127		Area (km^2)	
Period	n	*MCP*	*HM*
Annual	226	14.88	5.77
Monsoon	66	3.04	
Summer	85	13.03	
Winter	75	2.32	

Female-026		Area (km^2)	
Period	n	*MCP*	*HM*
Annual	194	6.09	2.07
Monsoon	61	0.75	
Summer	92	6.17	
Winter	41	1.08	

km2, n=43) home ranges are much smaller than the summer home range (8.08 km2, n=90, Figure 12). Only one centre of activity is noticed within its home range, where 80% of its activities were restricted to this small area of 2.39 km2 (80% HM; figure 12). This centre of activity also overlaps almost completely with its winter and monsoon ranges.

Female-026

Female-026 was radio-tracked for 14 months. Like female-024, the average seasonal home range size of female-026 is also 43 % of the annual home range (6.09 km2, n=194; figure 13). Its summer home range is large (6.17 km2,

Female-024		Area (km^2)	
Period	n	*MCP*	*HM*
Annual	198	8.20	2.39
Monsoon	43	0.44	
Summer	90	8.08	
Winter	65	2.22	

n=92) in comparison to the winter (1.08 km2, n=41) and monsoon (0.75 km2, n=61) home ranges (Figure 6.9). Its centre of activity is restricted within 2.07 km2 (80% HM; Figure 13). The centre of activity overlaps closely with its winter and monsoon ranges.

Female-129

Female-129 was monitored for 17 months. Unlike the other two radio collared females, its average seasonal home range size is as large as (81%) of its annual home range (5.08 km2, n=240; Figure 11). Its home range in the monsoon was very small (0.53 km2, n=56), but it ranged over a much larger area during winter (6.80 km2, n=84) and summer months (5.00 km2, n=100; Figure 11). The centre of activity is restricted to 2.46 km2 (80% HM; figure 11) and encompassed the monsoon home range completely.

Movement Pattern

Average distance travelled by all individuals sambar is 0.84 km (range: 0.008 km to 5.8 km). Males travelled longer distances (1.11 km, range = 0.011 km to 5.8 km) than females (0.67 km, range = 0.008 km to 4.8 km). Only Male-004 moved longest distances (1.49 km, range: 0.18

Female-129		Area (km2)	
Period	n	MCP	HM
Annual	240	5.08	2.46
Monsoon	56	0.53	
Summer	100	5.00	
Winter	84	6.80	

km to 5.8 km) during monsoon while all other radio-collared sambar travelled most during summer. Male-004 had the largest average of annual distance travelled within 24 hours (1.22 km, range = 0.073 km to 5.8 km) whereas female-024 travelled the least (0.63 km, range: 0.008 km to 4.39 km). Detailed results of seasonal and annual distance covered by the radio-collared sambar are given in table 6.

Habitat Use and Activity Patterns

Management of wildlife populations essentially incorporates management of habitat

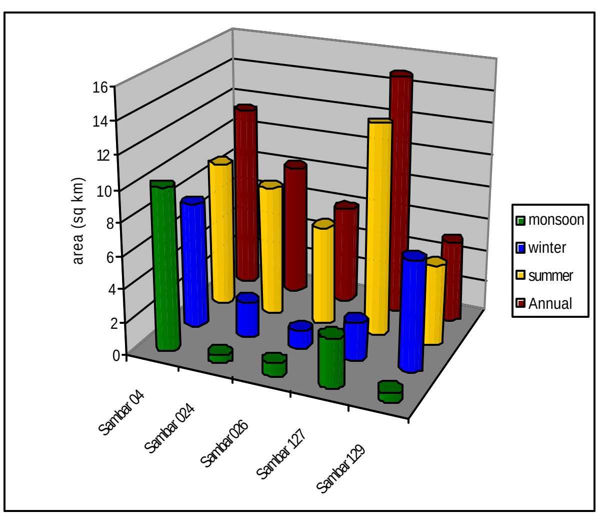
Table 6. Distances covered by radio-collared sambar within 4 hour period in PNP

Sambar	Summer			Monsoon			Winter			Annual
	Av. Dist.	Range		Av. Dist.	Range		Av. Dist.	Range		Av. Dist.
M-004	1.13	0.20	3.86	1.18	0.07	5.20	1.49	0.18	5.80	*1.23*
M-024	0.83	0.06	4.39	0.34	0.01	0.71	0.54	0.03	1.59	*0.63*
Males	0.98	0.2	4.39	0.76	0.01	5.20	1.01	0.03	5.80	*0.93*
F-026	0.82	0.02	3.07	0.42	0.09	1.21	0.53	0.02	1.59	*0.63*
F-127	1.30	0.18	4.95	0.91	0.01	3.26	0.69	0.04	2.95	*0.98*
F-129	0.98	0.09	4.79	0.78	0.03	3.77	0.63	0.04	3.23	*0.74*
Females	1.03	0.02	4.95	0.70	0.01	3.77	0.61	0.02	3.23	*0.78*

for wildlife populations. For proper habitat management, it is mandatory to have some understanding of species' requirements. Natural selection favours those individuals who prefer habitats in which reproductive success is higher and where they survive better (Krebs, 1994). Preference can be defined as the likelihood of a resource being chosen often, if offered on an equal basis with others (Johnson, 1980). Preference for suitable habitat increases fitness and reproductive success of the population and therefore a high equilibrium of density is maintained. Disproportionate use of a habitat compared to its availability is considered as an indication of preference.

There are only a handful ecological studies on sambar and chital that have been conducted

Figure 8. Comparison of seasonal home ranges of sambar.



in the subcontinent (Schaller, 1967; Mishra, 1982; Khan, 1990; Sanker, 1994). Management of tiger is in fact directly related to management of its prey and their biomass needs (Karanth and Stith, 1999). To evaluate the ecological requirements of sambar and chital, it was important to find out what habitat parameters dictate their well-being.

Analyses

Locations of radio-collared sambar and chital were used for estimating habitat use and preferences. These locations obtained from radio-telemetry monitoring of the radio-collared animals were overlaid on the habitat map of Panna Tiger Reserve. This habitat map was developed from satellite imagery. Seven distinct habitat types were classified using satellite LISS-III images based on ground truthing plots (Chundawat, unpublished report). These seven habitat types are:

1. Disturbed (settlements): 8% of the total park area
2. Open/Grassland: 22% of the total park area
3. Thorn forest: 10% of the total park area
4. Miscellaneous: 26% of the total park area
5. Mixed forest: 10% of the total park area
6. Mixed dense: 20% of the total park area
7. Water body: 4% of the total park area

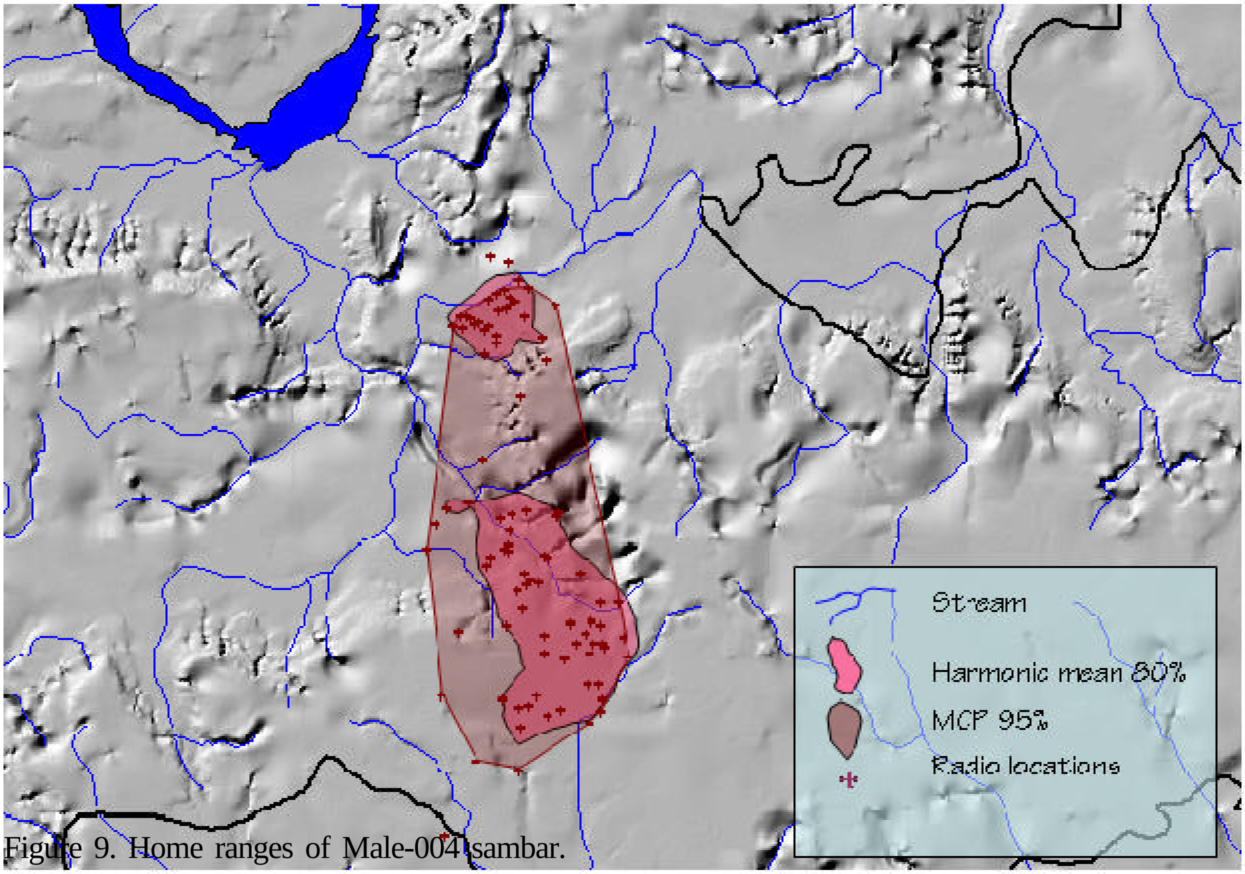


Figure 9. Home ranges of Male-004 sambar.

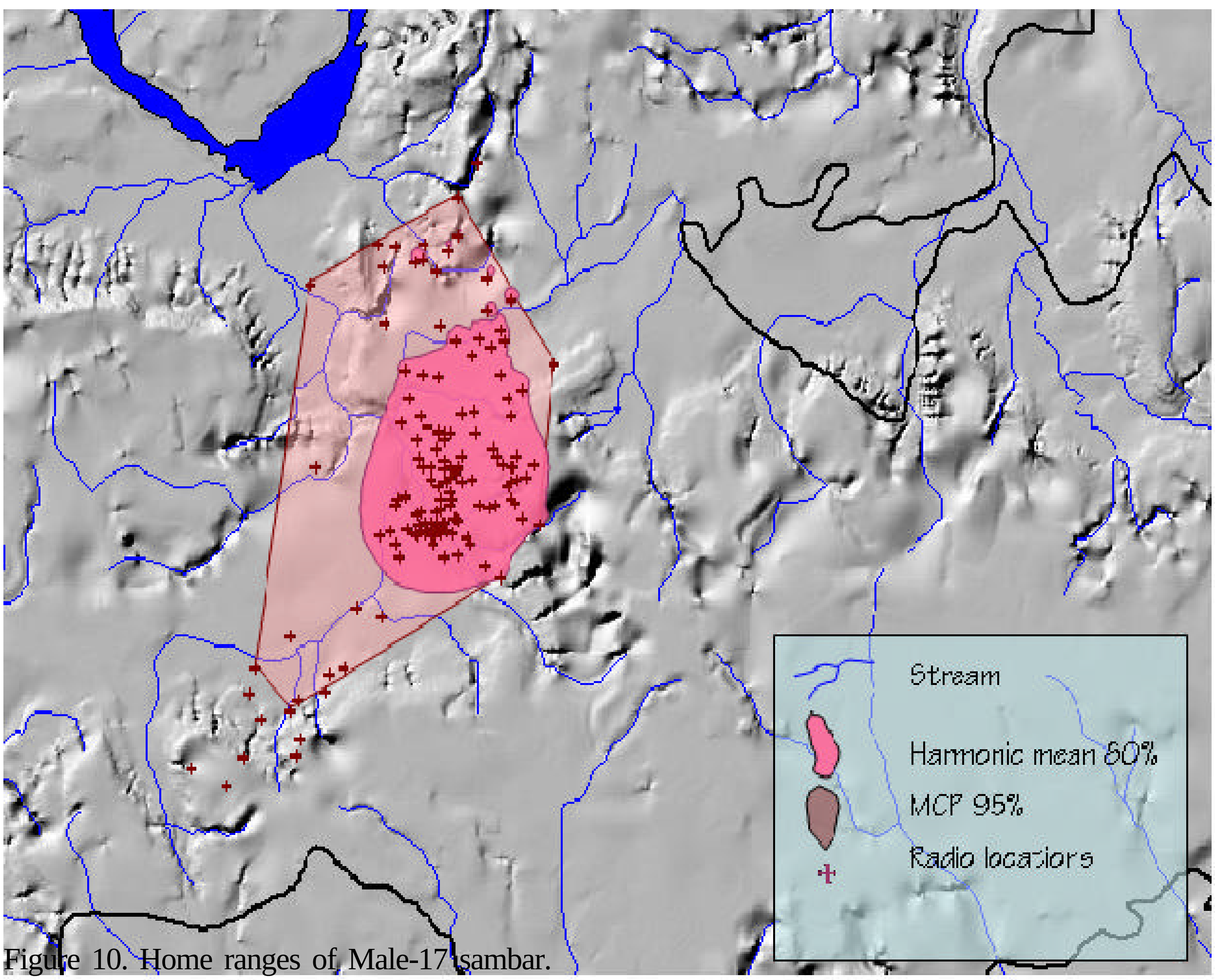


Figure 10. Home ranges of Male-17 sambar.

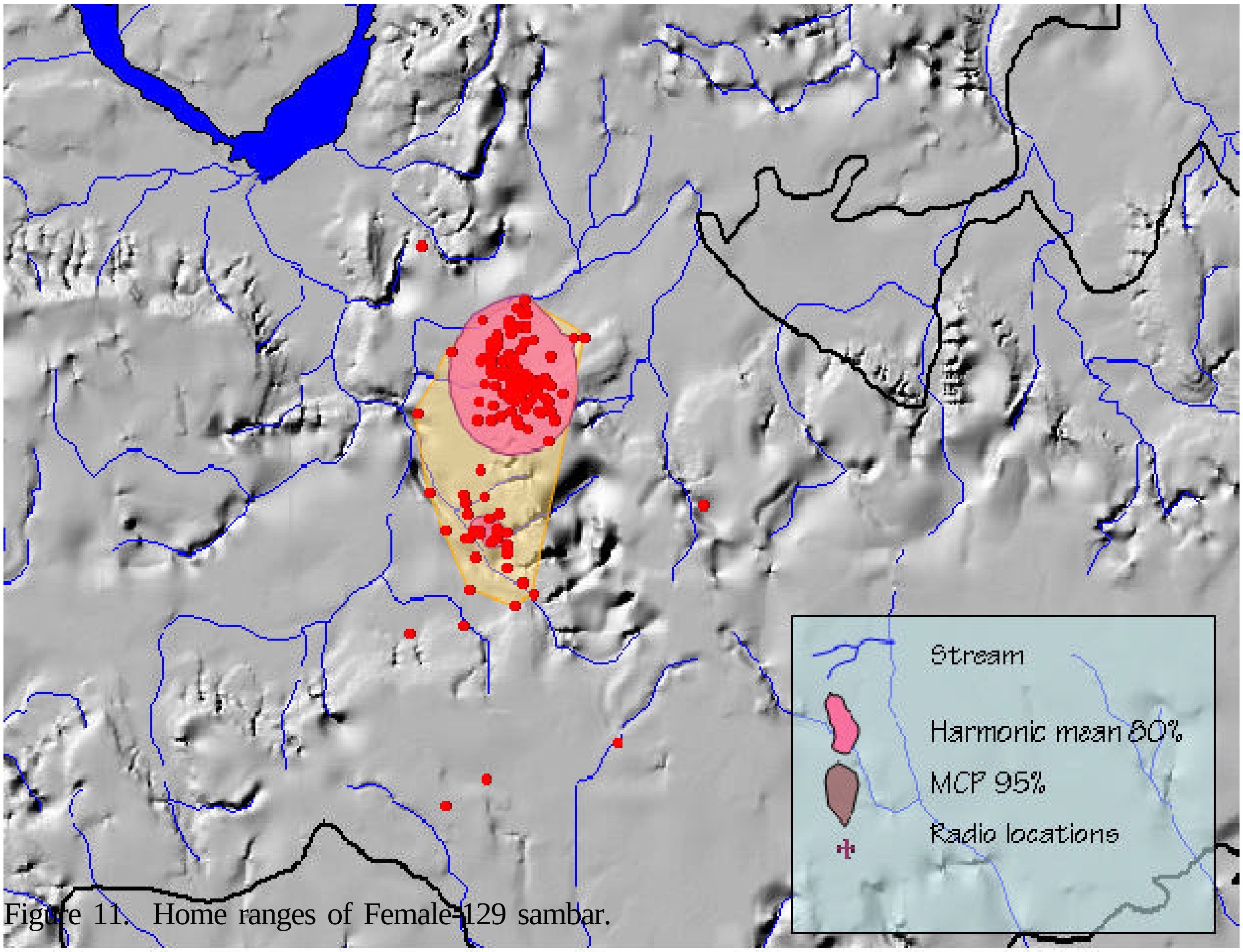


Figure 11. Home ranges of Female 129 sambar.

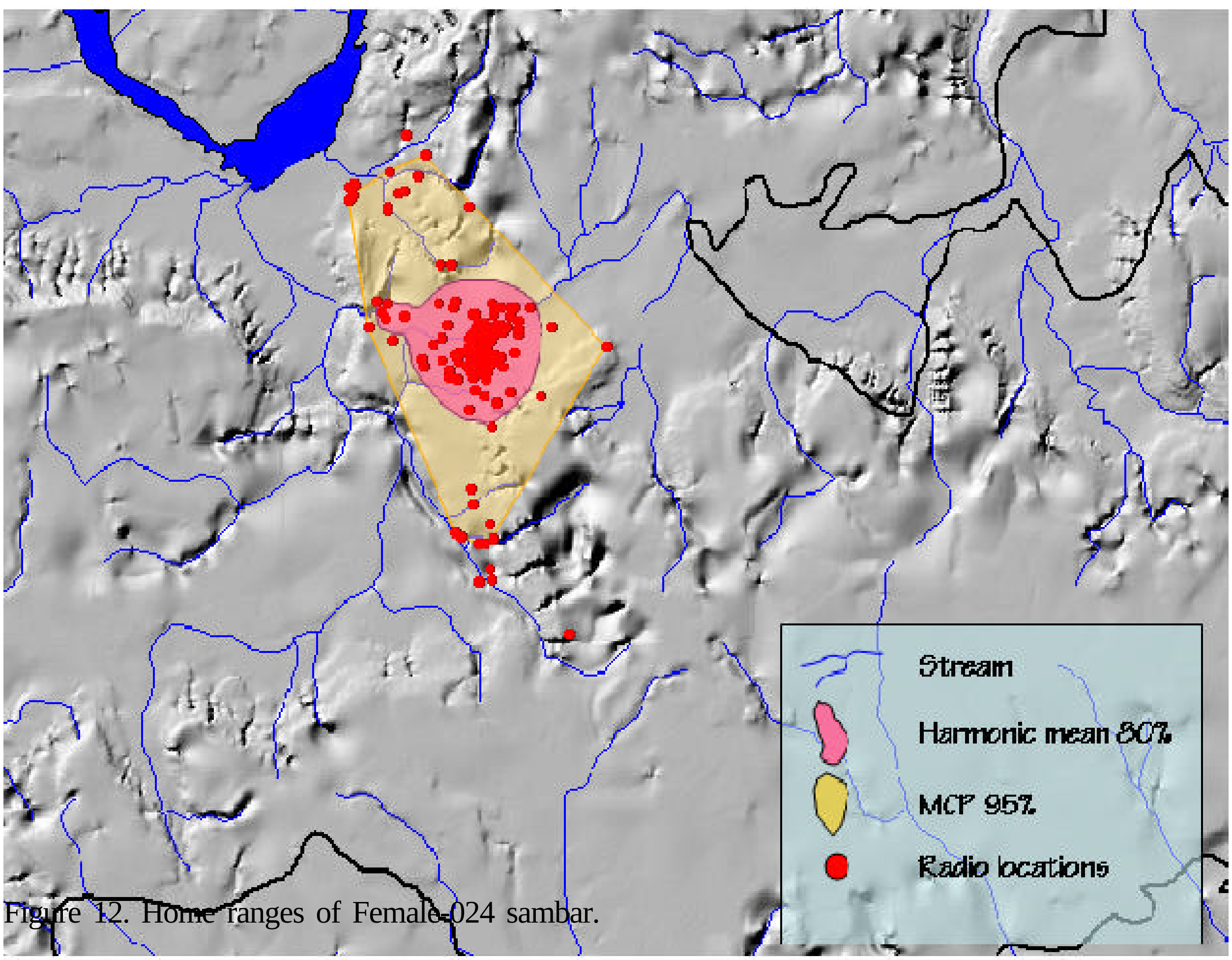


Figure 12. Home ranges of Female 024 sambar.

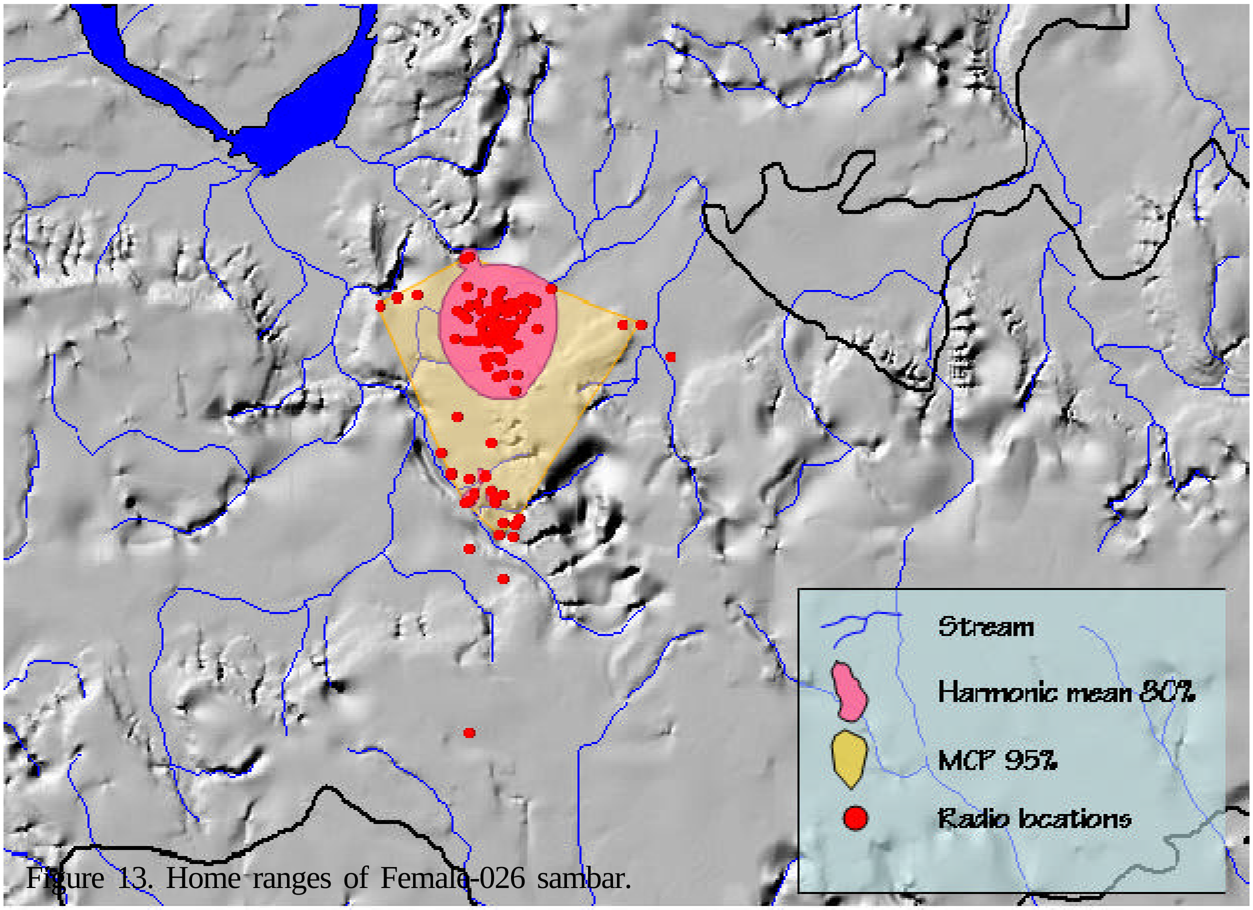


Figure 13. Home ranges of Female-026 sambar.

Water bodies were excluded from use and availability analyses. I followed methods described by Neu et. al. (1974), later modified slightly by Byers and Steinhorst (1984) to test for preference and avoidance and to determine which habitat types were preferred or avoided. For analyses, chi square was used to test for any significant preferences or avoidances within the six habitat types identified for the analysis. Bonferroni's confidence intervals were estimated to find out preference/avoidance of specific habitat types. This was done by estimation of Bonferroni's lower and upper confidence limits (LCL and UCL respectively) at 95% of proportion of use using the following equation:

CL= U ± [Z x ?U(1-U)/n]

We estimated the proportion of areas covered by the six habitat classes with respect to the total area of the park. Specifically designed macros using MS Excel were used for estimation of actual, expected, LCL and UCL of habitat proportions. Habitat preferences by radio-collared individuals were estimated using males and females as separate group and all sambar as another group to determine seasonal and annual preferences.

Results

Habitat preference and avoidance

All radio-collared sambar showed significant preferences (Figure 15) for mixed forests (41%) and mixed dense forest habitats (38.6%). But avoided disturbed (0.1%), open/grassland (6.1%) and thorn forest habitats (0.2%) throughout the year. Habitat use for male and females is calculated separately to find out if any different patterns exist. Our results do not show any differences but point to a similar pattern. A closer look at the individual level also did not reveal any different pattern in habitat use.

Annual

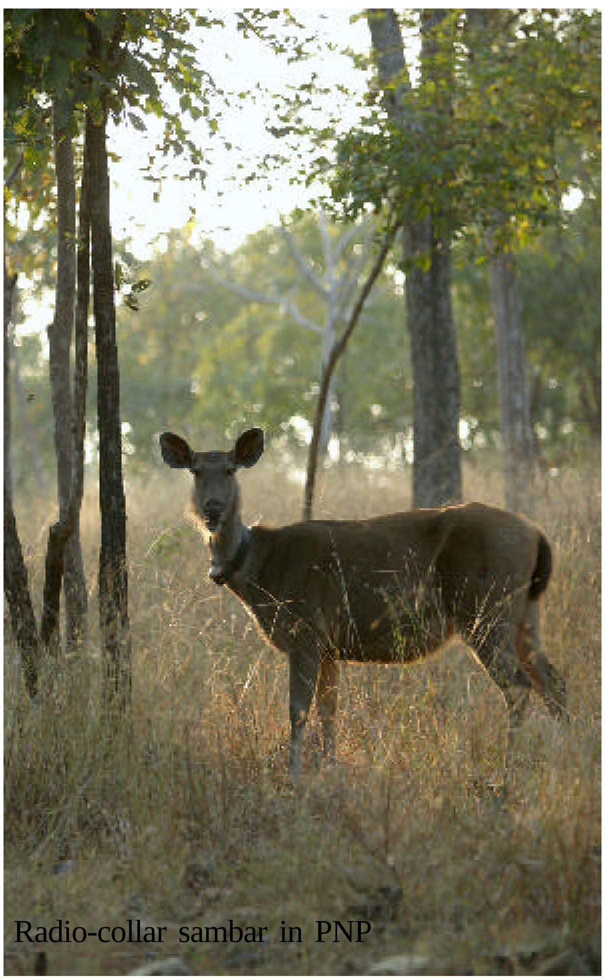
We also estimated separately the annual habitat preferences of all the five radio-collared sambars (Figures 15). It is observed that male-004 used miscellaneous habitat in proportion to its availability but other radio-collared sambar show significant preferences for miscellaneous,

Habitat	M004	M127	F024	F026	F129	Male	Female	all
Outside	0.9	-	9.1	-	-	0.5	3.0	1.7
Disturbed	-	-	-	-	0.6	-	0.2	0.1
Open/Grassland	11.2	8.8	-	5.6	1.2	10.0	2.3	6.1
Thorn Forest	-	0.6	-	-	-	0.3	-	0.2
Miscellaneous	20.6	13.2	4.2%	5.6	8.9	16.9	6.3	11.6
Mixed Forest	31.8	39.6	47.3	45.2	49.4	35.7	47.3	41.5
Mixed Dense	35.5	37.1	39.4	43.5	39.9	36.3	40.9	38.6
Water body	-	0.6	-	-	-	0.3	-	0.2
n=	107.0	159	165	124	168	266	457	723

Table 7. Habitat use by individual radio-collared sambar in PNP.

mixed forest and mixed dense forest habitats; they also showed avoidance for disturbed, open/grassland and thorn forest habitats.

Annual habitat selection by sambar males and females was similar: they preferred mixed dense (male 35.69%; female 47.02%), mixed (male 36.31%; female 40.94%) and miscellaneous forest (male 16.88%; female 6.2%) and utilised these habitats significantly more than their availability. Disturbed, open/grassland and thorn forest habitats were avoided: as these habitats were used less than their availability (table 7).


Radio-collar sambar in PNP

Seasonal

The seasonal habitat preferences were evaluated for pooled locations of males, females and for all combined. Only during the winters and monsoon, did male sambar use dense miscellaneous habitat in proportion to its availability. Similarly, miscellaneous habitat was used in proportion to its availability by males in monsoon. Preferences in all other seasons had a similar pattern as above (Figure 7.4 to 7.6 and table 8).

Male sambar (M-004 and M-127) used dense mixed habitat in proportion to its availability during monsoon (27.28%) and summer (46.9%), whereas the miscellaneous forest was used in proportion to its availability only in the monsoon season (22.02%). Mixed forest was preferred and was used more than its availability in all the three seasons. Preference for dense mixed forests was not as strong during monsoon for both male and female as was observed for other seasons (Figure XX). Females avoided the miscellaneous forest by utilizing it less than its availability in all three seasons.

Activity Pattern

Seasonal variation in activity pattern is observed in radio-collared sambar. Males and females showed similar activity patterns in

Figure 14. Habitat use (annual) by radio-collared male sambar in PNP.

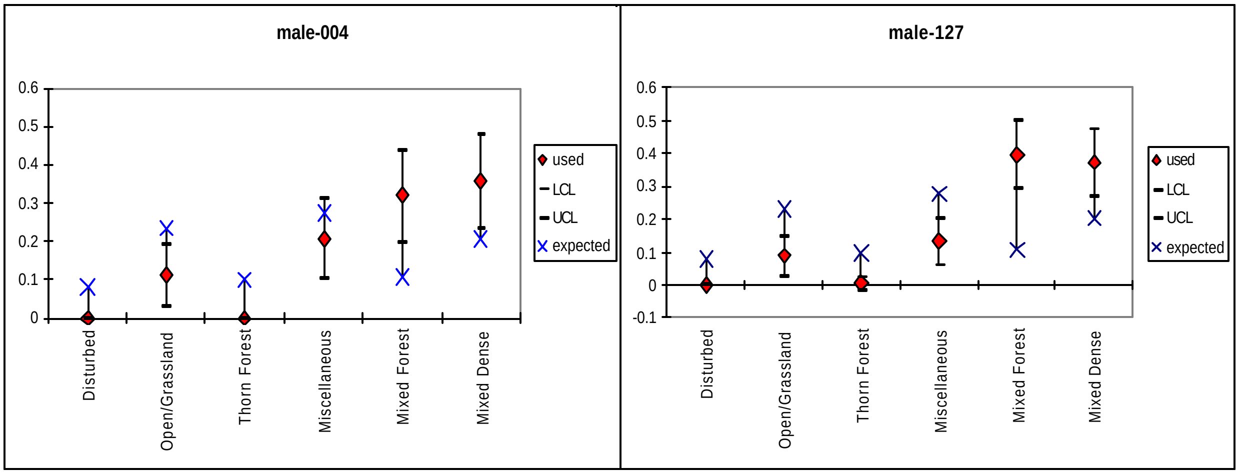
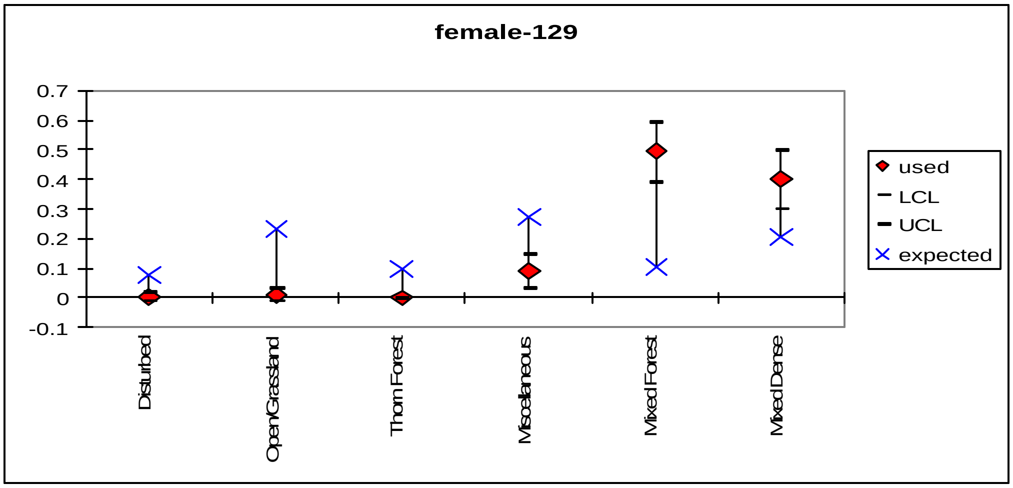
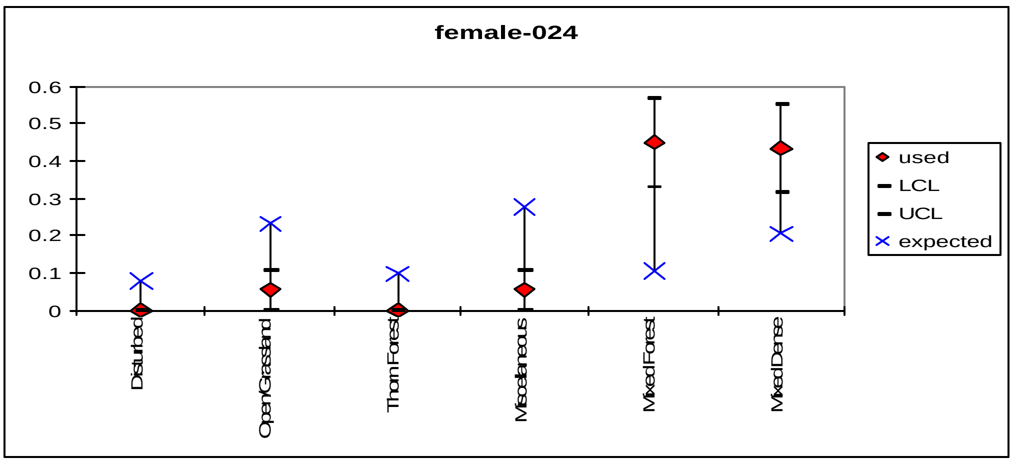


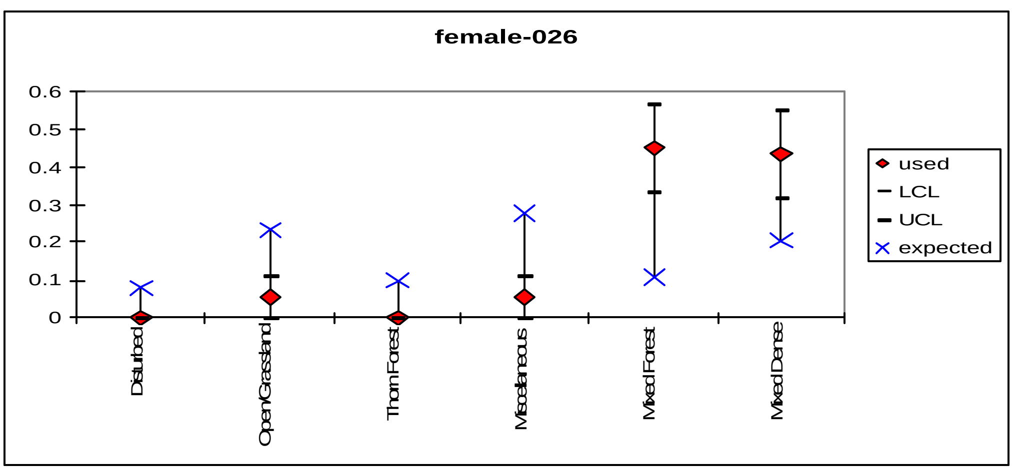
Table 8. Habitat use by male and female sambar and all radio-collared sambar in PNP.

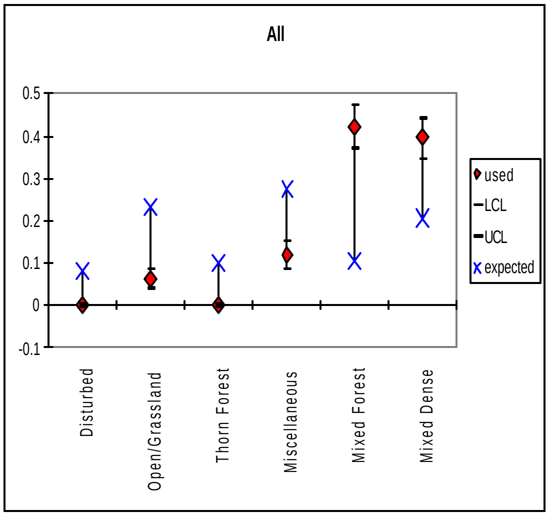
Habitat	Monsoon			Winter			Summer		
	Male	Female	All	Male	Female	All	Male	Female	All
Disturbed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3
Open/Grassland	10.3	6.2	8.2	6.7	5.8	6.3	13.6	3.7	7.7
Thorn Forest	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.3
Miscellaneous	22.0	2.7	12.2	17.9	2.0	10.0	13.7	11.2	12.2
Mixed Forest	40.4	57.7	49.2	45.7	51.5	48.6	24.9	38.0	32.8
Dense Mixed	27.3	33.4	30.4	29.7	40.7	35.2	46.9	46.6	46.7

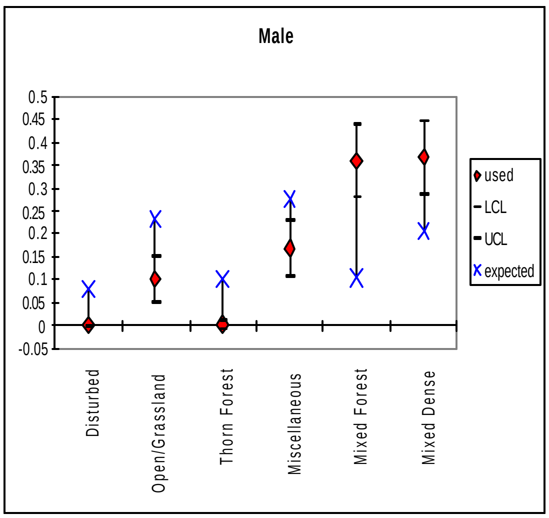
Fig. 14a. Annual habitat preference by female radio-collared sambar in Panna Tiger Reserve.











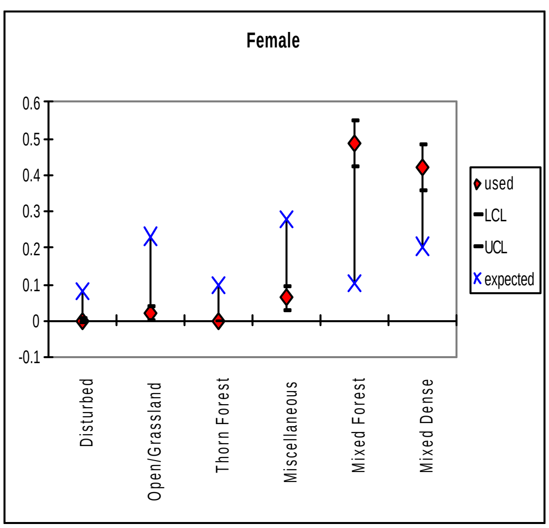


Figure 15. Habita use all samabrs (a)conbined (all), (b) all males and (c) all females.

monsoon and summer. In winter, male sambar are found to be more active throughout the 24 hour period (>60% active). In comparison, females show reduced activities (<60% active) during night hours (2000 and 0700 hours) reaching to a minimum (<20%) in the early morning hours, around 0400 hours. Summer activities show a very clear pattern with two distinct activities peaks (>60% activities) between 0500-1100 hours and 1600-2200 hours (Figure 17). In the middle of the day both sexes show least activities (<30%) 1200-1400 hours. No clear pattern is observed during the monsoon season and most of the time over 60% activity is recorded. Females remained marginally less active (<60%) during night hours (Figure 16)

Discussion

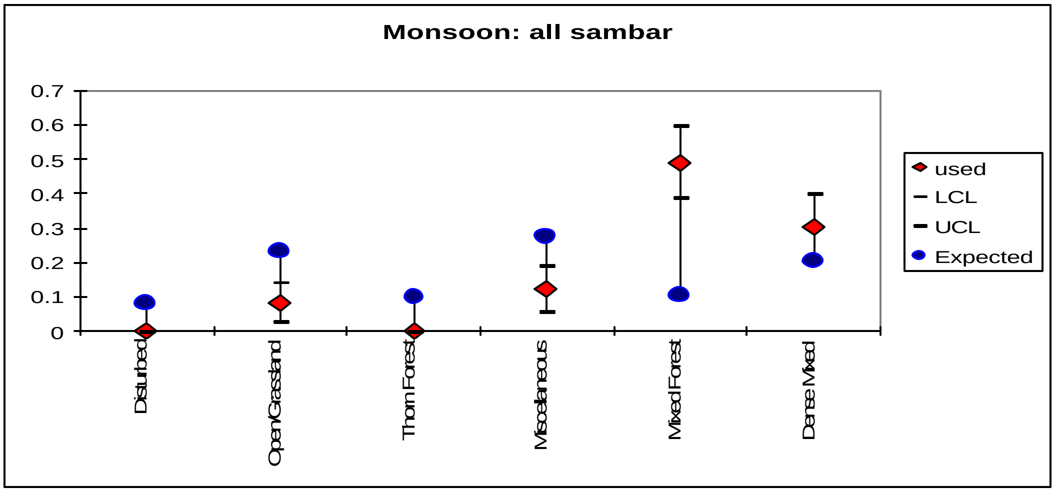
Home range and movement

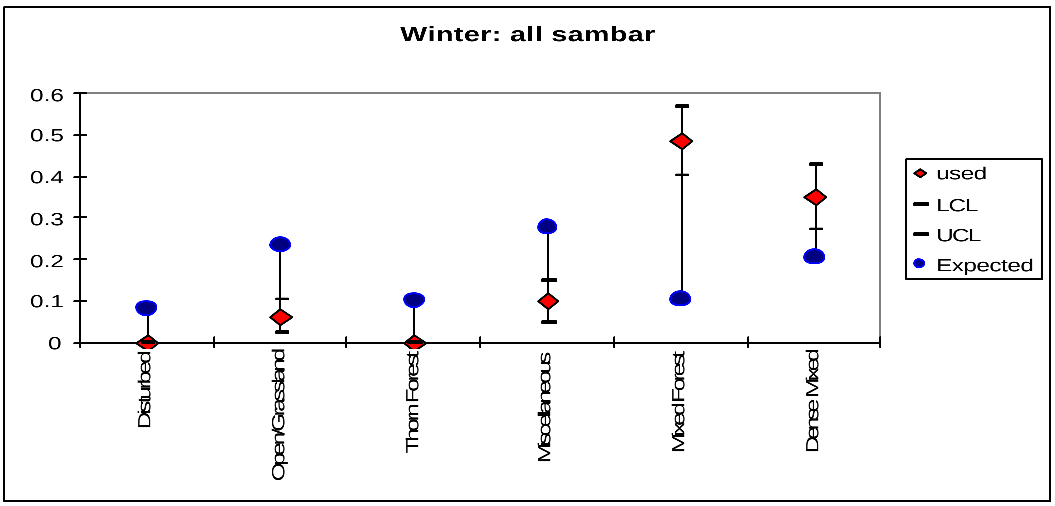
In Panna, as observed in many other areas and in other deer populations, the home ranges of male sambar are larger than those observed for females (Putman, 1988; Johnson, 1984; Mishra, 1982; Sanker, 1994). There are not many studies conducted in the Indian subcontinent to make such comparison except one conducted in Sariska (Sanker, 1994). Both studies document similar differences between male and female ranges. But the seasonal summer ranges are found to be larger in Panna.

Animals do not move randomly in the wild, they all have home areas in which they range to fulfil their minimum ecological and energetic requirements. In this area of regular use defined as home range (Sanderson, 1966), seasonal variations in environmental conditions alter the availability of forage and other ecological resources such as water and cover and can affect animals' reproductive activities. These ecological factors govern the movement pattern and home range sizes of many of the deer species (Putman, 1988).

In Panna Tiger Reserve, the seasonal variation that is observed in sambar home ranges is probably a response to the changing environmental conditions. Most of them use a very small area of a few hundred hectares during the monsoon (rainy season) months. It is during this season that the home range of sambar is smallest (Table XX). The monsoon is a season of plenty in Panna Tiger Reserve. Most of the

Figure 15 a. Seasonal habitat preference by all radio-collared sambar in Panna Tiger Reserve.





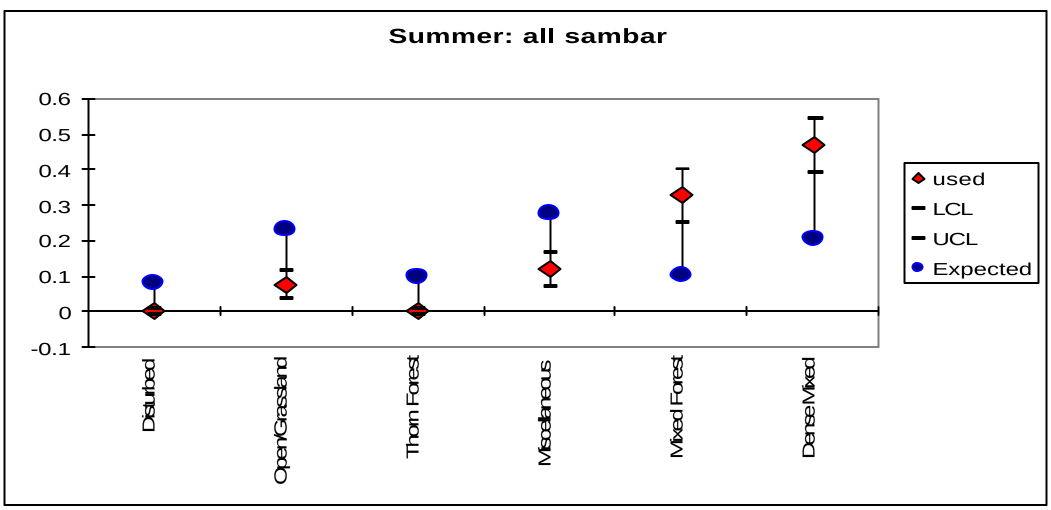
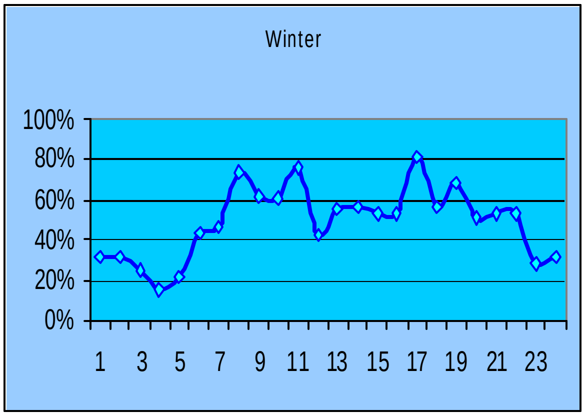
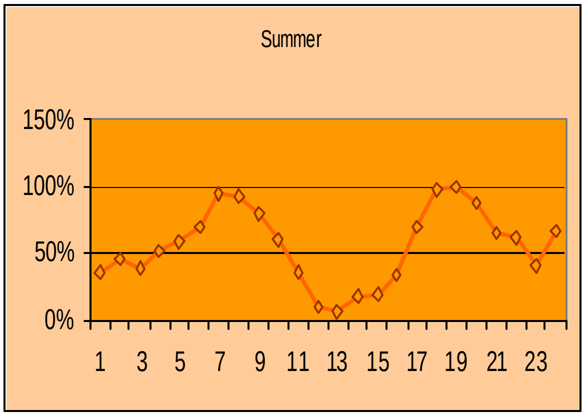
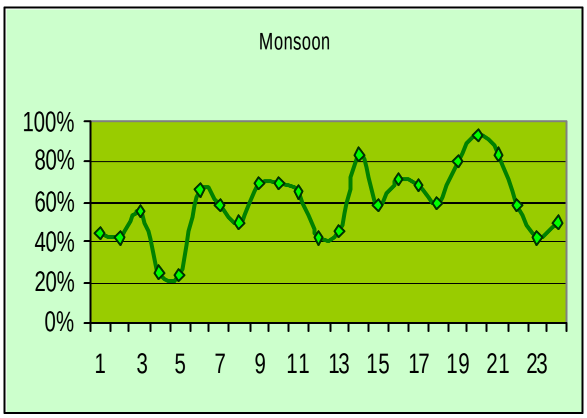
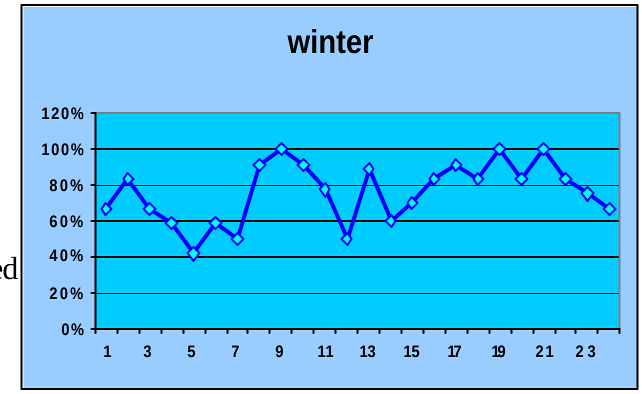


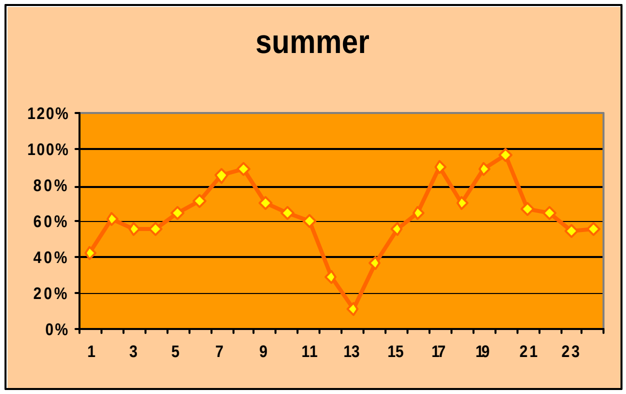
Figure 16. Activity chart for male radio-collared sambar.











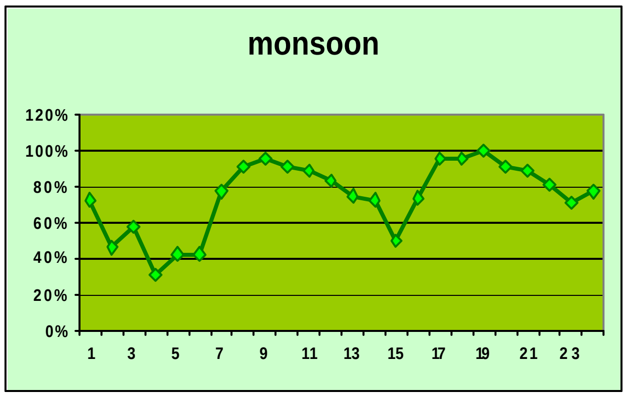


Figure 17. Activity chart for male radio-collared sambar.

important resources that govern the movement of deer (Putman, 1988) are available in abundance and distributed uniformly throughout the landscape used by the radio-collared sambar. Animals do not require to move larger distances and can fulfil their minimum energetic and ecological requirements within a relatively small area. Moreover, monsoon is also the season when fawns are born, therefore parental cares demand female sambar to remain close to its fawning site for an extended period. In addition to abundant food supply and its wider distribution, the fawning activity also affects the average distance travelled and movement pattern of sambar, especially of females. It is most likely this that is reflected in the smaller home range sizes during the monsoon season as determined by the radio-tracking of these animals. The only study conducted on sambar in India for reasonable comparison is the Sariska one where Sanker (1994) did observe similar sized home ranges during the monsoon.

Winter, a season, which follows the monsoon, still has a fairly abundant and wide resource distribution. This is also reflected in relatively small home ranges and similar trends that were observed in the monsoon. It is observed that males of many deer species move frequently during the rutting season and wander over larger areas in search of receptive females (Putman, 1988, Sanker, 1994). In Panna, the homes ranges of male sambar did not change much during winter months, which is the sambar rutting season, except for a minor increase. Average distances travelled in 24 hours only show marginal increase in activity over those travelled during the monsoon.

The largest home ranges and average distance travelled by radio-collared sambar was observed during the summer months. In contrast to monsoon, summer is a season characterized by poor quality and availability of forage, sparse distribution of water, limited cover due to the deciduous nature of the forest and of extremely high ambient temperatures during day hours. Most of these resources are not distributed uniformly and frequent forest fires add to the natural scarcity of these important ecological resources. Animals, therefore, are required to move larger distances in order to find sufficient food, water and cover to escape from the extreme temperatures. This behavioural adaptation may be what manifests in larger average distances travelled daily and bigger ranges as documented in this study through intensive radio-tracking of collared sambar.

It is observed that the females' home ranges overlapped considerably. Analysis of habitat use indicates that it is probably the availability of resources, including forage and cover, that result in higher site fidelity. Seasonal variations in home range sizes may have been dependant upon mating behaviour and availability of water, shelter and other resources in addition to the variable climatic conditions.

Habitat use

Sambar is classified as a browser (Putman, 1988) and has evolved successfully in forested habitats (Sunquist et al., 1999). Their anti-predatory strategies and food requirements necessarily demand forest cover for survival. It is found that sambar is generally very selective in their choice of habitat (Mishra, 1982; Sanker, 1994). Results of habitat preference using Bonferroni's confidence interval suggest that mixed forests, dense mixed forests and miscellaneous forests, which are associated with higher canopy cover and tree densities, are preferred by sambar in Panna Tiger Reserve. These results also reveal that sambar avoid open forests, grasslands, thorn forests: they are sensitive to anthropogenic pressures and disturbances and avoid such habitats. Results of this study corroborate that sambar and nilgai use distinctly different habitats (Mathai, 1999; Chundawat, 2001). This difference can be accredited to their anti-predatory behaviour. Nilgai prefers open terrain and large groups for more vigil; sambar rely upon small groups, camouflage and thickets for hiding (Putman, 1988). Distribution of sambar is therefore restricted mainly to dense forested habitats where they achieve higher abundance. These preferred habitats of sambar are also frequently used habitats for tiger and therefore these forests habitats are of significant importance for the management of tiger and its associated prey in the Reserve. The most regularly preferred habitat, i.e. mixed forest is only 10.1% of the total park area. To manage a healthy tiger population, which largely depends on the sambar in Panna Tiger Reserve, it is important to maintain a healthy mosaic of dense forested habitats.

No difference in habitat preference across seasons is observed in this study. Though, male sambar used dense mixed and miscellaneous forest within their proportion of availability during monsoon and winter. This proportional usage in winter can be credited to the large area that males cover during these two seasons possibly in search of mates (Putman, 1988). Females also show similar patterns of usage since they are more dependent on optimal forage availability (Putman, 1988; Mishra, 1982). It can safely be deduced here that forage is the critical resource for female sambar, whereas partner for mating mainly governs the terrain utilization by males.

Seasonal variation in activity patterns of radio-collared sambar gives a clear idea about energy budgeting. The day and night temperatures in monsoon do not vary much and it is reflected in overall activity pattern which did not vary across the entire 24 hour period. Whereas, in winter, day and night temperatures vary considerably but remained below 25oC, which allowed the animals to remain active throughout. Moreover, winter is the rutting season when males move great distances in search of mates (Putman, 1988; Mishra, 1982, Sanker, 1994). This may be one of the prime reasons for extended active periods as observed in the study. This is especially true for males which remain >60% active for most of the 24 hour. In contrast to males' activity pattern, females show reduced activities (<40% activity) for most of the night hours.

Temperature variations between minimum and maximum is at its highest (over 20oC) during the summer. In Panna, summers are extremely hot and temperatures can go up to 480C during mid day; hence there is a clear reduction in activity around mid day. Most of the activities are seen during early morning and in the evenings, when temperatures are optimal. These results show that there is diagnostic temporal energy budgeting during summers, where resources are scarce and sporadically distributed. During winter and monsoon, abundance of resources and independence from the temperature regime results in a less demarcated temporal variation in activity pattern within a 24-hour day. This is the first study to document the activity pattern of sambar.

Availability and dispersion of resources is a critical parameter that determines pattern of use by an animal. For widely dispersed availability of resources, the average daily movement of an animal would be larger. Large average movement would necessarily mean higher energy costs. Thus it is important that the benefits from these energy expensive movements be higher than the costs (Putman, 1988; Powell, 2000). From the study it appears that summer which is a season when important resources are scarce, this affects the space requirement for individual sambar and possibly controls the number of animals per unit area or abundance of sambar population. Hence the summer season seemingly determines the population size of sambar, one of the major prey of tigers in Panna Tiger Reserve. It is therefore reasonable to presume that availability of key resources during summer play a very important role in ecology of tiger in addition to other biotic factors such as grazing and anthropogenic disturbance.

TIGER-I: Social Organization and Estimation of Tiger Population.

Carnivores show a great diversity in their social organization and behaviour, some are solitary and others live in highly developed social units. The social organization and behaviour of a carnivore reflects its response to environmental and ecological factors and to its con-specifics.

Dispersal

Dispersal is defined as a movement away from the natal area to a place where dispersing individuals settle for breeding. Two kinds of movement are recognized: one in which an animal finds a suitable breeding spot near its natal area ? usually known as phillopatry; the other is a long-range movement away from natal area. The distance travelled by the dispersing individual determines the gene flow within or with neighbouring populations and determines the demography and social organization of the population.

In this study information on dispersal was collected through radio-collaring dispersing tigers and identifying individual tigers by facial markings and stripe patterns. Since dispersal was not the main focus of the study information on the subject was limited to radio-tagged individuals and identified tigers only. For this study, movement away from the mother's territory was taken as dispersal; if the animal was localized in an area to establish a territory and started breeding subsequently, this was considered phillopatric movement. Where an individual moved away, out of the study area, for a long time, this was considered long distance dispersal.

Results

Population characteristics

Most of the information obtained on tiger biology in this study comes from the radio-collared tigers and from several individually identified tigers (based on repeated photographs). Female-118 was the first adult female tiger radio-collared and the three female cubs (the three siblings Fm-111; Fm-120; Fm-113) of her first litter were radio-collared when they were either establishing their own territories or had established it, in areas adjoining their natal area (figure XX).

During the first year of the study, in 1996, a total of six tigers of over one year of age were identified within the intensive study area of 180 km2. This included two territorial females and two males. Both the females were raising cubs, the female "Female-118", who occupied the best habitat in the Reserve in Chapner and Bhadar region, was raising a litter of three cubs born in April/May 1996; she was radio-collared in January 1997. The other female "Bargadi female" (an identified individual) occupied the Bargadi region and was raising a litter of two cubs. The dominant large male, "Male-91" (radio-collared in April 1996) patrolled both the female territories and beyond, but no evidence of another resident female was found within his territory during the intensive monitoring and radio-tracking of his movements. A very old male had occupied the area south of Male-91's territory. The research team did not find evidence of other non-resident tiger in this intensive study area. Thus during the first year of the study four adult tigers were using an area of 180km2. This gave an approximate density of 2-3 adult tigers for every 100 km2. Extrapolating from this figure, it was estimated that there were maybe 18-20 adult tigers in the entire Reserve.

The first litter of Female-118 comprised of three female cubs. They all survived to adulthood and dispersed from the natal area and established their territories adjoining the mother's. Both the cubs of the Bargadi female, which comprised of one male and a female, later died at the early age of fifteen or sixteen months and twenty two months respectively. Bargadi, an old tigress, who had already lost a canine was displaced by the female dispersing cubs of Fm-118. In mid 1998, male-91 had a fight with a new male who took over part of it range near the river. Thus by the end of 1998, there were four female territories within the same study area and two different dominant males patrolled the region, increasing the density to over 3-4 tiger per 100 km2. Since 1996, the number of breeding females in the areas doubled from two to four. In the time between 1996 and 2002 and Fm-118 gave birth to four litters and her daughters females-111, 113, and 120 each had two to three litters. As a result, the number of transient and sub-adult animals increased considerably. In the study area, by early 2002, there were seven resident breeding females, two territorial males and four to five young known tigers. In 2002 the seven female tigers each had a litter; this included female-118 with three cubs and the other females-111, 113 and 120, the Amdar, Gata and Nararan females each had two cubs: altogether this accounted for 15 cubs. This meant that there were nine resident tigers ? two territorial males and seven territorial females ? and four or five known sub-adult tigers, plus fifteen cubs of various ages. These all accounted for a total population for over 28 tigers in an area of over 400 km2 intensively monitored.

Between 1996 and 2004, a total of 42 different tigers were identified and monitored, which included adult resident breeding tigers, young adult non territorial, non breeding animals and cubs over one year of age. Thirty-eight of them were positively identified, photographed and sexed. These included nineteen females and twenty males, giving almost an equal sex ratio. This may be due to the fact that during the later part of the study, between 2002 and 2004, there was a frequent change-over of four different dominant males. 'Hairy foot' took over after the dominant male 091 disappeared in 2002, but shortly after he was found dead, in early monsoon of 2003. Another young male, identified as "Broken-tooth", replaced him and took over the area.

Within the two dominant male territories being monitored, seven breeding female territories were identified by the end of 2001. Out of these seven females, four of the females and both the males were radio-collared. The ratio of breeding individuals favoured females, 3 : 1. It is observed that the breeding population in Panna is limited due to availability of space and due to the poor quality of tiger habitat available.

The rest of the tiger population was composed mainly of pre dispersal adult cubs and a few transient individuals. The transient population was mainly young adults from previous litters and it was the male sex that remained associated with natal areas longer and these were observed intermittently.

Reproduction

During the study we observed resident tigresses were either pregnant or raising a litter at any time of their reproductive age (> 3 to 14 years). This makes tiger very productive and resilient species. During this period, we monitored eight breeding tigresses giving birth to fourteen litters and a total of 32 cubs. It was also observed that female cubs tend to wean to independence and leave the natal area at an earlier age than their male siblings.

Age of sexual maturity:

In Panna we observed that, young females gave birth to their first litter, on average, at the age of 39.75 months (n=5); the earliest observed during the study was at the 32nd month. We were able to observe four female cubs dispersing and later breeding by placing radio-collars on three of them. On average a fresh litter is produced at an average gap of 21.6 months (n=14). Almost all the litters observed were produced on 22nd months, except one, which was produced in 20th months. Details of the litters produced is given in table ??

A female is capable of giving birth to a fresh litter in just a few months interval. This was observed in the case of tigress Fm-120, when her entire second litter, which was only four months old, was killed by a new dominant male, 'Hairy-foot'. These cubs of the second litter were last seen on 26th December 2001. Her third litter of two cubs were later seen on 10th March, when they about a week old, this meant that she conceived before her previous litter died. Signs of the new male 'Hairy-foot' visiting Fm-120 were seen on several occasions and once he was seen resting for hours just a few yards away from the mother and her litter.

Litter size and gestation period

Average size of litters observed during the study is 2.3 cubs per litter (n=14). This is based on the observation of cubs survived over 3-4 months. It is extremely difficult to find young cubs and only on three occasions were we able to observe litters a few weeks old and we did not observe any mortality at the age of 2 to 12 weeks.

Based on the twelve birth and matings observed by the research team, the average gestation period estimated in Panna tigers was 103 days. Mating was observed throughout the year, thrice in December, twice in August and once each in January, February, May, June, July, September and October. These field observations on the radio-collard tigresses suggest that estrous cycle and mating time depend on the first litter and subsequent mating shift accordingly by two to three months every birth. We did not see any seasonality in mating though it appears that most of the mating took place during monsoon and winter but we saw mating throughout the year.

Mortality and Survival

A total of 42 tigers were identified and monitored regularly during the study period. This includes thirteen adult, breeding tigers ? nine females and four males ? and 32 cubs. The cub population also includes the three female cubs who grew to adulthood and were later monitored as independent breeding tigresses (Female-111; 113; 120). Details of the 42 tigers survival observation is given in Appendix-II.

A total of nine mortalities in adult tigers are suspected but the research team could find only two carcasses of tigers. These nine suspected mortalities include the Bargadi female, who was the dominant territorial female of the Bargadi region who was displaced by Female-120 in 1998; it is suspected that she died most likely due to old age after she was displaced from her territory. Female-111, one of the siblings of Female-120 and 113, went missing over a cattle kill in October 2002 close to the periphery of the Park boundary near Talgaon. Her presence could not be confirmed by intensive camera trapping in the areas she usually visited. After three months of intensive monitoring and looking for other signs, this failure to confirm her presence led the research team to suspect mortality. A couple of months later, her sibling, Female-120 (radio-collared in 1999) was found dead in a snare, in December 2002. Her body was recovered and at the site, carcasses of sambar deer that had also been snared were recovered from the site. 'Hairy foot', a new male who replaced the dominant radio-collared male Male-091 (monitored since 1995 to 2002), was found dead in a well in June 2003. This was followed by the disappearance of the third sibling, Female- -113 (radio collared in 2000) by March 2004. Later, within a year, another male 'Broken-tooth" was seen with an injury on its shoulder. All the above-mentioned tigers were intensively monitored animals and there is no report of their survival during the period monitoring which continued up to March 2005. (Broken-tooth was seen later.) Of the other tigers that were monitored, though not as intensively, there is no further evidence of their presence in their areas; this includes the three females from Amdar, Nararan and Gata.

In addition to observations made on the survival and mortalities on adult tigers, we also observed the birth of 32 cubs from 14 litters between January 1996 and December 2005 and observed only eight mortalities up to two years of age. Both the cubs of the first observed litter of Bargadi females died (Table XX), one due to unidentified disease (carcass recovered) and the other died over a cattle kill (poaching suspected based on the circumstantial evidences). The other two mortalities were due to suspected infanticide of the second litter of Female-120 by the new male 'Hairy foot' after he replaced the radio-collared male-91. Other mortalities were either due to natural or due to unknown causes. Only on three occasions we were able to monitor litters from a very early age of few weeks and we did not see any mortality in these litters (seven cubs) of less then two months.

Survival/Mortality Rate

For calculating mortality and survival rate the study period was divided in two periods, 1996 to 2001 (Almost six years or 5.9 years) and 2002 to 2005 (3.3 years or almost three years). This was done because mortality rate increased significantly from 2002. We used computer software MICROMORT to calculate survival mortality rate (Ref XX)

It is calculated that for a tiger, irrespective of its sex, to survive through the nine years in Panna is very poor, just 21.7% (95% confidence interval of 0.075 and 0.626; Var = 0.013752). But for the first six years of the study survival probability is very high 81.6% (Confidence interval of 0.548 and 1.0). It drops significantly for next three years to astoundingly low 26%.

Probability that a female will survive during the first six years of the study is 70% but for the next three years it is only 24% and for the entire nine years it is only 16%. Probability that males will survive for the first six years is almost one. This is an overestimation due low sample size and absence of mortality in the monitored population. But after 2001, the chances of males survival for the next three years declines to 28% which is similar to the survival in the entire nine-year monitoring period.

Dispersal

We witnessed four female and one male cubs growing and dispersing and three of them, Female-111, Female-120 and Female-113, (later radio-collared) were siblings and the first litter of Female-118. Female-111 separated from the other siblings earlier, at the age of about 18 months and moved to a new area in the east; but for about six months, she continued to use and make kills within her natal area. Later she moved further east and established her independent territory adjoining her mother's. The other two siblings moved into an area occupied by the old Bargadi female west of their natal area. These two siblings moved in this area in coalition and displaced the old female. They remained in coalition for several months and were seen occasionally in association with the old female's male cub. The female-120 established her territory and patrolled this area until her death. Her coalition partner and the third sibling moved north to an area along the river Ken valley and established her territory immediately adjoining her mother,s. These three siblings were radio-tracked from 1998 to 2002. The fourth dispersal observed was that of another female cub of female-118, which belonged to her fourth litter. She had partially occupied space left vacant after the death of female-120. A Male cub of female-118 was seen as a transient animal and was observed mating with female-111 and also female-113.

Estimation of tiger population

As part of the ongoing investigation on tiger ecology, the research team also undertook fieldwork to determine tiger density in Panna Tiger Reserve. The tiger's secretive nature and inherent and relatively low density make hard it to estimate numbers reliably. But recent technological and theoretical advances, and their innovative application by field biologists now make it possible to estimate tigers number more reliably. The stripe pattern of every tiger is unique and this allows us to identify individual tigers when remotely photographed. The record of its capture history makes it possible to apply capture-recapture methods to estimate the population size. The photographic capture-recapture sampling method, developed by Karanth and Nichols, 1998 to estimate tiger density, is being used in Panna Tiger Reserve. This method has been used successfully in several tropical forest habitat of the Indian sub-continent and in other south Asian tiger habitats (Nichols and Karanth, 2002; Kawanishi, 2002; O'Brien, et. al; 2003).

The tiger population was estimated using the photographic capture-recapture method. The field exercise was conducted in association with the Centre For Wildlife Studies, who provided the camera equipment for the census operation in 2001. The data from the 2001 census is published in joint authorship with collaborating scientist in Animal Conservation.

We used camera traps manufactured by Trailmaster™. Each camera trap unit includes an electronic tripping device that uses an infra red beam to detect animal movements and fires two separate camera units when it crosses the beam. The cameras were placed on either side of the road at 3.5 to 4 metres apart so that both flanks of the passing animal can be photographed. These camera trap units consist of a transmitter and a receiver and two cameras were deployed inside a steel shell to prevent theft placed on both sides of the tiger's expected travel path in order to photograph both its flanks.

The intensive study area was selected for sampling; this included the territories of all the radio-collared tigers. This is also the area from where prey is estimated as part of the tiger Research Project every year. In this area, 60 camera trap sites were identified. Camera traps were placed at spaces determined after an intensive survey of the region and other methodological considerations. Each camera trap consists of cameras and an infra-red trigger unit, which is activated by an animal movement between the units. Two cameras are used at each site and are placed on either side of the trail to photograph both flanks of the tiger (repetition – delete here?).

Since we only had 20 camera traps units and needed to cover 60 trap-sites, for logistical reasons the sampling area was divided into three units, each with 20 trap locations. Each area was sampled for tiger ID pictures for 15 days and then the camera trap units were moved and deployed in the next sampling block. All the units were visited every day to record the capture details in a standard format to document all the necessary information needed for later analysis and to troubleshoot where necessary (Karanth & Nichols, 2002: page 183).

Each roll of film was marked with identification numbers and the unique number of the frames for each photograph recorded. This helped us to assign each capture correctly and match both profiles. In addition to this each tiger identified was given an identification number. Tigers were identified from their unique stripe patterns (Karanth et al., 2002).

We used CAPTURE software (Rexstad & Burnham 1991) to analyse the data. From the above field notes capture histories for the identified tigers was constructed following the standard protocol described in Otis et al., 1978 and Nichols, 1992. '1' indicated capture and '0' denoted no captured for that that occasion. Details capture histories are given in the Table-XX. For the analysis of this data we presumed that that the sampled population is demographically closed for the sampled period (Otis et al., 1978; Karanth, 1995; Karanth & Nichols, 1998) mainly because tigers are relatively long lived animals.

We considered the following models (Otis et al., 1978; Nichols, 1992) and estimation options implemented in CAPTURE:

Mo = Capture probability is the same for all tigers, and is not influenced by behavioural response, time, or individual heterogeneity.

Mh = Capture probabilities are heterogeneous for each individual tiger, but not affected by trap response or time.

Mb = Capture probabilities differ between previously caught and uncaught tigers due to trap-response behaviour, but are not influenced by heterogeneity or time.

Mt = Capture probability is the same for all individual tigers, but varies during the survey only due to time-specific factors.

The model selection process also considered more complex models such as Mbh, Mth, Mtb and Mtbh that incorporate effects of heterogeneity, trap response and time, in various combinations. The overall model selection test (Otis et al., 1978) scores potential models between 0.0-1.0, with a higher score indicating a better relative fit of the model to the specific capture history data generated by the survey. For each analysis program CAPTURE generated the number of individual tigers captured (Mt+1), estimated capture probabilities per sample ,and the estimated tiger population size (the number of tigers in the sampled area, inclusive of animals that were not photo-captured at all).

We used average half range length to determine the buffer distance. This buffer distance was used to generate a buffer around the trap polygon to calculate the sampled area; (Wilson & Anderson, 1985; Karanth & Nichols, 1998; Nichols & Karanth, 2002)

Results

In February-April 2002, camera trapping was done for 45 days and include three 15-day sampling. This accounts for a total 914 trap-nights. Thirty-six usable photographs (17 right flanks, 19 left flanks) of 11 individual tigers (8 females, 3 males) were obtained from this sampling. As generally expected for low density populations of tigers (Karanth & Chundawat 2002), the sample size or the number of individuals captured (Mt+1) was small in this study. The statistical test ($z = -1.494$, $P = 0.07$) supported the assumption that the tiger population was a closed population during the sampling period.

The goodness of fit test for model Mh (as

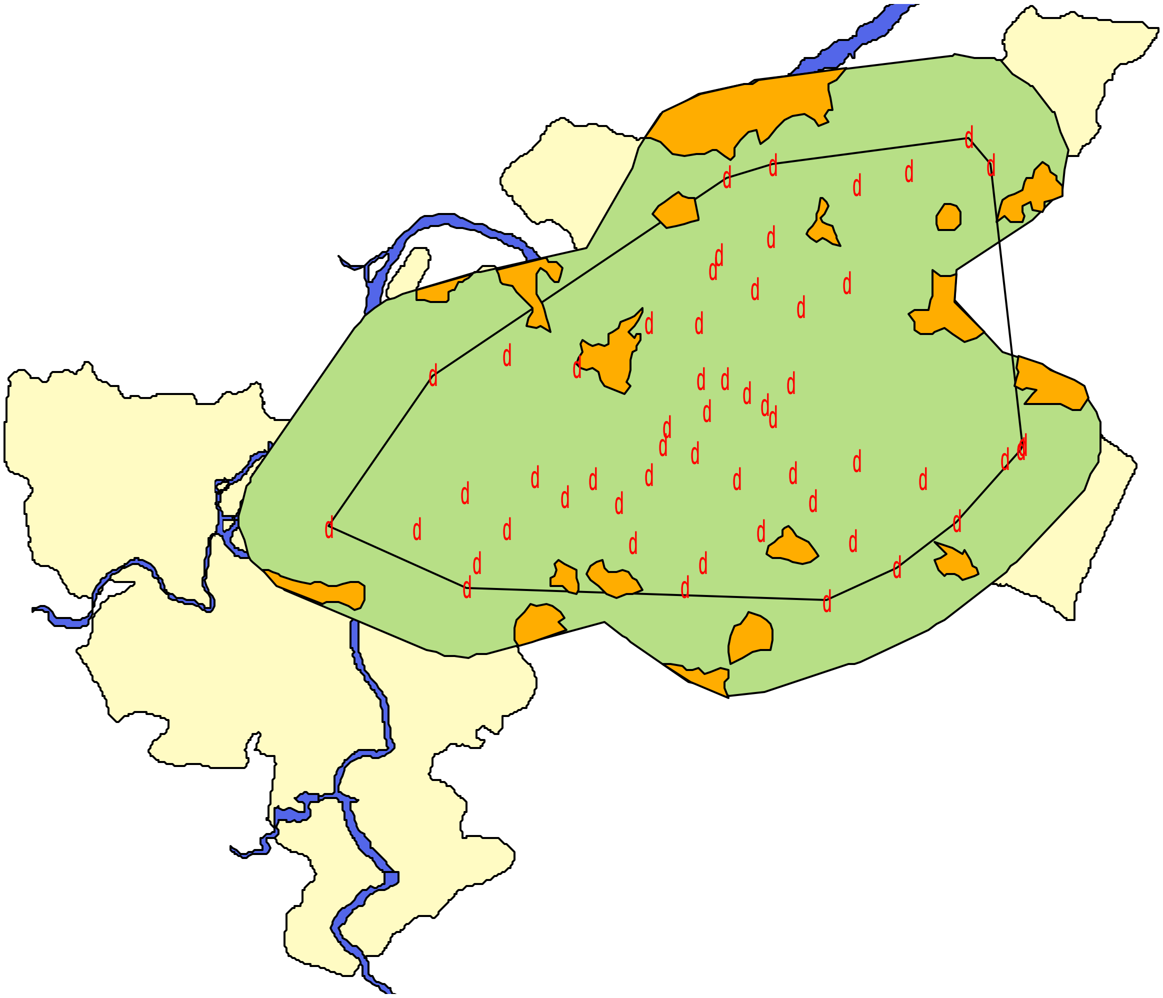


Figure 18. Map showing camera trap locations, sampled area (dark green) and non tiger habitat (brown polygon) in PNP.

Table 9. Capture history of photogrphed tiger in PNP.

Individual ID number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PAT-101	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PAT-102	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PAT-103	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PAT-104	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PAT-105	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**
PAT-106	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PAT-107	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**
PAT-108	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PAT-109	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PAT-110	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**
PAT-111	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**

Figure 19. Camera trap photographs of individual tiger showing distinct stripe patterns.

opposed to any alternative model) showed a reasonable fit (?2 =15.156; df =14; P = 0.37), as did a similar test for Model Mb (?2 =24.143; df =19; P = 0.19). Because of sample size constraints, we could not test the fits of models Mt or Mh against model Mo. The test of the behavioural response did not provide evidence in support of model Mb (?2 =1.614; df =1; P = 0.20). Similarly, the test for time-specific variation in capture probabilities during the survey did not provide support for model Mt (?2 =3.597; df =14; P = 0.997). Further comparisons showed Mh was a more likely model than Mbh.

The overall model selection test in CAPTURE scored the various competing models as follows: Mo=1.00, Mh=0.91, Mb=0.53, Mbh=0.79, Mt=0.0, Mth=0.46, Mtb=0.49, Mtbh=0.78. Although the null model Mo ranked higher, the estimator based on this model is not robust to violations of the underlying assumption that capture probabilities do not vary among individual tigers. Tigers have a complex social organization consisting of resident breeders that maintain home ranges that overlap between the two sexes. Additionally, a proportion of the population consists of non-breeding 'floaters' that move back and forth across the home ranges of several resident tigers (Sunquist, 1981; Smith, 1993; Karanth & Sunquist, 2000). These spatial patterns as well as locations of traps in relation to tiger movements and home range boundaries were likely to cause capture probabilities to vary among individual tigers. Overall, considering both ecological factors and model comparison results, we selected Mh as the most likely model to represent the underlying capture-recapture process that generated the tiger capture histories reported in Table 9.

During the survey, 8 individual tigers were captured only once, one animal was caught twice, one animal thrice and one animal four times (Table 1). We used the jackknife estimator (Burnham & Overton, 1978; Otis et al., 1978) implemented in CAPTURE, which had given reasonably acceptable results in earlier photographic capture studies of tigers (Karanth, 1995; Karanth & Nichols, 1998).

Average capture probability per sample was estimated to be 0.0391 by using the Mh jackknife estimator and the corresponding population size estimate (was 29, (SE= 9.65). Thus, the overall probability of capturing a tiger was only 38%. Therefore, it was critically important for us to have used a population estimation method that took into account the fact that not all animals present in the study area would be detected (Nichols, 1992; Williams et al., 2002). The trap polygon encompassed an area of 222.1 km2 (Figure 18). The buffer width was estimated to be 2.94 km, which resulted in 418.14 km2 of effective sampled area estimating tiger density. Tiger density was calculated dividing the estimated population size by the effectively sampled area . The density estimated for the sampled area of the Panna Tiger Reserve study is 6.94 tigers/100 km2.

Discussion

Social organisation, Population and dispersal

The monitoring of seven radio-collared tigers generated information on population characteristics, social organization, survival and mortality. This amounts to over 41years monitoring of radio-collared tigers. If the observation and monitoring of other tigers and cubs is included, it amounts to an astonishing 95years of tiger monitoring.

The sex ratio of the 38 tigers that were identified positively with sex and age is almost equal to unity (Female19: 20 males). But the ratio of the breeding animals favoured the females, 3:1 as documented in other studies conducted in Nepal (Sunqiust, 1981 and Smith, 1984). Though the ratio is much smaller than that known from more productive habitats where one male can include up to seven female territories. In 2002, the tiger population in the intensively monitored area consisted of only 31% of breeding individuals, 51% of cubs and sub adults and rest of the 17% belonged to non territorial, non breeding adults.

Female tigers reach sexual maturity at two to three years in captivity. There are very few observations from the wild. In Chitwan, Sunquist (1981) observed that one radio-collared female came into heat at 30 months. In Panna, we had the opportunity to radio-collared three young tigresses at an early age and observed that the females gave birth to their first litter on average, at 39.8 months. Considering 100 to 105 days of gestation period it appears that they would come to heat at about 36 months. The earliest record, of 29 months from Panna, is close to what was observed in Chitwan by Sunquist (1981). This female dispersed earlier then her other two siblings and established her independent territory first. The other siblings and cubs produced litters once they settled permanently in an area. Therefore it appears that the time of the first litter is dependent on finding a space for establishing a territory of their own. The average litter size of 2.3 (cubs at the age of 2-12 weeks) is very close what is documented by other field studies in the subcontinent (Schaller,, 1967; Sunquist, 1981; Smith, 1984). Another litter is produced after an average period of 21.6 months. Observations from other studies document that this period varies considerably for different litters from the same animal and between different individuals; it can range anywhere between 18 to 30 months (Schaller, 1967; Sankhala, 1978; Sunquist, 1981; Smith, 1984). Surprisingly in Panna, it worked quite clock like. We observed that almost all the litters (13 out of 14 litters) were produced at 22 months' interval, except one which was produced early, within a 20 months gap. This suggests that females come to oestrous when the previous litter is about 18-19 months old and weaned but not entirely independent; at this age they are capable of making their own kills but continue to share kills with the mother. Observations from captivity suggest a gestation period of 100 to 110 days. Based on the observation of twelve births and mating average gestation period in Panna is 103 days; this is very similar to what is the reported period in captivity and from other field observations. Mating was seen throughout the year; a casual observation may suggest peaks during winter and monsoon months but our field observations suggest different reasons for the oestrous cycle. It appears mainly due to the almost fixed cycle of oestrous and birth that was observed in Panna. In this case it appears that the birth of first litter was the determining factor and the subsequent mating and birth of a new litter shifted accordingly by two to three months (early).

In this study we were able to monitor and observe only four dispersals. All female tigers were radio-collared and established their territory at the adjoining vacant spaces and in one case by displacing an old established female. We did not see any evidence of male cubs establishing a territory in the area. But we saw them mating with territorial females which were part of their father's territory after he had lost its control over the area and it was occupied by a new dominant male.

Estimation of tiger population

The results obtained from photographic capture and recapture method are similar to the estimation based on the radio-telemetry study. This method which has been used successfully in many different habitat types (Karanth & Nichols, 1998; 2002) provides a suitable alternative and reliable method for estimating tiger population over the conventional pug mark based total counts. But it requires careful design and planning to address the issues of spatial sampling and observability (Thompson et al., 1998; Williams et al., 2002).

The estimated tiger density of 6.94 animals/ 100 km2 in Panna is also reasonably high despite high anthropogenic pressures and poor ecological conditions that exist in a Dry Tropical Forest. These results only indicate the potential of such tiger habitats in tiger conservation, especially in Tropical Dry forests which are the largest tiger habitat in the country. Tigers in Panna avoid using the dry, open forests that form a large proportion of their home ranges, because of water-scarcity and lack of shade for thermo regulation although these areas appear to support adequate prey densities (R. S. Chundawat, unpubl. data). Therefore, it initially appeared that high prey densities might not translate into high prey availability for tigers, suggesting that tiger densities may be below potential limits set by prey abundance. However, assuming that tigers crop about 10% of standing prey numbers annually (Schaller, 1967; Sunquist, 1981; K. U. Karanth, unpubl. data), the estimated tiger density of 6.94 tigers/100 km2 for Panna is close to the predicted density of 6.18 tigers/ 100 km2. Therefore, we propose that increased prey vulnerability and seasonal variations in prey selection behaviour, may enable tigers to achieve higher prey-cropping rates during summer in Panna, despite not fully utilizing their home ranges.

TIGER-II: Home range, movement and activity pattern and habitat use

To understand the ecology of an animal and its response to the environment, it is important to study its population characteristics and ranging pattern, including its home range size, shape and utilization pattern. It provides information about spatio-temporal use of its home range over time and season (Harris et al, 1990).

Many authors have tried to define and refine the concept of home range (Burt, 1943; Mohr, 1947; Baker, 1978; Dixon and Chapman, 1980; Anderson, 1982; Worton, 1989). No animal roams at random in an area and each individual has a home region, where it operates (Seton, 1909); the size of home region varies from species to species. In other words, home range/ territory can be defined as the area which an animal uses to carry out its normal activities and which fulfils its energy requirement (Burt 1943; Jewell, 1966; Brown, 1975; Harris et al. 1990).

However, territory is an exclusive use area fully defended by the dominant individual, whereas the home range may be shared either in part or completely. The animal may use the area evenly; its use dependant on the ecological characteristics of the area ? availability and dispersion of its resources, such food, cover and water. The animal may not patrol 100% of its territory regularly; there could be some areas, which it may visit in?frequently (check with original that I have interpreted correctly uncertain). The importance of such activity centres (Smith, 1990) is of significant importance for the management of tiger population as the reproductive success, abundance and viability of a population is largely dependent on these critical habitats/resources.

The size of the home range varies from species to species and it is dependent on body size (McNab 1963, Harestad and Bunnell 1979), guild and availability and dispersal of key resources such as food, water and cover (Seton, 1929; Smith, 1990). The home range sizes of tiger and resulting densities are directly related to the habitat quality (availability of prey and cover). In prime habitats, which contains high abundance and variety of ungulate prey base, the home range of a female tiger may be only 20 km2, or even less (Sunquist, 1981; Smith, 1993;

Karanth and Sunquist, 2000). In the Russian Far East, where the resources are very seasonal, prey availability is low and unevenly distributed, a female may require around 250 to over 400 km2 area to fulfil her requirement (Miquelle, et al., 1999).

Chemical Immobilization and Radio-Collaring of tigers:

Like most other cats, the tiger is also an elusive animal, and therefore, it is not always possible to see it. This makes it very difficult to study wild free-ranging tigers. To collect ecological information in a systematic and un-biased manner one needs to find a tiger at will and this can only be achieved with the help of a radio-collar. A total of 7 tigers were chemically immobilized and captured for the purpose of radio-collaring.

Chemical Capture

The radio collaring of tigers was mostly carried out in the winter season to avoid the problem of hyperthermia (rise in body temperature due to the effect of drugs). Attempts were made to locate the tigers on kills. Whenever the bait was killed, the area was scanned from elephant back to locate the tiger. Once the tiger was located, the body weight was estimated and darts were prepared on the spot by the veterinary doctors. To get the desired sedation, a combination of Medetomidine (0.05 mg/kg body weight) with Ketamine hydrochloride (3.5 mg/kg body weight) was used. Telinject equipment and pressure syringes were used for darting. Tigers were darted from elephant back at a distance of about 20-25m. Before darting two to three persons were placed on nearby tall trees to keep a close watch on the tiger's movement after darting. However, after darting, the tigers did not move much and walked only 40-50m distance, or less, before becoming sedated.

After confirming that the animal was fully sedated, it was approached carefully and radio-collared. Information on other parameters such as body morphometry, its load of ecto-parasites and its general health condition were recorded. During the operation, a veterinary doctor constantly monitored the tiger. The entire operation was carried out in the presence of three veterinary experts and finished within 20-25 minutes. The animal was revived with an antidote, Antisedan, a specific antagonist for Medetomidine. Details of the radio-collared tigers are given in Table

Radio Tracking:

For this study, we are using activity radio-collars, which are manufactured by Telonics Inc. Arizona. The frequency of these collars ranges between 150.00 MHz and 151.00 MHz. The approximate life of these collars is about 36 months and they weigh around 450 gm. With movement of the tiger's neck, the pulse rate of signals changes.

The radio-collared tigers were tracked with the help of directional H-antenna, Yagi antenna and a portable receiver. It was observed that the ground to ground range of the radio collars was around 1.5 to 2.0 km. However, in case of an elevated vantage point the range went up 6.0 km. Therefore, hillocks, watch towers and other elevated places in the field that received the signals efficiently were identified and marked as permanent vantage points. Apart from this, the existing roads were also marked at every 500m to prepare standard reference points. Co-ordinates of such reference points were obtained using GPS. Apart from these points, several other miscellaneous points were generated, whenever required.

The radio-collared tigers were tracked from elephant back, vehicle and at times on foot. To record unbiased information, without disturbing the radio-collared animals, a minimum distance of 300 to 400m was maintained. Triangulation (Tester and Sniff 1957, Heezen and Tester 1967 & Springer 1979) and homing technique (Mech, 1983) were used to locate the animals. To get better results with minimum error polygon, 4-5 bearings were taken from known reference points using the directional antenna and a hand held compass.

To obtain the locations (fixes) of the collared animals, these bearings and values of standard reference points were plotted by using a computer program 'LOAS'. In case of homing, the locations were directly obtained by using Geographical Positioning System (GPS). The study area maps were digitized by using GRASS 4.1 software and later analysed with the help of ARCHINFO. The locations were then plotted on a 1:50,000 scale Survey of India topo-sheets. Home ranges of each tiger were calculated by using "Minimum Convex Polygon" (MCP) method of Mohr (1947). In this method the outer most locations are connected to make a polygon and the area of this polygon gives the size of a home range. To find out the core areas (areas more frequently used) of the home range, 55% contour of harmonic mean method (HM) (Dixon and Chapman, 1980) was used.

Asymptotes for a number of locations at annual and different seasons were obtained to check the adequateness of sample size.

Movement Pattern:

To study the activity and movement pattern of tigers over a period of 24 hours, they were radio-tracked continuously. This tracking also gave information on the distribution of locations in different time zones. Since, radio-tracking tigers for a continuous stretch of 24 hrs was tiresome, the cycle was divided into 4 phases, each phase comprising of a minimum 6 hours. During such tracking phases, the activity (at every 10 minutes) and movement pattern (at every half an hour) of tigers were recorded.

The information gathered was plotted on the topographic sheets to study the movement and activity pattern. The seasonal variation in activity and movement patterns for male and female was studied.

Results

Sample size for estimating home ranges

The cumulative home range of radio-collared tigers is calculated by pooling ten successive radio-locations. This exercise is done to determine the minimum number of locations required to estimate a home range size. It is estimated that home ranges of all radio-collared tigers reached its peak at around 50 locations. In the case of female tigers, the minimum number of locations required to estimate a home range size is between 40 and 50 locations but in the case of male tigers, it is between 50 and 60 locations (Figure XX). At the rate of three to four locations a week, a minimum of five to six months of monitoring is essential to estimate a reliable home range size. During this study, every year over 120 locations were obtained for each of the radio-collared tigers. Therefore, home range calculations in this study provide a very reliable estimate.

Home range

The radio-collared tigers were monitored on a regular schedule as described in the methods. Home ranges are estimated using the software programmes "BIOTAS" and "LOAS" (XXXXX). Although information on the activity and movement patterns for all the radio-collared animals is recorded, the data is not included in this report. During the course of the study, seven tigers were radio-collared but only six of them were monitored for more than six months and information on these animals are discussed in detail in this report. These animals include four females and two males; details of the radio-tracking is provided in table 10a. The first animal that was radio collared was a sub-adult female, which died within five months of tracking due to unknown causes. Male tiger-91 was the second tiger radio-collared in the study followed by Tigress-118. Her three daughters from the same litter were subsequently collared and were monitored for several years. In this report data from 1997 to 2002 is used for describing home range and movement patterns.

Annual home ranges

The annual home ranges of males were four and half to five times larger than female ranges. The average annual range calculated for male tigers is 184 km2. The area of most activity (80%), which can be defined as the core area, on average remained limited to less than 20% of the average annual home range. This remained more or less consistent throughout the study period in both the males, despite considerable variation seen in the annual home range sizes in different years. Average annual home range of females is estimated to be 42.16 km2, which ranged between 24 km2 and 83.6 km2. The core area, which represents 80 % of their activities, remained consistently on average within 20% of the annual home range. The home ranges during the full monitoring period is considerably larger then the average annual home range (Table 10). The average home range size for the study period

Figure 20a. Estimation of minimum nuber of radio location required to estimate a reliable home range size for different radio-collared tigers.

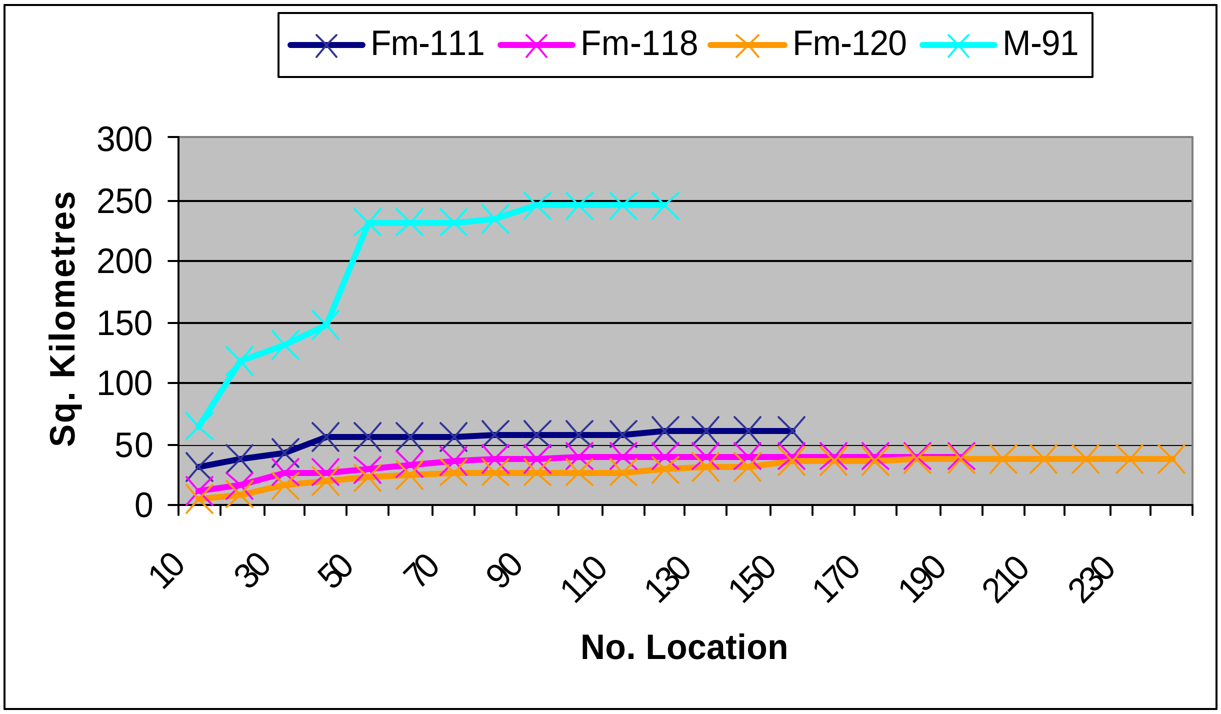


Table 10a. Date of capture, age at the time of callaring and duration of radio-tracking of radio-collared tigers

Tiger No.	Capture Date	Age at the time of collaring	Weight (Kg.)	Tracking Period (In Months)
Fm01	09-04-1996	Sub-adult		Six months
Fm-118/123	27-01-1997 to Nov. 1997 26-01-2001 and 10-1-2002	50-55 months	120	30 months
Fm-111	26-03-1998 and 22-12-2000	24 months	108	52 months
Fm-120	07-01-1999 and 27-01-2001	34 months	115	42 months
M-91	11-04-1996 and Oct. 1998	72-80 months	240	53 months
Fm-113	21-12-2000	56 months		22 months
M-125	12-01-2002-	96 –100 months	220-230	24 months

Table 10. Over all and annual home ranges of radio-collared tigers in PNP.

Radio-collared Tigers	Minimum Convex Polygon	Harmonic Mean	% use
Male-91			
Total 1996-2001	290.0	68.3	23.5
1996.0	252.2	54.8	21.7
1997.0	257.0	64.6	25.1
1998.0	184.1	43.8	23.8
1999.0	137.1	27.9	20.3
2000.0	91.0		0.0
Male-125	210.0	28.6	13.6
Males- Annual average	188.6	36.6	19.4
Female-118			
1997.0	41.0	13.5	32.8
Total 2000-02	40.6	13.9	34.2
2000-01	37.5	8.2	21.8
2001-02	32.3	9.2	28.4
Annual average	34.9	8.7	24.9
Female-111			
Total 1999-2002	53.0	16.6	31.4
1998.0	60.9	12.3	20.2
1999.0	34.9	4.6	13.3
2000.0	50.5	13.7	27.0
2001.0	26.3	3.6	13.7
2002.0	26.2	4.7	17.8
Annual average	39.8	6.6	16.7
Female-120			
Total 1999-2002	54.2	16.9	31.2
1999.0	38.8	12.5	32.3
2000.0	36.7	9.8	26.7
2001.0	45.3	12.8	28.3
2002.0	39.9	6.7	16.7
Annual average	40.2	10.4	26.0
Femlale-113			
Total 2001-02	83.6	16.4	19.6
2001.0	83.6	22.6	27.0
2002.0	24.0	3.6	15.0
Annual average	53.8	13.1	24.3

Table 11. Seasonal home ranges of the radio-collared tigers in PNP.

Tiger IDs	Yearly	Monsoon	% of annual	Summer	% of annual	Winter	% of annual
M-91							
2000.0	91.0	45.3	49.8	61.9	68.1	63.4	69.7
1999.0	137.0	106.2	77.5	98.2	71.7	76.7	56.0
1998.0	184.0	74.0	40.2	177.1	96.2	68.9	37.4
1997.0	252.0	45.9	18.2	167.2	66.3	73.6	29.2
1996.0	256.0	102.0	39.8	118.5	46.3	212.1	82.9
M-125-2002	210.0						
average	184.0	74.7	45.1	124.6	69.7	98.9	55.0
Females	Yearly	Monsoon	%	Summer	%	Winter	%
F-111							
1998	60.9	31.5	51.8	16.7	27.4	12.5	20.5
1999	34.9	27.6	79.0	20.5	58.7	9.3	26.6
2000	50.5	41.1	81.3	17.6	34.8	30.8	61.0
2001	26.3	6.4	24.4	9.5	36.1	10.0	38.0
2002	26.2	18.6	71.0	12.9	49.2	23.3	88.9
average	39.8	25.0	61.5	15.4	41.3	17.2	47.0
F-113							
2001	83.6	63.3	75.8	31.8	38.1	49.1	58.8
2002	24.0	5.3	21.9	8.8	36.7	19.3	80.3
average	53.8	34.3	48.8	20.3	37.4	34.2	69.5
F-118							
1997	41.0	22.3	54.4	32.3	78.8	35.1	85.6
2001	37.5	20.1	53.7	31.3	83.6	22.1	59.0
2002	32.3	25.7	79.5	15.8	48.9	23.9	74.0
average	36.9	22.7	62.5	26.5	70.4	27.0	72.9
F-120							
1999	38.8	32.3	83.2	15.3	39.3	34.8	89.7
2000	36.7	31.5	85.8	20.1	54.7	24.1	65.6
2001	45.3	37.3	82.3	19.2	42.4	29.6	65.5
2002	39.9	25.1	62.8	8.1	20.3	34.9	87.5
average	40.2	31.5	78.5	15.7	39.2	30.9	77.1
Female averages	42.7	28.4	62.8	35.5	47.1	27.3	66.6

for female is 57.85 km2 and for males it is 210 km2.

Seasonal home ranges

On average seasonal home ranges are small and represented 40-65 % of the annual home ranges. No clear seasonal trend in home range size is observed in radio collared tigers of the Tiger Reserve. Seasonal ranges, however, changed considerably in size over the years. For detail see table 11.

Monitoring Radio-collared Tigers

Female-118

Tigress '118' was radio-collared in January 1997 (table-10a) and was monitored for eleven months. Her collared stopped functioning in November 1997. The last location obtained from that collar was on 29th November 1997. The research team was able to monitor her without her collar, but in a limited way. Several attempts were made to replace her old collar but her non-functional collar was replaced only in February 2000. In December 2000, while dragging a sambar kill, this collar broke off. She was radio-collared for the third time within a month, in January 2002. Her last location was recorded during March 2005 after 38 months of monitoring by the radio-collar. The female-118 was raising a litter of three 7-8 month-old female cubs, at the time she was collared for the first time. Unfortunately the radio-collar malfunctioned after eleven months. The research team continued to monitor her movements and other activities, though intermittently, till she was radio collared once again. Later the research team was able to radio-tag all the three female cubs of her first litter after they became independent and had established their own territories. In the in-between period of the first and second collaring, Female-118 had a second litter of two male cubs, which, like her first litter, survived to adulthood and dispersed. At the time of the second radio-collaring she was raising her third litter of three cubs comprising of two males and one female. Her third litter also survived to adulthood and dispersed. She gave birth to a fourth litter comprised of two males and one female.

Animal	Mean Distance km (SE)	Std. Dev.
F-123		
Monsoon	1.74 ± 0.36	1.089 km
Summer	1.65 ± 0.286	0.905 km
Winter	1.71 ± 0.52	1.169 km
Annual	1.7 ± 0.026	0.045 km
F-111		
Monsoon	2.09 ± 0.65	1.462 km
Summer	1.53 ± 0.47	0.947 km
Winter	1.58 ± 0.44	0.887 km
Annual	1.73 ± 0.17	0.309 km
F-120		
Monsoon	2.38 ± 1.00	2.232 km
Summer	1.92 ± 0.50	0.871 km
Winter	2.04 ± 0.14	0.257 km
Annual	2.11 ± 0.13	0.238 km
M-91		
Monsoon	3.85 ± 0.49	2.203 km
Summer	4.74 ± 0.74	3.664 km
Winter	4.53 ± 0.48	2.296 km
Annual	4.37 ± 0.26 k	0.465 km

Table 11. Average distance travelled by radio-collared tigers in 24 hours.

Female-118 occupies an undisturbed high prey density habitat in the core area of the Park. The estimated home range for 2000 to 2002 (MCP 100%) is 40.6 km2 with the core area 13.9 km2 - where she spends over 80% of the time; this represents only 34% of the range. Her range overlapped with that of her daughters, female-111, female-120 and female-113 (Figure 20). However, we did not see any association with her daughters after they became independent and established their territories. Soon overlap with the daughters' territories reduced considerably. Female-118 had a larger home range prior to her first litter establishing their territories. Subsequently part of her range was taken over by her daughters and as a result her range reduced by approximately 20%. Her annual home range size is 34.9 km2 and 80% of her activity is limited to 25% of the annual home range. Home ranges changed with the season and also over the years (see Table-11 for details). Her monsoon ranges (22.7 km2) are smaller than her summer (26.5 km2) and winter (27 km2) ones. Seasonal home ranges of tigress-118 only account for 60 to 70 % of the annual home ranges (Figure 30).

Female-111

Female-111 is one of the three siblings of the first litter of female-118. She was first radio-collared in April 1998, when she was in the process of dispersing. Initially she used part of the mother's territory frequently and stayed there for several months before establishing her own territory on the upper Talgaon plateau. After 6-7 months of several forays into the surrounding areas, she established her own territory in an adjoining area immediately southeast of her mother with some overlap. Her territory extended beyond the Park boundary by three to four kilometres into the neighbouring territorial forests of South Panna Forest Division. She 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 comprised of three cubs but the research team was not able to identify the sex of these cubs. Female-111 occupied an area close to the periphery of the Tiger Reserve and her territory included areas close to several villages situated inside and at the periphery of the Reserve. The research team lost contact with her in September 2002. Her last locations were on a cattle kill and she disappeared mysteriously after feeding for a couple days on the kill. The research team made attempts to confirm her presence by placing camera traps in the area and monitoring her frequently used areas but failed to find any evidence even after three months of intensive monitoring. Later, after six months, this empty territory was occupied by another tigress, who was seen mating with the male tiger-125 and photographed. This confirmed that tigress-111 had most likely died due to unknown causes, but from circumstantial evidence and because she disappeared from a cattle kill, it is reasonable to assume that it is possible that she was victim of human caused mortality.

She was radio-tracked for fifty four months (4.5 years). Female-111 patrolled a large area of 53 km2 (100% MCP)and most of her activity (80% HM) was restricted within 31% of her range on the upper Talgaon plateau (Table 10). The area used by her has low prey abundance but very high cattle presence and most of her kills were of cattle. Moreover, during the hot summer months, when there is no water available within her territory on the upper plateau inside the Tiger Reserve, she either has to come to the base of the escarpments on the Hinauta plateau in search of cool resting-places and water or has to visit a water hole more then 3 km outside the Reserve boundary (Figure 22). In this area she regularly killed livestock. This brought her into direct conflict with local human populations, whenever she killed livestock in this unprotected forest habitat. Her average annual home range size calculated is 39.8 km2. This highlights the fact though she used part her home range over the years but her annual range and centre of activity changed over the years (Table 11). That is reflected in her small centre of activity (6.6 km2) representing only 16.7% of the annual range on average. In contrast to tigress-118, female-111's monsoon home range was larger (25 km2) than her summer (15.4 km2) and winter (17.2 km2) ones. Seasonal ranges represent 40 to 60 % of the annual ranges (Figure 29).

Female-120

Female-120 was radio-collared in January 1999, when she was approximately 32 months old. She had established her territory in the area west of her mother's territory, which she occupied by displacing an old territorial female from the area (Figure 25). She was able to displace the territorial female with the help of her third sibling (female-113), 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 accompanied by her sibling and remained in association with her for another couple of months after radio collaring. She gave birth to her first litter at the age of around 42 months in December 1999. This litter comprised of two cubs, one male and one female. These cubs grew to adulthood and dispersed successfully. She gave birth to her third litter in 2000. During this time the dominant male-91 was replaced by another male tiger we called 'Hairy foot'. Her movements were different from her previous year and she never brought her litter to her core area for any duration; this area was frequented regularly by 'Hairy foot'. She was constantly on the move and her behaviour indicated stress. We last saw her litter in December 2001. She gave birth to a third litter in March 2002, which confirmed our doubts that 'Hairy foot' had killed her second litter, fathered by male-91. What was interesting was that female-120 apparently came into oestrus and mated successfully when her second litter were still alive. This is the first record from the wild of a female coming into oestrus while raising a litter and giving birth to a new litter within 100 days of losing the litter to infanticide. 'Hairy foot' was seen on several occasions visiting the litter site and spent several hours with the female within a few metres of weeks-old cubs at regular intervals. Unfortunately, 'Hairy foot' did not survive long and was found dead in mysterious circumstances in a well inside the Reserve. Within a few months, this exposed the female-120 yet again to another male tiger who had not fathered her cubs. She once again left her core area and moved into an area away from the new male's activity. This area, at the periphery of park, suffers from intense human pressure. One tiger was poached in this area in the early nineties, well before the project began. Female-120 succumbed to the same fate as the earlier tiger and was found dead in a snare. At the time of her death, her two cubs were almost nine months old.

Like her mother, she also occupied a prey-rich, undisturbed forest habitat on the middle plateau. But her range extended up to the Park boundary and included areas adjoining the territorial forest and villages at the southern periphery of the Park. She was not as successful as her mother and other siblings as she was exposed to a frequent change-over of males in the area, which coincided with litters fathered by previous males.

She was radio tracked for 35 months; during this period she ranged over an area of 54.2 km2 (MCP 100%). Most of her activity was restricted to small areas of 16.9 km2, which represent about 31% of the total range (Table 10). Her average home range size is calculated as 40.2 km2 and its centre of activity (80% HM) is limited to 10 km2 only. Seasonal ranges are small but her monsoon and winter ranges are relatively large and represent over 70% of the annual ranges. Summer range is smallest approximately 40% of the average annual range (Figure 27).

Female-113

The third daughter of female-118, was radio-collared in December 2000. Like her other two siblings (F-111 and F-120), she also had established a territory in an area adjoining the mother's territory and partially occupying female 118's range. Her territory was to the north of her mother's, female-118's range (Figure 23). At the time of her collaring in December 2000, she was also raising a litter of two cubs, one male and a female, 15-16 months old. She occupied an area on either side of the River Ken but most of her range included areas south of the river and in the tourism zone. Her range also extended up to the periphery of the Reserve north of the Ken river. Her collar was removed in 2002 because of disturbance created by heavy pressure from tiger shows that occurred almost every day for several hours during the peak tourist season. She later disappeared in 2004 and was last seen in December 2003. She had raised two litters to adulthood, which dispersed successfully.

She covered a large territory of 83 km2 (MCP 100%) but spent most of her time in a much smaller core area of 16.4 km2 (Harmonic mean 80%) which is of similar in size to that estimated for her other siblings? but not female-118; Table 11. Her range reduced to 24 km2 during the second year with a core area of only 3.6 km2. She occupied a very narrow belt of tiger habitat along the river Ken. Her seasonal range size changed considerably across the seasons and over the years too. On average, the winter ranges showed the largest area patrolled by the tigress, representing almost 69% of the annual range; this was followed by that of the monsoon range of 48.8% (Figure 28).

Male-91

The male-91 was radio-collared in April 1996; its first collar was replaced in October 1998. His second collar continued to give signal for the next two years and finally stopped functioning in October 2000. At its peak, male-91's range covered an area of 290 km2, which is more then 50% of the entire Park area (table 11). At the early stages of monitoring, in 1996 and 1997, this enormous range included only two female territories female-118 and the other, Bargad,i female, who was later ousted by female-120. Later, between 1998 and 2000, his territory included 118's daughters, female-120 and female-111 but he lost part of his range to male-125; this part included the territory of the third sibling, female-113. This occurred after a serious fight that took place in September 1998. With female-118, 111 and 120 he fathered six litters and two from the Bargadi female. These eight litters amount to seventeen cubs, of which thirteen survived to adulthood in the five and a half years when he remained as dominant male in the area. Over the years he has lost a considerable part of his territory to other males, 125 and 'Hairy foot', after several battles. His territorial behaviour has been discussed in detail in earlier reports and publications (Chundawat et al, 1999). After these territorial fights his range was reduced to a mere 91 km2 and only partially covered the territories of the three females he once dominated (Figure 21).

His annual range gradually declined from over 250 km2 to 91 km2 at the end of his tenure a dominant male of the area.

Male-125

The tiger, male-125 was radio-collared in January 2002; therefore only information from the first year is discussed in this report. Male-125 first appeared in mid 1998 in the Madla area and later he was seen fighting with Male-91. This battle resulted in some very serious injuries to M-91. As a result, male-125 took over a large part of male-91's area. Over the next few years, male 125 extended his range across all three plateaux, covering an area from Billiya Seha to areas adjoining Rampura. His territory included three females' territories and one of them, female-113, was radio-collared. The other two were a female on the upper plateau, in the area between Jardhoba and Rampura village known as the 'Amdar female' and one that occupied a range around the Gata area and known to us as the 'Gata female'.

After the death of 'Hairy foot' male-125 partially moved into 'Hairy foot's territory, but after mating with female-113 for the third time in 2003 he left the area and remained exclusively on the upper Talgaon and Hinauta plateaux. A younger male, 'Broken tooth' was seen in the area and soon after male-125 left the area, this young male also mated with female-113, which unusually continued for several weeks. In 2003 and 2004, their activities became somewhat complicated: male-125 returned to patrol the area in 2004 and 'Broken tooth' left it and was seen later patrolling the majority of the territory once used by 'Hairy foot'. Female-113 disappeared and her mother, female-118, extended her range and re-occupied part of this vacant space; this was after six years and beyond her original territory. Her doin g this further confirmed the loss of female-113 from the area. In this area male-125 was seen frequently in association with female-118. This was the first time since we knew these individuals that they were seen together.

Male-125 occupied a fairly large territory of 210 km^2 in the year 2002. Most of his activity remained within 20% of his annual range, which is similar to that of male-91 (Figure 26).

Movement Pattern

The average daily distance travelled by female tigers is 1.84 km, The distance is calculated as the distance between two locations on successive days and these were taken 24 hours apart. This information only provides an approximate index of movement by the radio-collared animals but does not provide information on the actual distances covered by the animals. Actual distances travelled by the animals in a 24-hour period are much larger than the distances calculated in a straight line

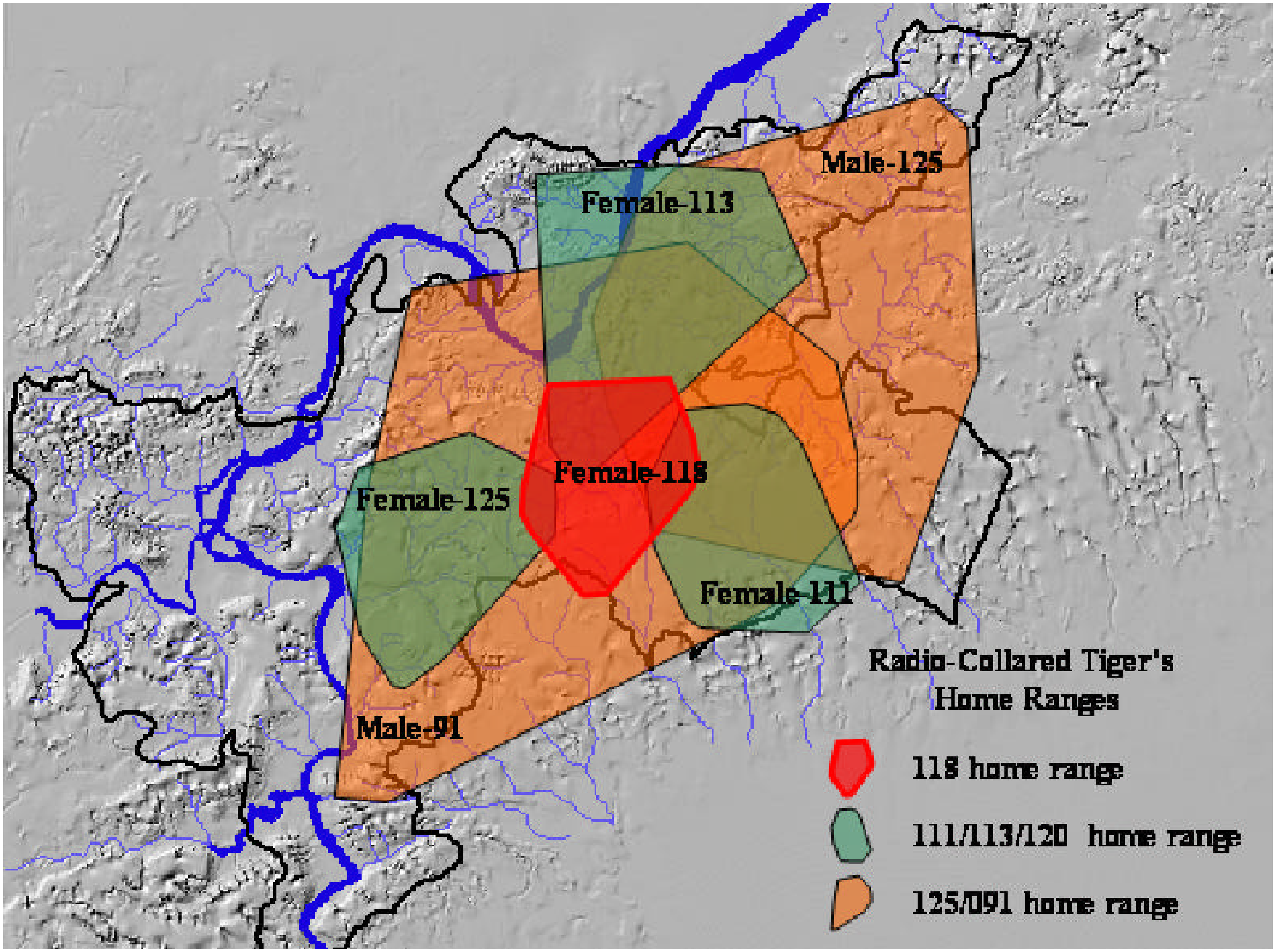


Figure 20. Home ranges of radio-collared tigers in Panna National Park.

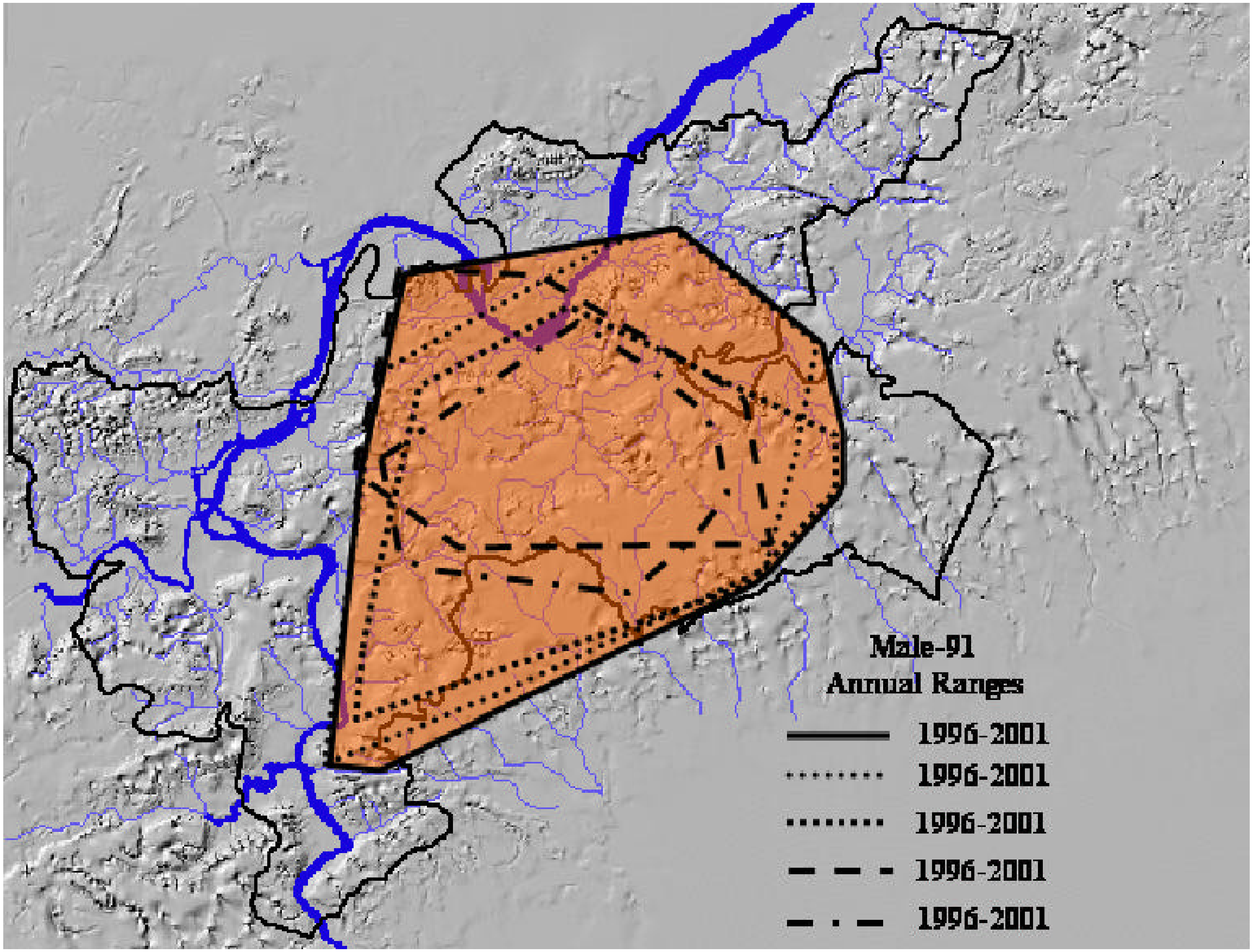


Figure 21.nnual hHome ranges of male-091 radio-collared tiger in Panna National Park.

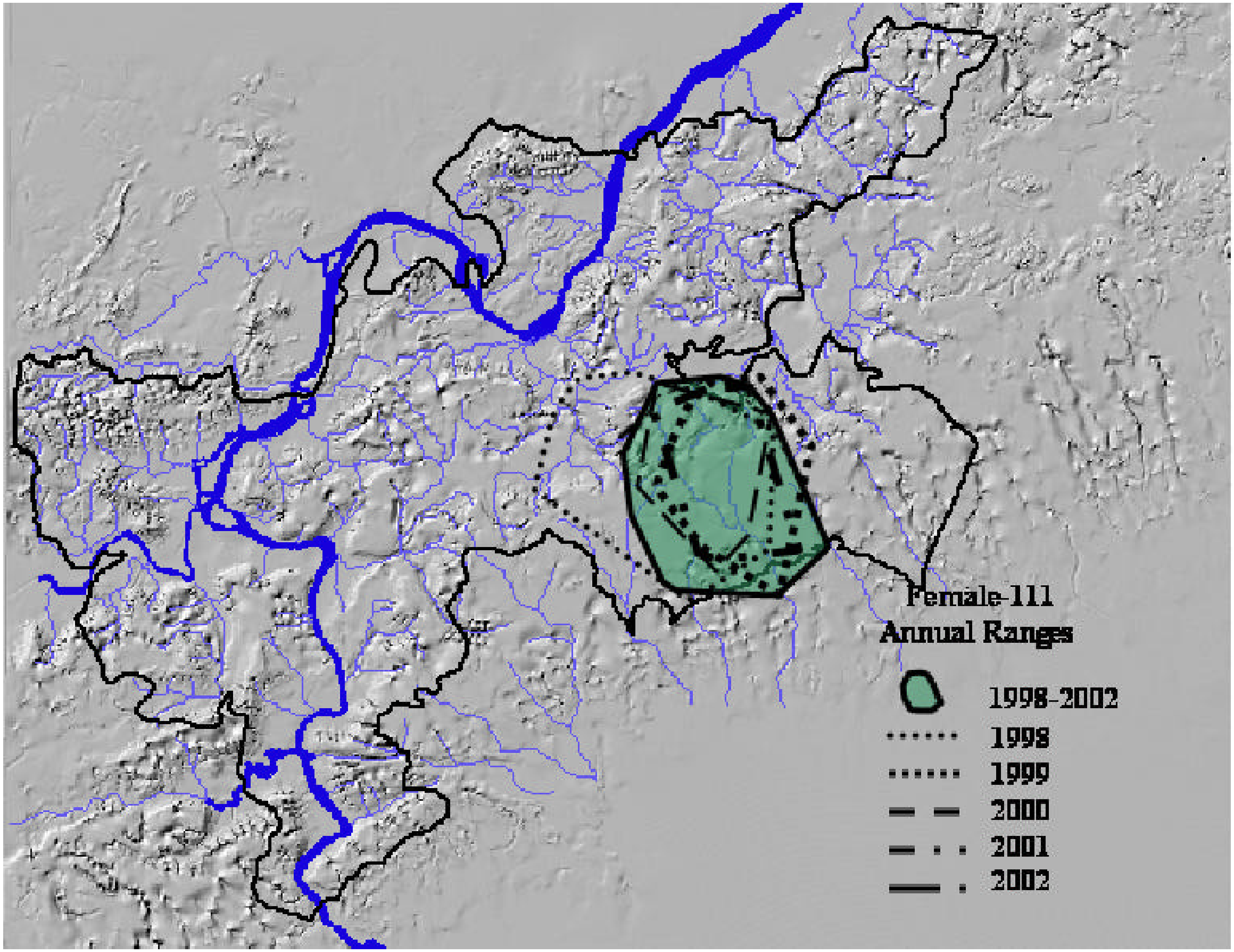


Figure 22. Annual home ranges of radio-collared tiger female-111 in Panna National Park.

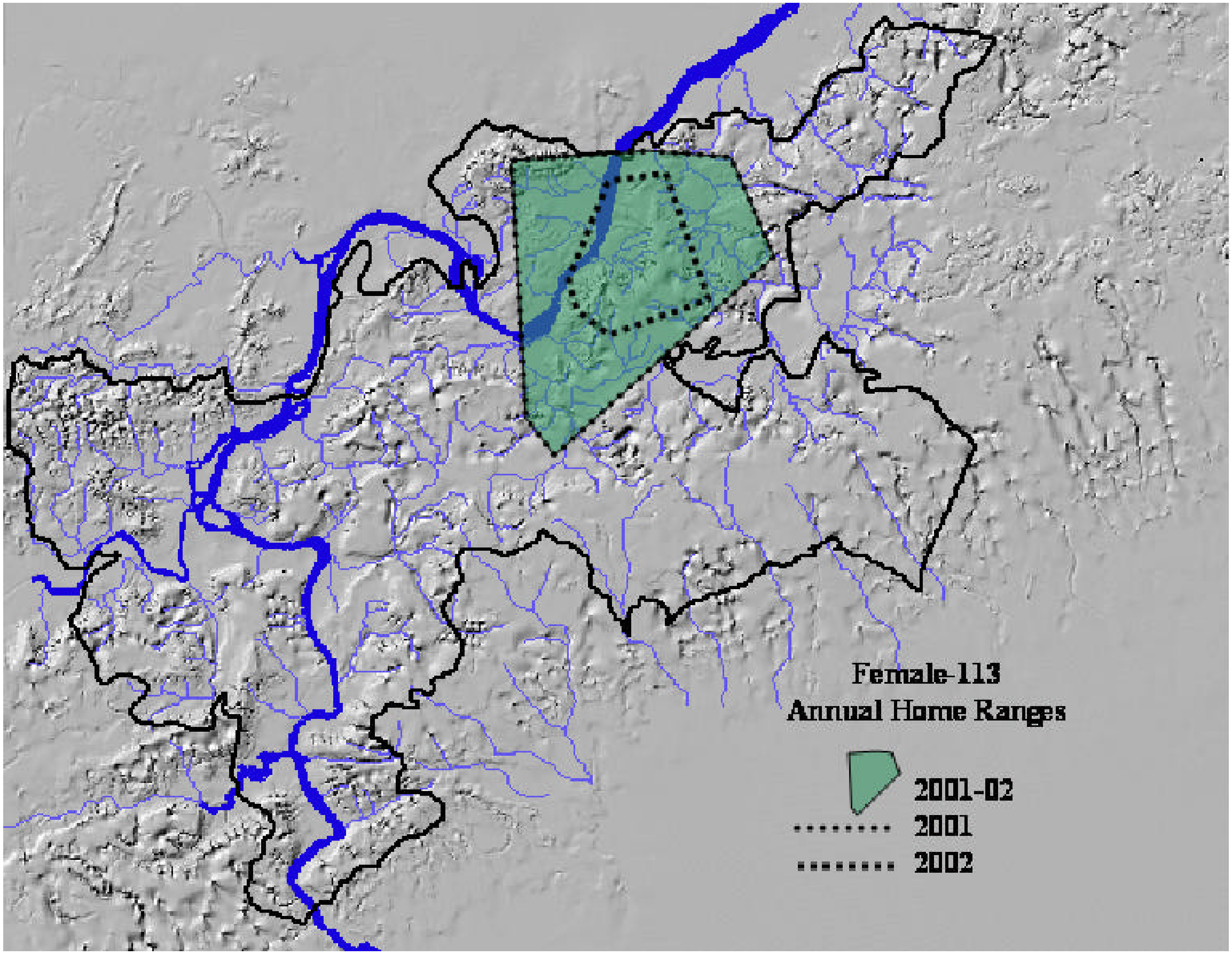


Figure 23. Annual home ranges of radio-collared tiger female-113 in Panna National Park.

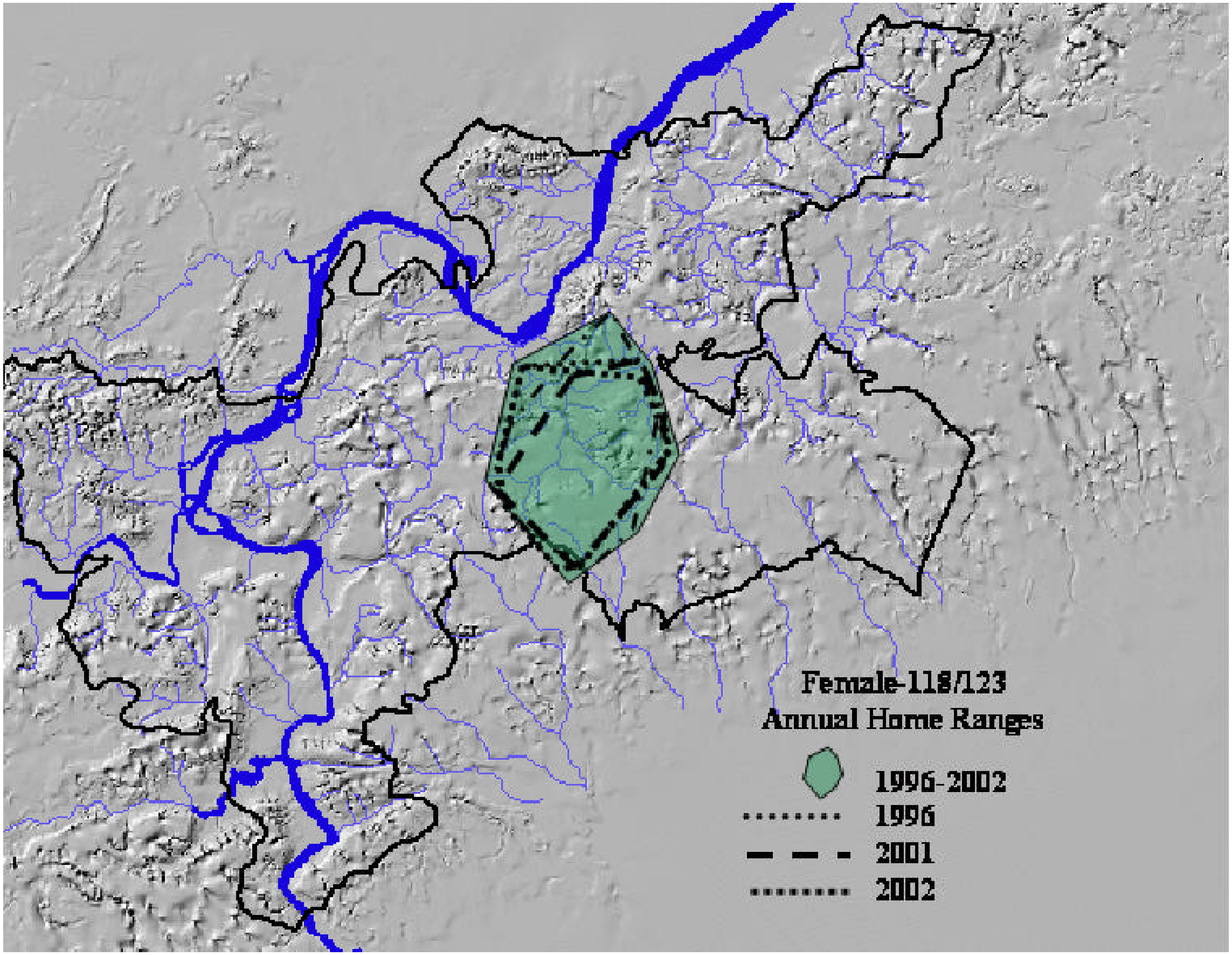


Figure 24. Annual home ranges of radio-collared tiger female-118/13 in Panna National Park.

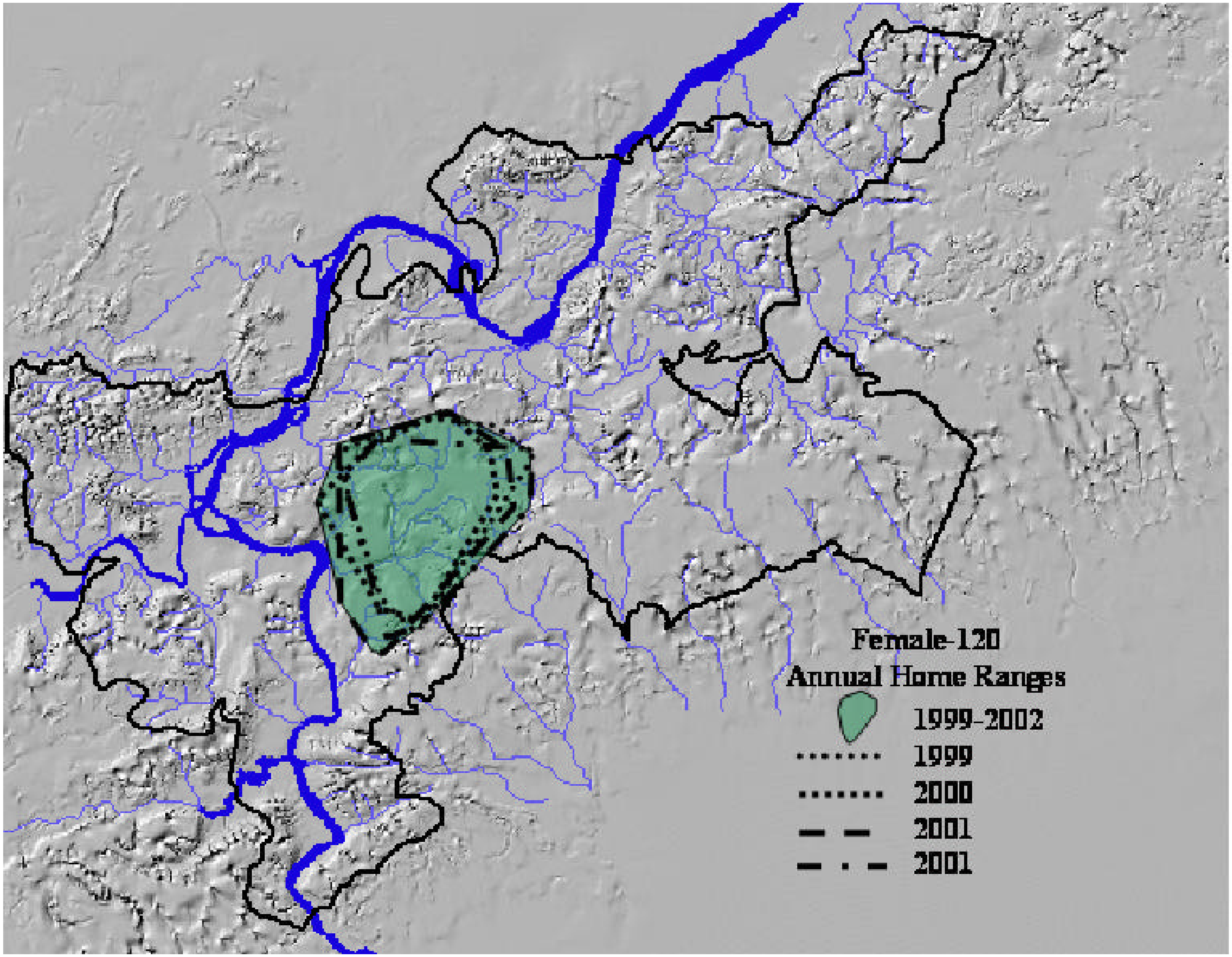


Figure 25. Annual home ranges of radio-collared tiger female-120 in Panna National Park.

Figure 25. Seasonal home ranges of radio-collared tiger male-0091 in Panna National Park.

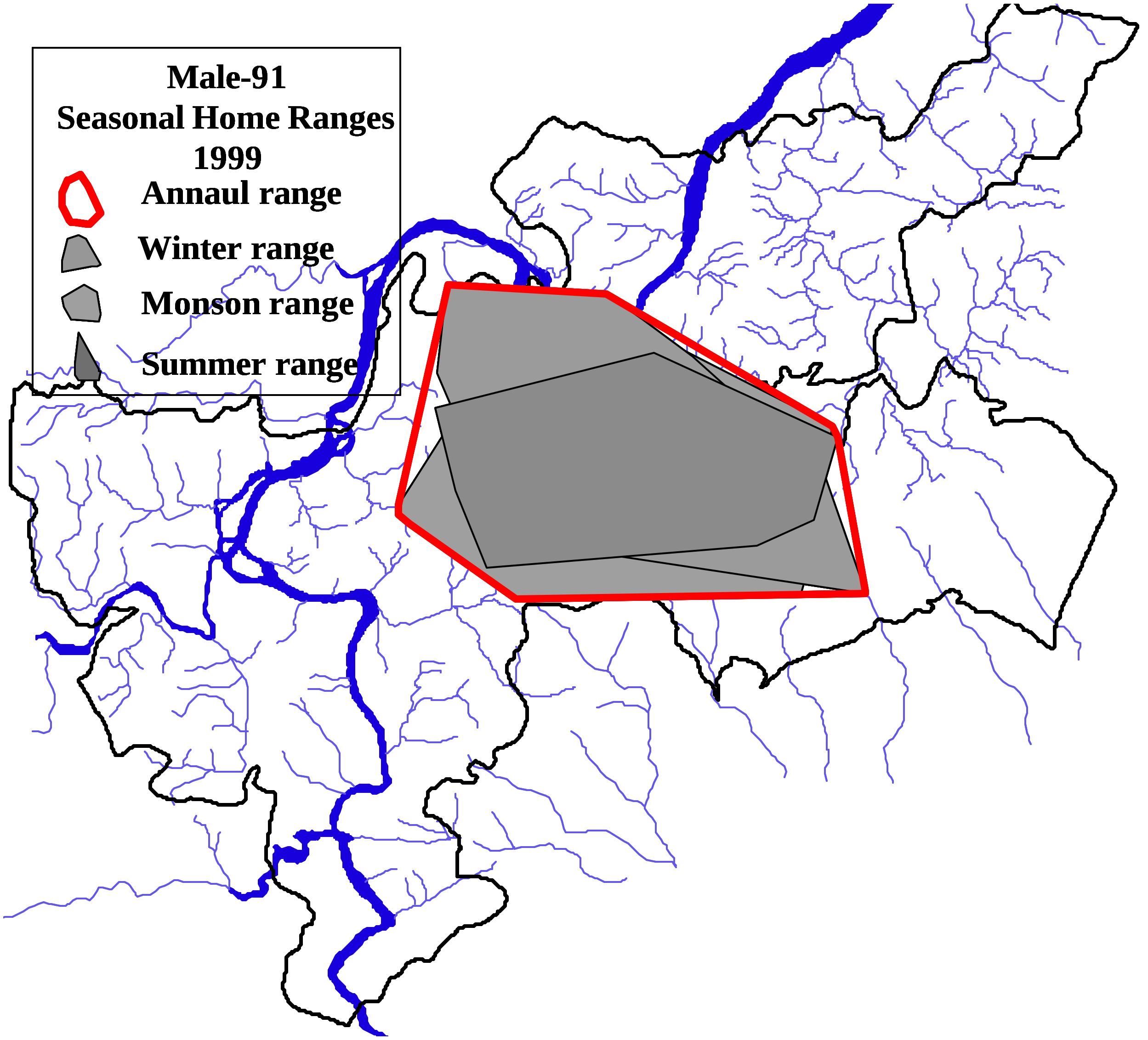


Figure 26. Seasonal home ranges of radio-collared tiger male-125 in Panna National Park.

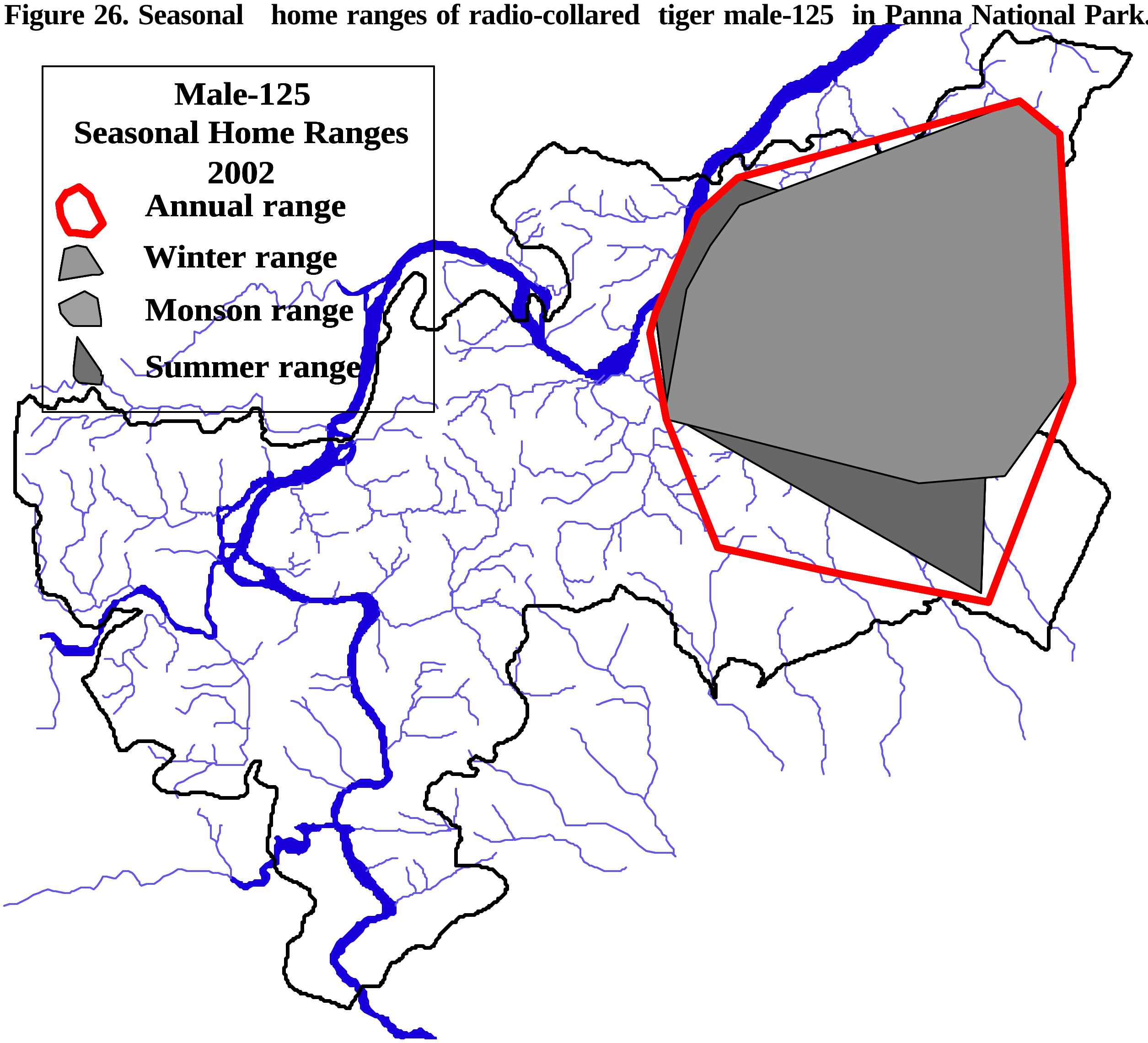


Figure 27. Seasonal home ranges of radio-collared tiger female-120 in Panna National Park.

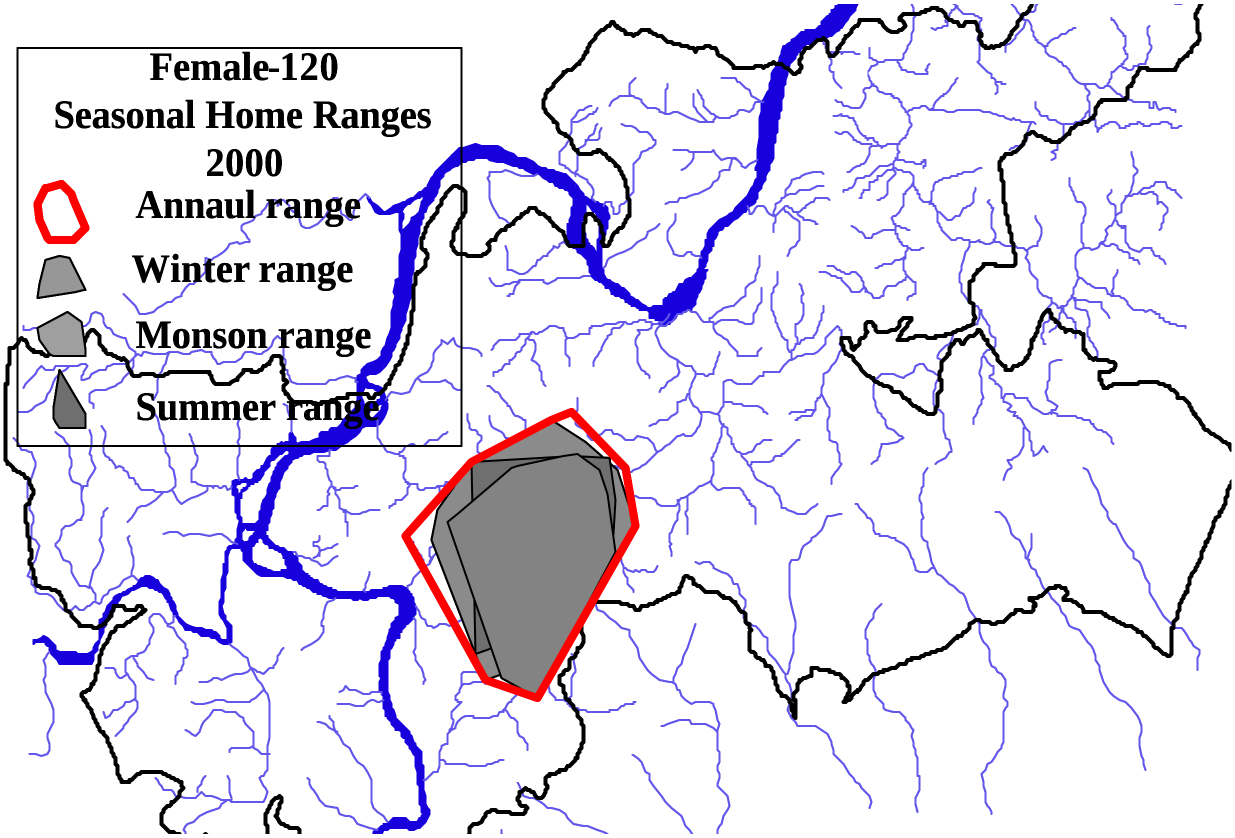


Figure 28. Seasonal   home ranges of radio-collared tiger female-113 in Panna National Park.

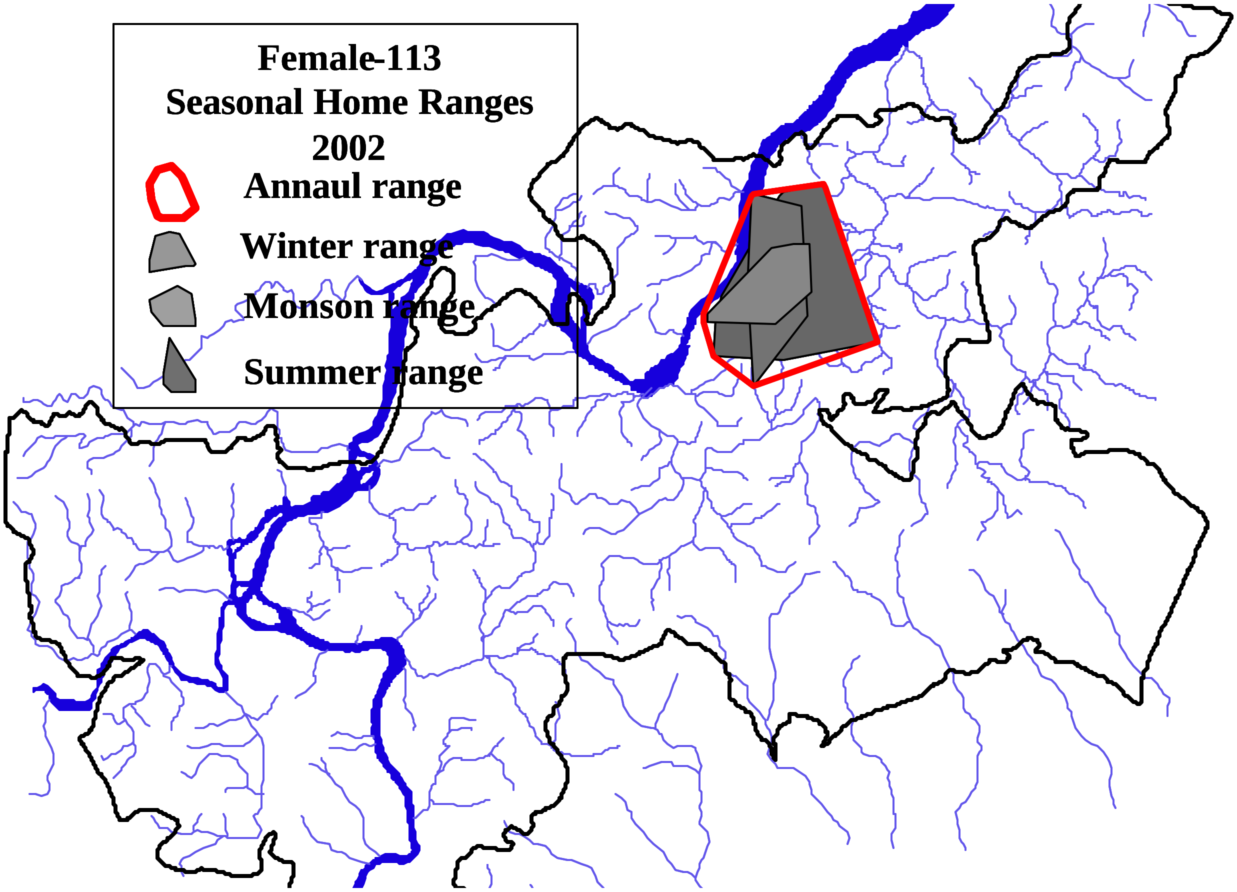


Figure 29. Seasonal home ranges of radio-collared tigerfe male-111 in Panna National Park.

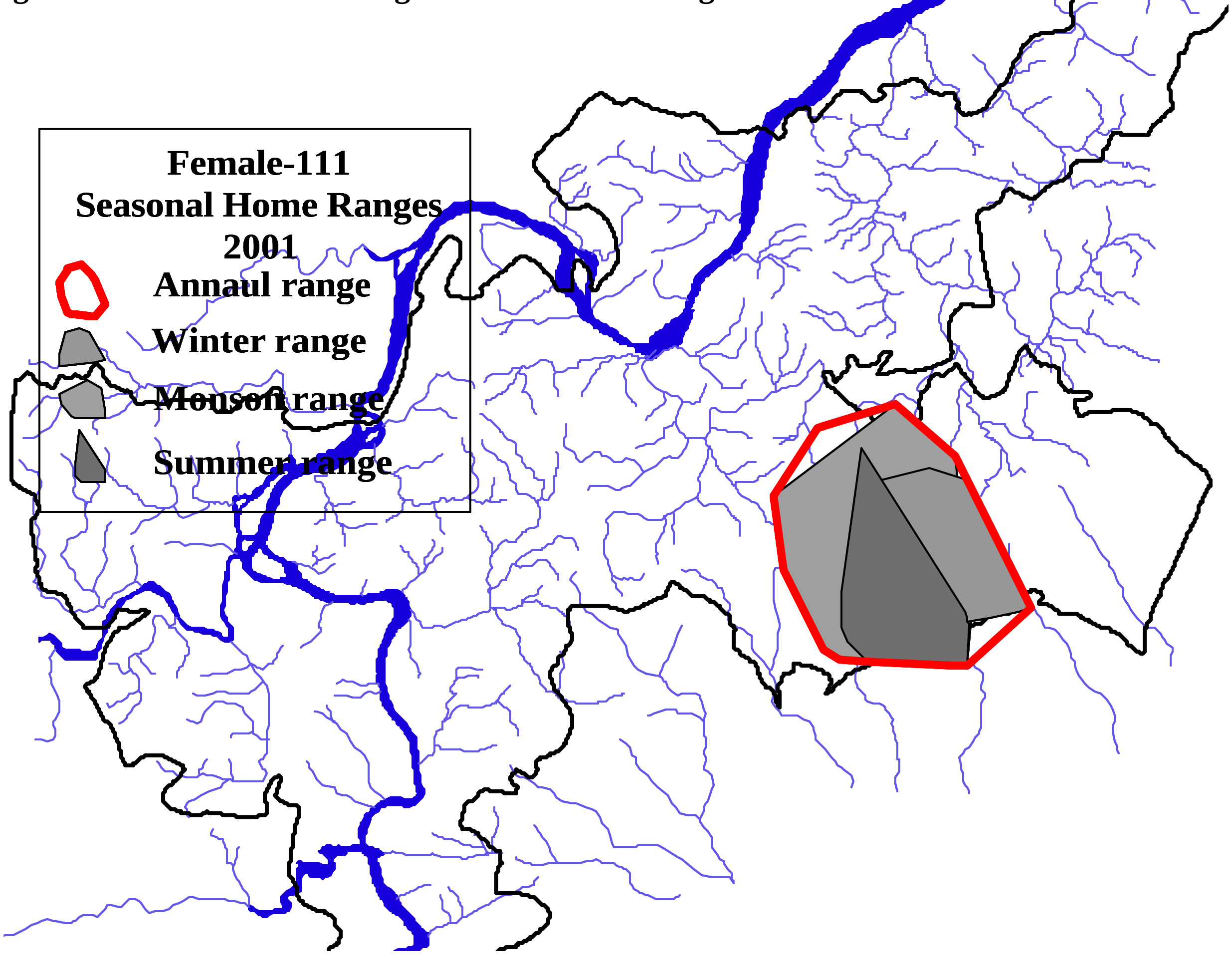
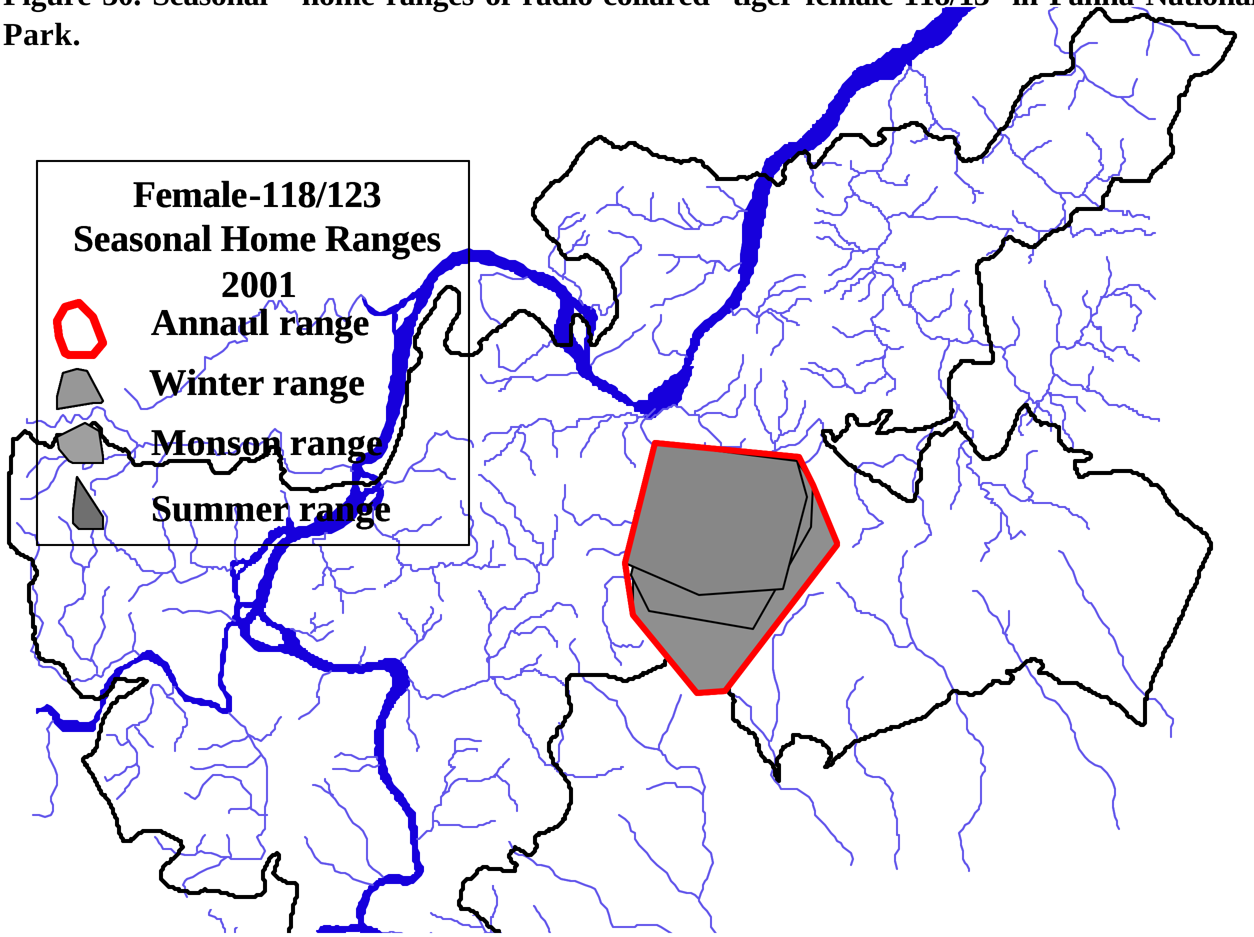


Figure 30. Seasonal home ranges of radio-collared tiger female-118/13 in Panna National Park.



between two locations. Details for individual animals are given in Table 12. Male tigers covered distances twice as large as the female tigers. The average distances travelled by male tigers is estimated at 4.37 km. No clear seasonal pattern is observed in distances travelled by tiger in Panna Tiger Reserve, which is very similar to the seasonal home range size observed in the Reserve.

Activity Pattern

Tigers in Panna Tiger Reserve show distinct seasonal activity patterns. On average they are crepuscular, showing two activities bursts (defined as more than fifty percent active records). This pattern is clearer during the monsoon months showing two distinct activity peaks – one in the early morning hours, between 0600 to 0800 hours, and second in the evening between 1800 to 2100 hours. During the middle of the day activity reaches its minimum. However, in winter only one distinct peak of activity is observed: in early morning hours 0700 to 1000 and hovering around fifty percent in the evening from 1600 to 2100 hours. Activity declines to its minimum during the middle of the night and remains below 30% throughout the night or until sunrise. Activity picks up with sunrise and remains over 30% for most of the day hours. The summer activity pattern is in sharp contrast to the winter pattern: only one distinct activity peak is seen where it reaches above 50% after sunset around 1900. Activity hovers around 40% during the most of the 24 hour period but reaches its minimum and below 20% during midday between 1100 and 1700 hours (Figure 31).

Habitat Use

Habitat use by tiger

All tiger locations are pooled into male and female groups and analysed to determine habitat use by tiger. A detailed map of different habitat types is prepared from satellite data (Figure 1). From this detailed habitat map, availability of each habitat is calculated for tigers. Six different habitat types are identified and mapped:

1. Disturbed (including human habitation and highly degraded habitat).
2. Open/Grassland (including grassland and very open savanna type forest habitat).
3. Thorn forest
4. Miscellaneous
5. Mixed forest
6. Mixed dense Forest

Figure 31. Seasonal activity chart of the radio-collared tigers in PNP.

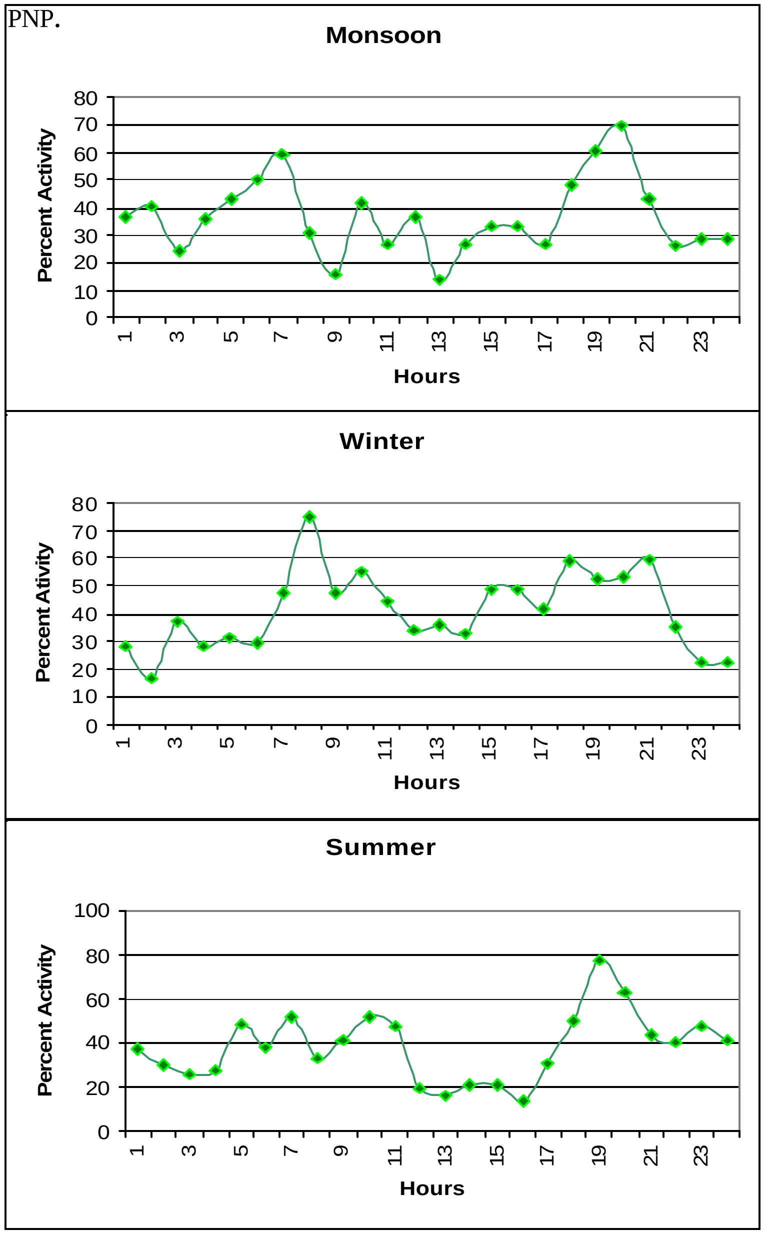


Table 13 Habitat use by all female (a) and male (b) radio collared tigers in Panna Tiger Reserve. (* = significant usage; + = preferred; - = avoided)

a. Female					
Habitat categories	**Relative area**	**Expected usage**	**Observed Usage**	**Lower CL**	**Upper CL**
Outside	**0.005**	**10.8**	**45**	**0.013**	**0.031 * +**
Disturbed	**0.077**	**153.7**	**39**	**0.011**	**0.028 * -**
Open/Grassland	**0.222**	**445.7**	**270**	**0.114**	**0.155 * -**
Thorn Forest	**0.095**	**191.2**	**75**	**0.026**	**0.049 * -**
Miscellaneous	**0.264**	**528.3**	**604**	**0.273**	**0.329 * +**
Mixed Forest	**0.101**	**202.1**	**318**	**0.136**	**0.181 * +**
Dense Forest	**0.196**	**392.3**	**635**	**0.288**	**0.345 * +**
Water bodies	**0.04**	**80.8**	**19**	**0.004**	**0.015 * -**
Z= 2.7299993038177					
X^2=608.080810546875					

b. Male					
Habitat categories	**Relative Area**	**Expected usage**	**Observed Usage**	**Lower CL**	**Upper CL**
Outside	**0.005**	**10.8**	**45**	**0.013**	**0.031 * +**
Disturbed	**0.077**	**153.7**	**39**	**0.011**	**0.028 * -**
Open/Grassland	**0.222**	**445.7**	**270**	**0.114**	**0.155 * -**
Thorn Forest	**0.095**	**191.2**	**75**	**0.026**	**0.049 * -**
Miscellaneous	**0.264**	**528.3**	**604**	**0.273**	**0.329 * +**
Mixed Forest	**0.101**	**202.1**	**318**	**0.136**	**0.181 * +**
Dense Forest	**0.196**	**392.3**	**635**	**0.288**	**0.345 * +**
Water bodies	**0.04**	**80.8**	**19**	**0.004**	**0.015 * -**
Z= 2.72999930381774					
x=643.3832397460938					

Table 14 Use of space in relation to chital abundance by all female (a) and male (b) radio collared tigers in Panna Tiger Reserve. (* = significant usage; + = preferred; - = avoided).

a. Female tiger					
Chital abundance	**Relative Area**	**Expected Usage**	**Observed Usage**	**Lower CL**	**Upper CL**
Very low	**0.048**	**96**	**88**	**0.032**	**0.055**
Low	**0.651**	**1304.00%**	**882**	**0.412**	**0.468 * -**
Medium	**0.163**	**327**	**518**	**0.234**	**0.283 * +**
High	**0.138**	**277**	**517**	**0.233**	**0.282 * +**
x=456.992156982421					
Z= 2.4999995231628					

B. Male tiger					
Chital abundance	**Relative Area**	**Expected Usage**	**Observed Usage**	**Lower CL**	**Upper CL**
Very low	**0.048**	**56.2**	**93**	**0.06**	**0.099 * +**
Low	**0.651**	**762.1**	**485**	**0.378**	**0.450 * -**
Medium	**0.163**	**191.0**	**302**	**0.226**	**0.290 * +**
High	**0.138**	**161.8**	**291**	**0.217**	**0.280 * +**
Z= 2.4999995231628					
x=292.447875976562					

Table 15 Use of space in relation to sambar abundance by all female (a) and male (b) radio collared tigers in Panna Tiger Reserve. (* = significant usage; + = preferred; - = avoided).

a. Female tiger					
Sambar abundance	**Relative Area**	**Expected usage**	**Observe d Usage**	**Lower CL**	**Upper CL**
Very low	**0.613**	**1228.66%**	**800**	**0.372**	**0.426 * -**
Low	**0.118**	**236.59**	**272**	**0.117**	**0.155**
Medium	**0.045**	**91.228**	**65**	**0.023**	**0.042 * -**
High	**0.224**	**448.318**	**868**	**0.405**	**0.461 * +**
Z= 2.499999523162					
x= 456.9921569824					

b. Male tiger					
Sambar abundance	**Relative Area**	**Expected Usage**	**Observed Usage**	**Lower CL**	**Upper CL**
Very low	**0.613**	**717.589**	**471**	**0.366**	**0.438 * -**
Low	**0.118**	**138.178**	**117**	**0.078**	**0.122**
Medium	**0.045**	**53.28**	**69**	**0.042**	**0.076**
High	**0.224**	**261.836**	**514**	**0.403**	**0.475 * +**
Z= 2.49999952316284					
x=335.470642089843					

Table 16 Use of space in relation to nilgai abundance by all female (a) and male (b) radio collared tigers in Panna Tiger Reserve. (* = significant usage; + = preferred; - = avoided).

a. Female tiger					
Nilgai abundance	**Relative Area**	**Expected Usage**	**Observed Usage**	**Lower CL**	**Upper CL**
Very low	**0.153**	**306.9**	**134**	**0.053**	**0.081 * -**
Low	**0.188**	**376.9**	**625**	**0.286**	**0.338 * +**
Medium	**0.168**	**336.8**	**463**	**0.207**	**0.254 * +**
High	**0.491**	**984.25**	**783**	**0.363**	**0.418 * -**
Z=2.499999523162					
x=349.1095275					

b. Male tiger					
Nilgai abundance	**Relative Area**	**Expected Usage**	**Observed Usage**	**Lower CL**	**Upper CL**
Very low	**0.153**	**179.2**	**104**	**0.068**	**0.110 * -**
Low	**0.188**	**220.1**	**368**	**0.28**	**0.348 * +**
Medium	**0.168**	**196.7**	**282**	**0.21**	**0.272 * +**
High	**0.491**	**574.8**	**417**	**0.321**	**0.391 * -**
Z= 2.4999995231628					
x=211.211044311523					

7. Water bodies

Most of the Tiger Reserve areas (approximately 32%) fall under open forest habitat, i.e. open/grassland and thorn forest. Approximately 29 % of the area is covered by relatively dense forest and 26 % is medium density forest. On average, tigers used the densely forested areas more then other habitats and of these, the mixed and mixed dense Forest along the base of the escarpment was used most (female, 47% and male, 52%, Figure 32). 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 winter. However, overall, distribution of tigers 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.

Space use by tiger in relation to its prey availability

The study aims to find out whether the distribution of tiger is related to its prey and if it is then to which prey species it is more closely related. 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 according to the availability and abundance of its major prey. Details of the distribution of the prey species are given in Table xx. 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 density (< 1 animal/km2).

When tiger distribution is seen in relation to pooled animal density for these ungulates, it is observed that its distribution is closely related to the 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 than 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.

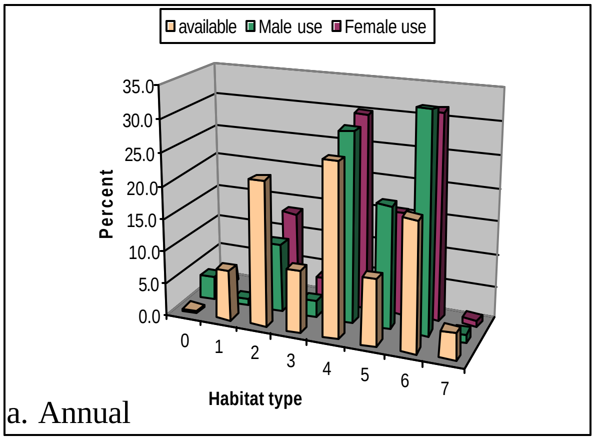
In a dry environment like Panna, water plays a key role and it was noticed that during the summer months not only was prey species distribution related to its availability, but tiger distribution was also very closely related to water (Figure 33).

Discussion

Home ranges

As known from other studies on the land tenure system of tiger (Sunquist, 1981, Smith, 1984; Karanth and Sunquist, 2000), in Panna both the sexes of tiger also maintained mutually exclusive home ranges which can be defined as territories. Male territories overlapped with relatively fewer females then known from studies conducted in Royal Chitwan Nation Park (Sunquist, 1881 and Smith, 1984). In Panna, the home ranges of the male radio-collared tigers included only two three female territories, whereas in Chitwan the number included ranged from three to six. Territorial tigers did not share their core areas with their neighbours but peripheral areas of their home ranges did overlap with neighbouring tigers. But this overlap is limited to a small proportion of their ranges, usually less than 10% of the home range. Their use of core areas did not change over the years, but the shape and size of the annual home range did vary slightly year to year. This confirms that tiger show site fidelity once they have established a territory and continue to defend and occupy the area for life.

Seasonal homes in monsoon and winter of female tigers are 22-23% smaller to the annual home range but about 40% of the annual ranges



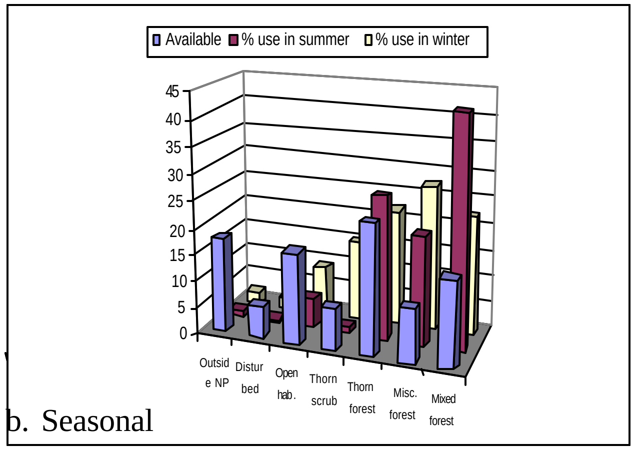


Figure 2. Habitat use by radio-collared tigers in PNP.

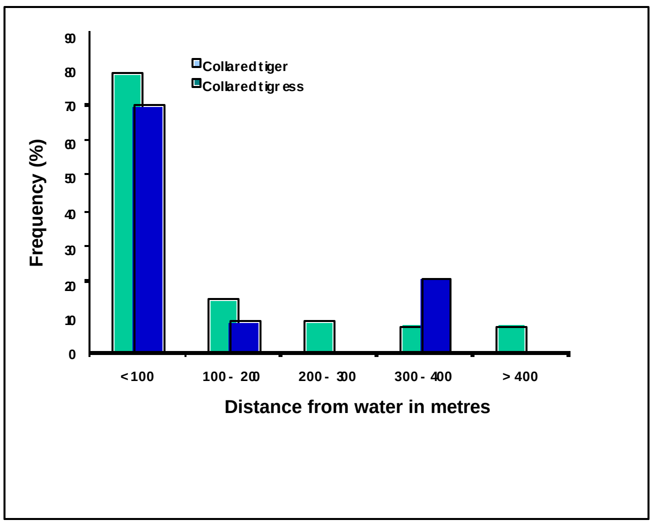


Figure 33. Distribution of tiger location in relation to water holes during summer months in PNP.

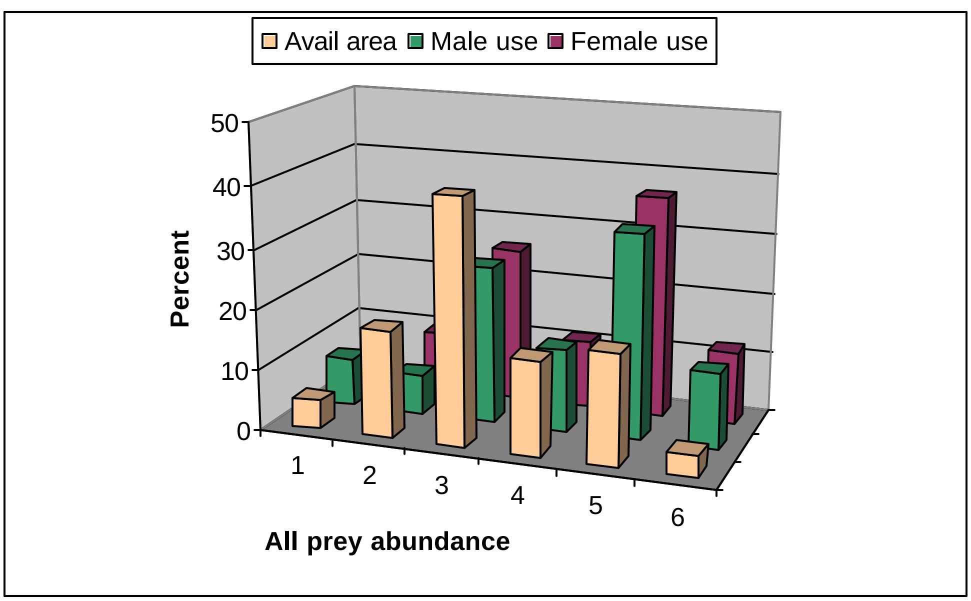


Figure 34. Use of space by radio-collared in relation to prey abundance in PNP.

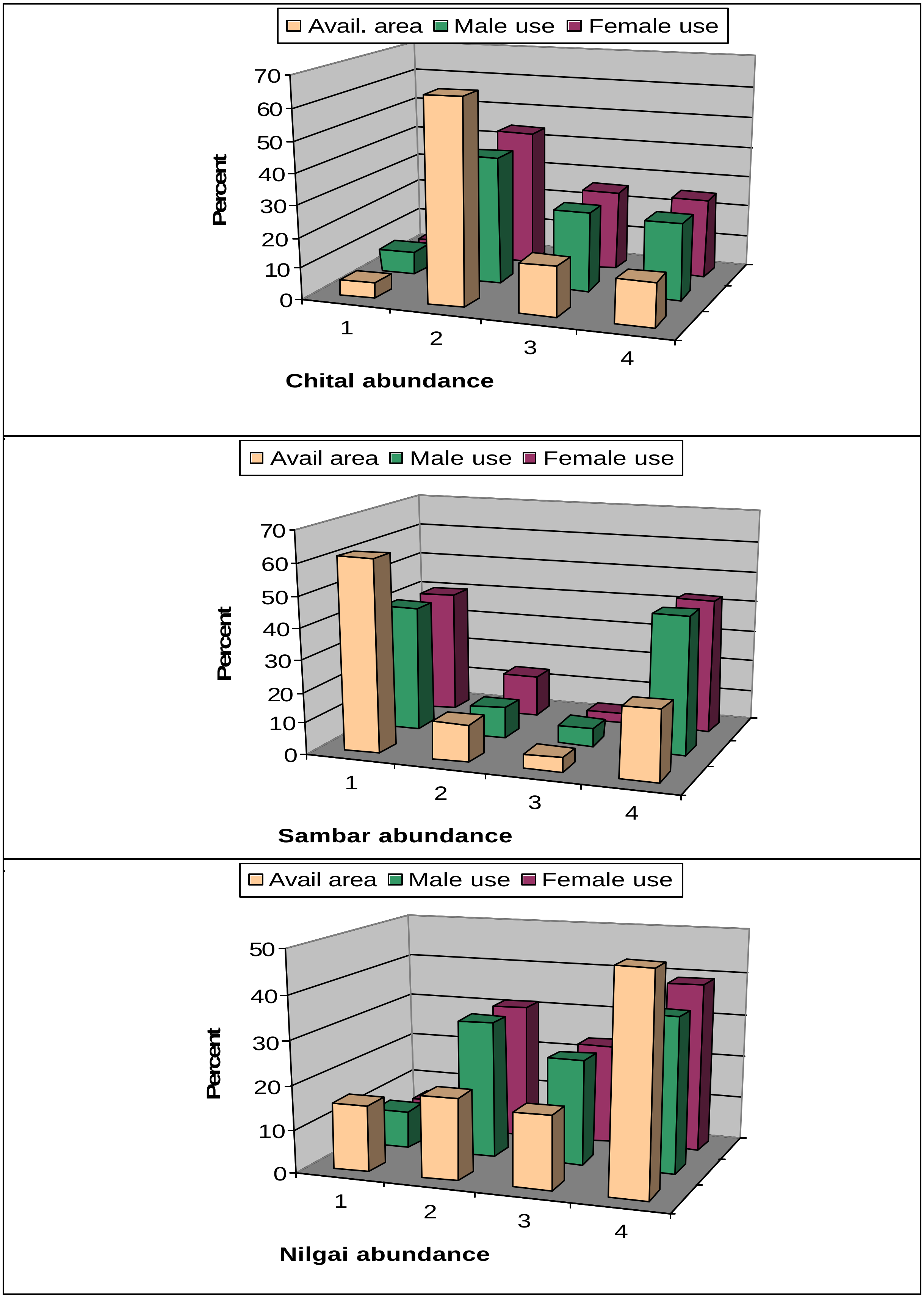


Figure 35. Use of space in relation to abundance of different prey speceis in PNP.

during summer. But a similar trend is not observed in males; they have, on average, 40-50% smaller seasonal ranges. This indicates that the tigers exploit different areas according to the seasonal availability of the resources. In monsoon and winter when environmental conditions are optimal, tigers made use of most of the areas, including open habitats. In the summer months open habitat are avoided and tiger distribution is limited to areas near water holes and cool resting places. Area of intensive use (core area), where the tiger was located 80% of time is limited to 19% of the annual range in males and 24% in females. An understanding of the characteristics of these core areas is, therefore, very important for managing an area in a way that can fulfill the minimum ecological requirement of tiger.

Tigers are highly mobile animals and move long distances patrolling their territories and in search of prey. On average males tiger covered distances twice as large as the female tigers. The average distances travelled by tigers only provides an approximate index of their movement, not the actual distances covered by the animals. No seasonal pattern is observed in distances travelled by tigers in Panna Tiger Reserve in the way observed in seasonal home range sizes.

The home ranges of tiger in Panna are larger than those known from 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 20to 30% of unsuitable habitat, uneven distribution of prey, high human disturbance and sparse water distribution in summer. Furthermore the heterogeneous distribution of resources over time and space makes resource availability unpredictable. Larger home ranges in Panna may well be a response to this highly spatial and temporal unpredictable resource availability. In order to create more stable availability of resources throughout the year, tigers in Panna manage by including a larger proportion of unproductive and less suitable habitat within their home ranges. As a result of this ecological response, Panna supports a smaller tiger 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.

Tigers in Panna Tiger Reserve show distinct seasonal activity patterns. They show a crepuscular pattern with two activities bursts. This pattern is clearer during the monsoon, with least activity during mid day. In winter most of the activity is seen soon after sunrise in the morning hours. The tigers remain active throughout the day, more than they are in the night. The least activity is noticed during the coldest hours, between the middle of the night to the early morning. Activity declines to its minimum during middle of night and remains below. Summer activity pattern is in sharp contrast to winter indicating that thermo-regulatory requirement plays an important role and governs activity patterns. The least amount of activity is seen during hottest period and activity picks up only after sunset in the evening.

Habitat use

In Panna radio-collared tigers used densely forested habitat more than other open habitats. Open habitats are used more only in the cooler winter season. During summer they used dense forest habitat at the base of the steep escarpments which provide suitable cool places to escape from the intense heat. 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 forests. 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 to prey found in open habitats. The 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.

Tiger-III: Food habits and predation

Predators like tiger play a significant and definite role in the dynamics of an ecosystem. Conservation management of large carnivores is different from other conservation approaches (Ginsberg, 2001). This is due to the fact that large carnivores like the tiger often live in human-dominated landscapes in Asia and come into direct conflict with humans due to their predation on livestock (MacDougal, 1987). This conflict with the human population tends to be sharpest in areas where the prey population is declining. It is for this reason that conservation and management of tiger has always remained a highly controversial subject for conservationists and the communities who live alongside these large predators (Joslin, 1973; Schaller, 1983; Sawarkar, 1986; McDougal, 1987; Sunquist, 1981; Seidensticker et. al., 1999; Karanth, 1991; Chundawat; 1999; Gingsberg, 2001).

Recent studies have documented prey depletion as a major factor responsible for tigers' declines in most places (Karanth and Stith, 1999). There are several factors that govern the predation pressure on prey populations and availability of its major prey is one of them. Another factor associated with this aspect of abundance is the availability of alternate and suitable prey. Apart from these factors availability of suitable hunting cover and competition play a significant role (Sunquist and Sunquist, 1989).

It is not always easy to gather information on predation by large carnivores from direct observations on a regular basis. Therefore food habitat and predation by tiger and other carnivores is determined from the scat analysis and kill records (Flyod et al., 19778; Sunquist, 1981; Tamang, 1982; Johnsingh, 1983; Ackerman et al., 1984; Leopold and Krausman, 1986, Karanth and Sunquist, 1995, Chundawat and Gogate, 1999). Scat analysis has several advantages over other methods (Reynolds and Aebischer, 1991); it is non-invasive and scats samples can be collected easily. But one of the major constraints, which can affect the interpretation of the data on the basis of percent occurrence, is that smaller prey items are usually over represented in the scat analysis (Karanth, 1993 and Karanth and Sunquist, 1995). Flyod et al., 1978 found an inverse relationship between the number of field collectible scats and the prey size. Based on this relationship Ackerman, et al., 1984, developed an equation to estimate biomass consumed per scats for cougar (Felis concolor). For estimating the biomass consumed by tiger, many scientists (Karanth, 1993, Karanth and Sunquist, 1995, BiswasXX) have successfully used this correction factor that was developed for cougar. This approach is also employed in this study to determine the food habits of tigers in Panna Tiger Reserve.

Results

Science for Saving Wild Tigers in Dry Forests of the Peninsular India

Being a large and charismatic carnivore, the tiger has attracted considerable attention in the conservation community the world over. In spite of this overwhelming care, the status of this predator has been deteriorating rapidly. Recently, this has reached more serious proportions than at any other time in the history of tiger conservation in India. Three subspecies (Panthera tigris balica, P. t. virgata, and P. t. sondaica) have already become extinct, P. t. amoyensis is on the brink of extinction (Nowell and Jackson, 1996) and populations of P.t. altaica, P.t. sumatrae and P. t. corbetti are holding on against great odds. The royal Bengal tiger, P. t. tigris, found in the Indian sub-continent, had provided hope for the future of the species, mainly due to the fact that it accounted for more than 60% of all the wild tiger population. Many believe that the foremost chance of saving tiger for posterity rests with India. Although India held nearly half the world's wild tiger population, its future is precarious and is threatened by poaching, habitat loss and loss of habitat quality caused by depletion of prey either due to poaching or to other forms of human disturbance (Panwar, 1982; Seidensticker, 1986; Wemmer et al, 1987; Johnsingh et al. 1991; Karanth, 1993; Curry, 1996; Sahgal and Thapar, 1996).

A population of over 3,500 tigers in India may look very promising, but a closer, critical look, shows all the promise to be superficial. In fact the status of the tiger in most parts of the country is extremely grim. Besides the problems mentioned earlier, there are two more characteristics of the tiger population in India, which could lead to the future doom of the sub-species. One is the small and isolated nature of the tiger habitats; tigers are divided into hundreds of small populations. More than 80% of the protected areas that support tiger populations in India are smaller than 400 km^2 and the average population size of tigers in these protected areas is shockingly low - less than 15 individuals. Such small populations of a large carnivore are extremely vulnerable to extinction due to demographic and environmental stochasticity that operate on small populations (Gilpin and Soule, 1986; Caughley, 1994).

When a tiger population of over 3,500 animals is considered as one large contiguous population, survival prospects look very different from the reality of many scattered small populations. Any modelling using the total figure will predict a much longer survival. In fact the extinction processes are acting on each of these isolated populations simultaneously and separately. As a result these small and isolated tiger populations will be lost much sooner than one large continuous population.

Tiger is not a habitat specialist: it occupies diverse habitats, ranging from the hot arid regions of western India, to the mangroves and humid rainforests of tropical Asia and the Arctic climate of Siberia (Sunquist et al., 1999). In different habitat types and environments its response varies; tigers achieve maximum density in a productive and prey rich tropical climate such as the terrai flood plains and in moist tropical forests (Sunquist, 1981). The projection for survival will vary in different habitats.

It is more or less an accepted fact that the tiger population in India has declined and is continuing to decline. Unfortunately official figures do not agree with expert opinion and the overwhelming peoples' perception that the tiger population is in serious crisis due to this decline. After thirty years of tiger conservation efforts, we do not have a monitoring protocol that can track the changes in populations and show where this decline is occurring; nor is it capable of telling us in which habitats tigers are most vulnerable. The way our official census figures are collected give very little indication of trends and are of very little use in answering such basic questions.

We in India boast that if the tiger survives, it will be in India, but we prefer to ignore the precarious status of most of the tiger populations in our country, which are not very different from populations in the rest of the world. Our track record in understanding the ecological needs required for efficient management of tigers, is extremely poor. In the past thirty years of tiger conservation under the auspices of Project Tiger, which includes a strong mandate for research, there has failed to be a single long-term study on tiger. We still have to consult Schallers' book, "The Deer and the Tiger", published in 1967. Management of wildlife populations is a highly specialized field and in the present scenario management can ill afford ad hoc management decisions; it requires informed decisions. Unfortunately management of most of the Parks in the country suffer due to deficient scientific information on wildlife populations. Instead of benefiting wildlife, ad hoc, whimsical intervention, due to lack of knowledge, can and does destroy habitat and its populations.

To address the declining status of the tiger population in India it is important to have information on where this decline is taking place and what can be done to stall this decline. Since there is very little information available to answer these simple questions we gathered basic data on presence and absence of tigers in protected habitats (national parks and wildlife sanctuaries) from peninsular India (excluding the north-east states). We analysed this data to determine where tiger was present fifty year ago and whether it is still present or absent now. This simple analysis was conducted in 1996 and provided us with some shocking results (Table 13). It also showed us where most of the decline was taking place. It indicated that tigers have disappeared from 70% of their original protected habitat in semi-arid forests and from 35% in Dry Deciduous Forests. The crucial factor is that these two habitats together form the largest (> 46%) tiger habitat (known as Dry Tropical Forest) in India. In addition, the number of livestock per square kilometre of forest and human population is high in Dry Forest creating another biotic pressure on the ecosystem.

This was an alarming result. What it indicates is that if this trend continues then a large number of tiger populations in India will be lost soon and mostly from the Dry Forest habitats. The recent loss of tigers from Sariska Tiger Reserve and Kaila Devi Wildlife Sanctuary, a part of the Ranthambhore Tiger Reserve, are examples and vindicate our predictions made nine years ago, highlighting the extreme vulnerability of tigers in these habitats. Low rainfall, long, a hot dry season, extreme climatic variations and high anthropogenic pressures on these habitats make these tiger habitats sub-optimal. Any loss of breeding tigers in these small and isolated populations can have disastrous consequences. Management has to be ever alert to the existing threats to provide stability to the tiger populations. Therefore in order to save wild tigers immediate attention and high priority must be attached to every tiger population found in the Tropical Dry Forests of India.

The other aspect we observed through these investigations was that the average size of the protected areas in these habitats is small (mean = 290 km2) and the average tiger population in each PA is also small (< 10). This is a major limiting factor. If you compare the results of Dry Forests with other more productive systems, we found that tigers survive in most of the Tropical Moist Forest (83%) and terai flood plains (100%)protected areas. It is clear from the data that tigers in Dry Forest habitats survive only in larger PAs and this is an important factor adding to the vulnerability of the tigers in Dry Forest habitats. However small the tiger population is in the Dry Forests, saving each and every one of them is crucial to ensure the long-term survival of this subspecies. Conservation and management of such highly vulnerable tiger populations requires intensive management, especially when the PAs are small and populations are divided into several small units.

Good conservation is always based on good science; unfortunately this is where wildlife management of this country has lagged behind and much work is needed. Detailed scientific information is required on the ecology of tigers. Most of the information on tiger ecology comes from studies conducted in optimal habitats with high productivity and prey abundance and not from Dry Forests from where it is urgently required. That is why this study on tiger in Panna Tiger Reserve is important and was designed to find out the ecological requirements needed to maintain a demographically viable population and identify factors responsible for the decline of tiger population in the Dry Tropical Forests. Until this study, almost nothing was known from this habitat, which is a typical and large tiger habitat

Table 1. Assesment of tiger vulnerability in different bio-unit/ forest types of Penninsular India.

Habitat types	Average Protected Area size in km^2			Human $/km^2$ of forest	Cattle $/km^2$ of forest
	All PAs	Tiger present	Tiger lost		
Terrai flood plains	418 (n=12)	418 (100%)	nil	1800	600
Moist deciduous	660 (n=63)	774 (83%)	180 (17%)	573	269
Rain forest	342 (n=8)	400 (90%)	<100 (10%)	1600	340
Dry deciduous	316 (n=39)	400 (65%)	230 (35%)	881	563
Semi-arid	270 (n=26)	350 (30%)	236 (70%)	1170	1700

All= average size of all protected tiger habitat
Tiger present= average size of protected tiger habitat where tiger still occur;
Tiger lost= average size of the protected tiger habitats from where tiger have been lost;
n= number of protected areas sampled;
Figure in bracket= percent of protected areas;
Humana and cattle
$/km^2$ of forest= rural human and cattle population per km^2 of forest

of peninsular India but where the tigers are most vulnerable. Findings from this research reveal how resilient the tigers are but also warns how insecure populations like Panna tigers can be if management is lax and not attentive to existing threats.

Tigers are specialized hunters and their responses vary according to variable ecological conditions. It is, therefore, important to study their behavioural responses because it can help us understand why tigers are so vulnerable in its largest habitat, the Dry Tropical Forest. For example in a prey depleted area, tigers may be killing livestock more often than expected, bringing the population into direct conflict with humans. The response of the tiger population could be low survival rates and poor reproductive success and the end result would be a highly vulnerable tiger population.

To understand tiger ecology it is important that we gather very reliable information. This requires unbiased information on its ecology; to achieve this, it is essential to locate tigers for observations at will. But tigers are difficult to locate and observe and direct observations are limited in the wild. A few opportunistic observations from direct sightings, and assumptions based on these limited observations, could be highly biased and therefore misleading. Radio-telemetry is, therefore, an important tool for gathering information in an unbiased manner and in much greater detail. An unexpected spin off of intensive and constant monitoring of radio-collared tigers is that it can reduce substantially any human caused mortality and provide security in a way no other monitoring can.

One of the major findings of this study in Panna is that the home ranges of tigers are much larger than known from other, more productive, habitats of the sub-continent. Male tigers on average ranged over 210 km2 and females 58 km2. These ranges are two to three times larger than those estimated from Chitwan and Nagarahole National Park. This is a significant finding. Not because it is new information but because it has serious conservation implications, especially in a Dry Forest habitat. Larger home ranges mean that tiger densities in Panna are low and fewer breeding territories could be accommodated within the protected area. This is an important finding because it is an established fact from other studies that populations with larger home ranges are highly vulnerable to local extinction. Therefore, if larger ranges are a typical characteristic of Dry Forest habitat, it can be safely stated that tiger populations of Dry Forests are highly vulnerable. However, in sharp contrast to the need for larger areas, PAs of Dry Forest are small (mean= 316km2). They can support fewer breeding individuals and these small populations, even in the best of situations, will find it hard to survive. This is one of the major reasons why tigers in dry and semi-arid areas are disappearing at a faster rate.

Tiger avoids open forest in Panna and it is estimated that approximately 30% of the habitat is naturally unsuitable for tigers in the Reserve because it is avoided by them. This further adds complexity for the management in understanding the minimum ecological requirements of tigers. Large home ranges of tigers in Panna could be one of the responses to this ecological condition. As a result fewer breeding territories could be accommodated in Panna. During this study we identified a maximum of only seven breeding female territories in the Reserve, south of the river Ken. This accounts for only two breeding units belonging to two dominant males with three to four female territories each. This is an extremely small breeding population and unlikely to ensure long-term survival of the population.

Another aspect which adds to vulnerability of the tiger population, associated with the large home ranges is that the territories of all the breeding tigers monitored by the research team, extend either up to the periphery of the Reserve or beyond its boundaries into the tiger habitats available outside (see map page…). This is where conflict rules; tiger here predate mainly on livestock and come in direct conflict with the local human population, exposing themselves to human caused mortalities. Since most of the protected areas in Dry Forest habitats are smaller then Panna, it is likely that a similar situation exists in most of them. Thus none of these breeding tigers are fully protected within the Reserve. Management can provide all the protection within its boundaries but when its breeding tigers venture outside its management jurisdiction they are unsafe. It clear from the monitoring of tigers in Panna how unsafe these breeding individuals are. Out of the known eleven breeding tigers monitored by the research team, Panna Tiger Reserve has lost eight of them. This is a significant loss of breeding tigers. Such high losses and even turnover of breeding population does not augur well for the tigers' long-term viability. When this is true for breeding individuals, it is difficult to provide stability to the breeding population. To achieve maximum reproductive success and save wild tigers, stability of the breeding population is an essential requirement. This is an important issue in saving the tiger in

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
Kajiranga NP	69.85	30.14	70.91
Nagarahole. NP	56.13	44.13	73.91
Ranthambhore NP	54.76	44.59	69.3
Panna NP	75.62	20.03	37.57
average	52.7	46.435	70.74

Table . Percent biomass and number of tiger prey in different protected areas.

its largest habitat and one that needs to be urgently addressed by wildlife managers. Immediate action would be to include, wherever possible, all the adjoining tiger habitats within the PA management as buffer, with immediate effect. This can be done without a change in their legal status; what is important, is that these crucial breeding areas must come under one management unit to ensure stability of the breeding population.

From the studies conducted in Panna, it is clear that survival of a tiger population is not dependent on the total number of tigers it has but on the size of the breeding population it supports. From the study we learned that not all tigers in a population are territorial - rather it consists of territorial (breeding) and non-territorial (transient sub-adult cubs and fewer non breeding adults) individuals. The territorial population usually remains constant (in ideal condition) and it is the non-territorial population that fluctuates. Any instability in the breeding population can be disastrous. In a typical tiger population there would be a larger proportion of non-territorial and a smaller proportion of territorial animals. The viability of the population is dependent on how large or small this breeding proportion is and its reproductive success. For example, if you have a population of hundred tigers in an area but only 10% of them are breeding, the population may not be viable in the long term in spite of it being a large population. This is because it mainly consists of a non-territorial population, which fluctuates and contributes little to the viability of the population. Therefore, to save a tiger population in the wild, management needs to maintain an appropriate proportion of territorial population within the protected area and provide this population with stability and an environment suitable for its successful breeding. Preliminary analysis of our data indicates that a minimum of nine female (breeding) territories would keep a Panna population of 35 tigers viable for a long period. Finding space for these nine breeding territories is not easy and it becomes more difficult when other ecological factors need to be considered. Not all the territories will be equal in habitat quality and fulfil minimum requirement of a breeding territory. This can reduce the over all reproductive success of the population. To compensate for this, additional breeding territories must be identified, included and protected to ensure successful breeding in the area. These are difficult goals to achieve in areas where human populations dominate the tiger habitat. Therefore, for a stable and viable tiger population, an inviolate area large enough to support a breeding population capable of sustaining a viable tiger population is essential and must not be compromised if we wish to ensure that tiger populations survive for decades to come.

Our efforts to save wild tigers are helped by the fact that tiger is a resilient species. With a little support it can bounce back, if its minimum ecological requirements are satisfied and human-caused mortalities are kept to a minimum. This is what was witnessed in Panna between 1996 and early 2002. We documented one of the finest recoveries of a tiger population from 2-3 tigers per 100 km2 in 1996, when the project started, to 7 tigers to every 100 km2 in 2002. We have monitored tigress-123 and her family for over seven years. During this period we saw 26 cubs produced by her and her children. We have witnessed three generations (grandchildren) of tigers, their survival, breeding and land tenure systems. Out of these 26 cubs, 20 survived to adulthood and dispersed. Such a high survival rate is a remarkable achievement for the management and indicates the reproductive potential of tigers. Long term monitoring of this family unit in one neighbourhood provided us with insights that can help management plan a strategy to save tigers based on objective information now available to them from this study.

What characterizes a breeding habitat? What are the ecological requirements for tigers to breed successfully? Such basic information is important for management to know. This study documents the ecological requirements of tiger in detail for the benefit of the management. To achieve an optimal reproductive success it is important that all breeding territories must fulfil certain minimum ecological requirements. In failing to do so, reproductive success of the population and ultimately its survival, is affected. In Panna, when monitoring adjoining female territories over the study period, it was observed that the tigresses' responses differ with the variable ecological conditions that exist in these territories. One of the female's territories (female-123) has an even distribution of resources, such as high uniform distribution of prey density, water, cover and no disturbance. The result was a high reproductive success and the tigress was able to raise most of her cubs (almost 90% survival of 11 cubs in four litters 3+2+3+3) successfully and survived throughout the study period. However, in neighbouring territories, which are characterized by uneven resource distribution of water, cover and prey densities, higher livestock population and included larger disturbed habitats, the tigresses had only limited (<40 %) reproductive successes in raising the cubs to adulthood. Moreover, none of the breeding females survived the entire study period and died within five to seven years. This variability in the quality of the breeding habitat in the system affects the over all reproductive success and viability of the tiger population.

It is estimated from the study that tigers in Panna kill more than 6 cattle annually, which translates to over 30% of the prey biomass consumed and approximately 15% of the number of prey killed. Observation of kill data of radio-collared tigers show that contribution by cattle to the tiger's diet could be as high as 40% and even higher for male tigers. In order to maximise its reproductive success a male tiger covers large areas to encompass several female territories. Its large range includes a greater proportion of disturbed habitats. Because strategy of a male tiger is mainly mate oriented, he is constantly on the move and patrols his territory extensively to fight off any challenger. This occupation keeps him very busy and forces him to move large distances. A male tiger, therefore, more often encounters and takes advantage of this easy prey. Such persistent killing of livestock by male tigers, as observed in Panna, brings them into direct conflict with the local people. The male tiger plays a very crucial role in tiger biology. Male tigers not only bring fresh genes into the population and contribute three to four times more cubs then a female but, most importantly, he also ensures cubs survival. A constant changeover of males as seen in Panna in the later part of the study between 2002 and 2005, adversely affects the reproductive success of the population. If human caused mortality on males is high, its effect on the population can be catastrophic and will seriously jeopardize its survival.

The females' strategy on the other hand is resource oriented because they spend most of their time raising cubs. They occupy areas where food and other resources are in abundance. We now know how much food, what kind of prey and where and when it is needed, through this study. The tiger's food can be classified as preferred and principal. 'Preferred' is food that is eaten more often when given a choice. 'Principal' food is the staple diet – food that is eaten frequently and forms the bulk of the intake. The study suggests that at least one of the major prey species of tiger should always be present in abundance to be available as the principal food. When prey availability and composition of Panna is compared with other high tiger density areas, it is obvious that this is not the case here. Three major ungulate prey species - nilgai, sambar and chital - form the bulk of the ungulate biomass in Panna. The nilgai's preference for open habitats precludes it from substituting as the principal prey for tigers in dry forest habitat. In Panna, tigers do not kill nilgai as much as one might expect from its availability. These large antelopes, well suited for open habitat, are predated only when frequenting forested habitats also frequented by tigers. Tigers do not purposely avoid nilgai but they do not frequent nilgai habitat often. Wild ungulate biomass from open and disturbed habitats does not, therefore, necessarily translate into high prey availability for tigers. Besides, nilgai, like sambar, cannot become the tigers' principal food as neither can achieve the densities that chital can. The potential principal food for tigers in Panna is therefore chital, like it is in most of the tiger habitats of the sub-continent. On average the principal food, or chital, contributes about 46% of the total prey biomass and over 70% in terms of number animals in high tiger density areas such as Kanha, Nagarahole and Kaziranga. Whereas in Panna, chital are limited in number and also restricted in distribution, its contribution is only 20% of available prey biomass and 37% in term of number. Other large prey - sambar and nilgai - together on average contribute over 70% to the prey biomass but can never achieve the abundance frequently reached by chital in the sub-continent. Chital and other similar sized prey such as wild pig and hog deer can attain higher densities and their super abundance makes it possible for a tiger to get food at regular intervals. The collared tigress raising three one year old cubs kills, on average, a medium to large bodied prey once every six days. Low availability of medium size prey is compensated by increased intake of smaller prey, such as langur and four horn antelope, in Panna. The role of medium size prey as principal food in the ecology of the tiger is an important factor affecting the tiger's responses (such as tiger densities, land tenure, distribution and reproductive success) significantly more than other prey species. A wider availability of principal food with increased abundance will have a positive effect on restoring tiger ecology in Dry Forests.

In Dry Forests, at the end of the growing season when most of the pastures are grazed, pressures intensify on the intact plant biomass of the Protected Areas. In these areas, livestock populations are dependent on forest resources for most of the year. The cumulative effect of higher human pressure, altered ecological conditions, unpredictable resource distribution, high conflict, low prey availability and smaller breeding units makes tiger populations in these areas more susceptible to the extinction process; a slight perturbation will have a pronounced effect on them.

One must attend to these problems at the earliest, otherwise India could lose a large part of its tiger population very soon. Increasing the size of PAs is not always possible, therefore an alternative management strategy is required to save these populations. Wildlife populations and their habitats are dynamic systems and require constant monitoring and intervention to protect its characteristic (biodiversity) and functionality. Wildlife management in India requires scientific information to direct the management actions on the right path, help plan management strategies and save our natural system. We need to move beyond the old philosophy of protecting an area and leaving nature to take its own course. Given the current status of our wildlife, we can ill afford to sit back and let the situation be. We do not have the luxury of large areas free from human disturbance where nature can play its true role, unimpeded.

After the great tiger population recovery success story, the sudden loss of tigers in Panna proves just how inadequate our monitoring systems are and limited our management system is. What was observed in Panna after 2002 is what makes tiger populations so vulnerable to extinction in Dry Forests. In 2002, the tiger population was estimated to be 29 tigers (including cubs) in 410 km2 of the sampled area using the photographic capture-recapture technique. This included seven breeding females, all with a litter of two cubs each except one who had a litter of three cubs. This accounted for fifteen cubs of different age groups but most of them over one year old. These female territories were dominated by two territorial breeding males. In addition to this there was evidence of four to five other adult non-territorial tigers that included a male cub of female-123 from her previous litter. But once it was believed that the tiger population was safe and management became lax, mortalities, mainly human caused, struck at regular intervals and Panna Tiger Reserve lost most of its breeding population. Out of the eleven breeding tigers known to the research team, nine of them disappeared. Almost no cubs were recorded by the censuses conducted by the staff and the research team. Most of the cubs and sub-adult tigers disappeared too; survival rates declined sharply. This loss of tigers in Panna highlights why tiger are vulnerable in Dry Forest. Losses of tigers in Sariska and Kaila Devi exemplify the past trend we have noticed from our presence/absence analysis of tiger populations. It is now very clear from the examples of these losses from Sariska, Kaila Devi and Panna that if we are going to lose tigers in India, it will be first from Dry Forest habitats.

Less than 4% of the country comes under the protected area network and 80% of the Protected Areas are less then 400 km2 in size. They exist in a populous country with many human demands on the natural resources. In such circumstances management has to work intensively and in so doing cannot afford to rely on guesses based on individual opinions. We need hard facts and information in order to develop creative solutions to the problems faced by PA management. Such serious data and information can only come from scientific studies like this one. This is where wildlife science plays a crucial role in wildlife conservation. It cannot save tigers but can guide management towards an appropriate path. We need constant monitoring of our wild heritage because management problems will never disappear, they will change over time and new ones will appear. Scientific knowledge of the situation is the only way forward to take informed actions to mitigate each new set of problems. Otherwise, uninformed actions can create more problems than they solve. Over the past three decades the role and importance of science in wildlife conservation has been highlighted and discussed in every national and international forum yet very little progress has been made. Due to lack of progress we still have to refer to the DEER AND the TIGER and THE BOOK of INDIAN ANIMALS or, when more detailed information on some common animals such as sambar, nilgai and chital is sought, we have to refer to those written on introduced populations in Texas, USA. We need to correct this, hopefully in the coming decades we will be able to change the status of wildlife science in India so that wildlife management will be equipped with appropriate and adequate information. In the absence of scientific knowledge wildlife management will remain in its infancy. Better understanding of the problems and innovative actions to protect these highly dynamic biological systems will help management evolve into a more mature and effective system. Only in this way can we take conservation forward into this new 21st century so that tigers and all the other diverse array of the natural world in India may exist for generations to come.

Literature Cited

Anderson, D. R., Burnham, K. P., Lubow, B. C., Thomas, L., Stephen Corn P., Mrdica, P. A. and Marlow, R. W. (2001). Field trials of line transect methods applied to estimation of desert tortoise abundance. J. Wildl. Manage. 65:583-597.

Anonymous, 1993. Proceedings and resolutions. International Symposium on the Tiger, New Delhi. Project Tiger, Ministry of Environment and Forests, Government of India.

Biswas, S. & Sanker, K. (2002). Prey abundance and food habit of tiger (Panthera tigris tigris) in Pench National Park, Madhya Pradesh, India. J. Zool. Lond. 256:411-420).

Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H. and Bishop, J. R. B. 2003. Distance 4.1. release-2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Buckland, S. T., Anderson, D. R., Burnham, K. P. & Laake, J. L. (1993). Distance sampling: estimating abundance of biological populations. London: Chapman & Hall.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Brochers, D. L. and Thomas, L. (2001). Introduction to distance sampling: Estimating abundance of biological populations. Oxford: Oxford University Press.

Burnham, K P and D R Anderson, 1984. The need for distance data in transect count. Journal of Wildlife Management. 48:1248-1254.

Burnham, K P, D R Anderson, J L Laake, 1980. Estimation of density from line transect sampling of biological population. Wildlife Monographs. 72. The Wildlife Society, Washington DC. 202pp.

Burnham, K.P. & Overton, W.S. (1978). Estimation of the size of a closed population when capture probabilities vary among animals. Biometrika 65: 625-633.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy. 24: 346-352.

Byers, C. R., Steinhorst, R. K. 1984. Clarification fo a technique for analysis of utilization-availability data. J. Wildl. Manage. 48(3): 1050-1053.

Carbone, C., Christie, S., Conforti, K., Coulson, T., Franklin, N., Ginsberg, J.R., Griffiths, M., Holden, J., Kawanishi, K., Kinnaird, M., Laidlaw, R., Lynam, A., MacDonald, D.W., Martyr, D., McDougal, C., Nath, L., O'Brien, T., Seidensticker, J., Smith, D., Sunquist, M., Tilson, R. & Wan Shahruddin, W.N. (2001). The use of photographic rates to estimate densities of tigers and other cryptic mammals. Anim. Conserv. 4: 75-79.

Champion H. G. and Seth, S. K. 1968. The revised survey of the forest types of India. Manager of Publications. Govt. of India. New Delhi. 404 pp.

Chaudhary, P.K. 1996. Economic Dependence of Enclaved and Surrounding Villages on Panna National Park - A Search for an Alternative. Consultancy Project Report under GOI-UNDP Project.

Chawdhry, P.K. 1997. Management Plan for Panna National Park (Period 1997-98 to 2006-07) - A draft report. Forest Department, Government of M.P.

Chellam, R. 1993. Ecology of the Asiatic Lion (Panthera leo persica). PhD. thesis, Saurashtra University, Rajkot, India. Pp. 170.

Chundawat, 2001. Tiger conservation Dry Tropical Forests of India. Technical report: 2000-2001.

Chundawat, R. S. & Gogate, N. (2001). Saving tigers in Dry Tropical habitats. In Saving wild tigers. Thapar, V. (Ed). Permanent Black, Delhi. 385-394.

Chundawat, R. S., N. Gogate and A.J.T. Johnsingh, 1999. Tiger of Panna: Preliminary results from an Indian Tropical Dry Forest. In Riding the tiger: Tiger conservation in human-dominated landscape. Seidensticker, J., Christie, S. 7 P. Jackson (Eds). Cambridge: Cambridge University Press.

Debroy, S. (1996). Halting the decline of the tiger. J. Wildl. Res. 1(2): 224-228.

Dixon, K. R. and J. A. Chapman, 1980. Harmonic mean measure of animal activity areas. Ecology. 61(5): 1040-1044.

Dobson,F.S. 1982. Competition for mates and predominant juvenile male dispersal in mammals. Anima. Behav. 30:1183-1192.

Eberhardt, L.L. 1968. A preliminary apprasial of line transect. J. Wildl. Manage. 32: 82-88.

Eisenberg, J F and J Seidensticker, 1976. Ungulates in southern Asia: a consideration of biomass estimates for selected habitats. Biological Conservation 10:293-308.

Eisenberg, J. F. & Lockhart, H. (1972). An ecological reconnaissance of Wilpattu National Park, Ceylon. Smithson. Contribution. Zool. 1001:1-118.

Eisenberg, J. F. 1981. The mammalian radiations: an analysis of trends in evolutions, adaptation, and behaviour. The University of Chicago Press. Chicago.

Ellner, S. and L. A. Real. 1989. Optimal foraging models for stochastic environments: are we missing the point? Comments. Theoretical Biology. 1: 129-158.

Garshelis, D. L. 2000. Delusion in habitat evaluation: measuring use, selection and importance. In Research techniques in animal ecology: controversies and consequences, eds. Boitani, L. and Fuller, T. K. Columbia University Press. Pp 111-164.

Gates, C.E. 1980. Linetran, a general computer program for analysing line transect data. J. Wildl. Manage..55:393-396.

Gee. E. P., 1964. The wildlife of India. London.

Hall, L. S. Krausman, P. R. and Morrison, M. L., 1997. The habitat concept and a plea for standard terminology. Wildlife Society Bulletin. 25:173-182.

Jathanna, D., Karanth, K. U., Johnsingh, A. J. T. (2003). Estimation of large herbivore densities in the tropical forets of southern India using distance sampling. J. Zool., London. 261: 285-290.

Jennrich, R. and E. Turner, 1969. Measurement of non circular home range. Journal of Theoretical Biology. 22:227-237.

Johnsingh, A. J. T. (1983). Large mammalian prey-predator in Bandipur. J. Bombay Nat. History Soc. 80:1-57.

Johnsingh, A.J.T., H.S. Panwar and W.A. Rodgers. 1991. Ecology and conservation of large felids in India. In Wildlife conservation: present trends and perspectives for the 21st century. Proceeding of the International Symposium on Wildlife Conservation in Tsukuba and Yokohama, Japan.

Johnsingh, AJT, 1983. Large mammalian prey-predators in Bandipur. Journal of Bombay Natural History Society. 80, 1-57.

Johnson, D. H., 1980. The comparison of usage and availability measurement for evaluating resource preference. Ecology. 61:65-71.

Johnson, T. H. 1984. Habitat and social organization roe deer (Capreolus capreolus). Ph. D. Thesis. University of Southampton.

Karanth K. U. 1993. Predator-prey relationships among the large mammals of Nagarhole National Park, India. Ph.D. thesis, Mangalore University.

Karanth, K and M E Sunquist, 1992. Population structure, density and biomass of large herbivores in the tropical forests of Nagarahole, India. Journal of Tropical Ecology 8:21-35.

Karanth, K and M E Sunquist, 1995. Prey selection by tiger, leopard and dhole in tropical forests. Journal of Animal Ecology 64, 439-450.

Karanth, K. U. & Chundawat, R. S. (2002). Ecology of the tiger: Implications for population monitoring. In Monitoring Tigers and their Prey: A manual for researchers, managers and conservationists in Tropical Asia: 9-21. Karanth, K. U. & Nichols, J.D. (Eds). Bangalore: Centre for Wildlife Studies.

Karanth, K. U. & M. E. Sunquist, 2000. Behavioural correlates of predation by tiger (Panthera tigris), leopard (Panthera pardus) and dhole (Cuon alpinus) in Nagarahole, India. J. Zool. Lond. 250, 255-265.

Karanth, K. U. & Nichols, J. (1998). Estimation of tiger densities in India using photographic captures and recaptures. Ecology. 79(8): 2852-2862.

Karanth, K. U. & Nichols, J. D (eds), 2002. Monitoring tigers and their prey: a manual for researchers, managers and conservationists in Tropical Asia. Natraj Publication. Pp. 111-120

Karanth, K. U. & Sunquist, M. E. (2000). Behavioural correlates of predation by tiger (Panthera tigris), leopard (Panthera pardus) and dhole (Cuon alpinus) in Nagarahole, India. J. Zool., Lond. 250: 255-265.

Karanth, K. U. (1991). Ecology and management of the tiger in tropical Asia. In Wildlife conservation: present trends and perspectives for the 21st century. (Eds) N. Maruyama, B. Bobek, Y. Ono, W. Reglin, L. Bartos & R. Ratcliffe, pp 156-159. Japan Wildlife Research Centre, Tokyo.

Karanth, K. U. (1995). Estimating tiger Panthera tigris populations from camera-trap data using capture-recapture models. Biol. Conserv. 71: 333-338.

Karanth, K. U. (1999). Counting tigers with confidence. In Riding the tiger: tiger conservation in human-dominated landscapes: 350-353. Seidensticker, J., Christie, S. & Jackson, P. (Eds). Cambridge: Cambridge University Press.

Karanth, K. U. (2003). Tiger ecology and conservation in the Indian subcontinent. J. Bombay. Nat. Hist. Soc., (In press).

Karanth, K. U. and B. M Stith, 1999. Prey depletion as a critical determinant of tiger population viability. In Riding the tiger: Tiger conservation in human-dominated landscape. Seidensticker, J., Christie, S. 7 P. Jackson (Eds). Cambridge: Cambridge University Press.

Karanth, K. U., J. D. Nichols, N. S. Kumar, W. A. Link and J. E. Hines, 2004. Tigers and their prey: predicting carnivore densities from prey abundance. PNAS. 101(14): 4854-4858.

Karanth, K. U., Kumar, N. S. & Nichols, J. D. (2002). Field surveys: Estimating absolute densities of tigers using capture-recapture sampling. In Monitoring Tigers and their Prey: A manual for researchers, managers and conservationists in Tropical Asia: 139-152.

Karanth, K. U. & Nichols, J.D. (Eds). Bangalore: Centre for Wildlife Studies.
Karanth, K. U., Nichols, J. D., Seidensticker, J., Dinerstein, E., Smith, J.L.D., McDougal, C., Johnsingh, A.J.T., Chundawat, R.S. & Thapar, V. (2003). Science deficiency in conservation practice: The monitoring of tiger populations in India. Anim. Conserv. 6: 141-146.

Karanth, K.U. 1987. Tigers in India: A critical review of field censuses. In Tigers of the World: The Biology, Biopolitics, Management and Conservation of an Endangered Species, eds. R.L. Tilson and U.S. Seal, pp. 118-33. Park Ridge, New Jersey, Noyes Publications.

Kawanishi, K. (2002). Population status of tigers in a primary rainforest of peninsular Malaysia. Ph.D. dissertation. Gainesville: University of Florida.

Khan, J.A., R. Chellam, W.A. Rodgers and A.J.T. Johnsingh, 1996. Ungulate densities and biomass in the tropical dry deciduous forests of Gir, Gujarat, India. J. Trop. Ecol. 12: 149-162.

Khan, J. A. 1990. Gir Lion project: ungulate-habitat ecology in Gir. Wildlife Institute of India Dehra Dun. 214pp.

Khan, J. A. 1997. Estimation of ungulates densities by line transects method in Gir forest, India. Tropical Ecology 38(1):65-72.

Khan, J. A. (1996). Factors governing the habitat occupancy of ungulates in Gir Lion Sanctuary, Gujarat, India. Int. J. Ecology. Environ. Sci. 22:73.83.

Krebs, C. J. 1994. Ecology: the experimental analysis of distribution and abundance. HarperCollins College Publishers. New York.

Kumar, N. Samba, 2000. Ungulate density and biomass in the tropical semi-arid forest of Ranthambhore, India. M.Sc. dissertation. Pondichery University, Pondichery.

Laake, J. L., Buckland, S. T., Anderson, D. R. & Burnham, K. P. (1998). Distance: User's guide. Fort Collins, CO: Colorado State University.

Laake, J.L., K.P. Burnham, D.R. Anderson. 1979. User's manual for program TRANSECT. Utah State University Press, Logan. 26pp

Laake, J.L., S.T. Buckland, D.R. Anderson and K.P. Burnham. 1994. Distance: User's guide. Colorado State University. Fort Collins.
Lancia, R.A.,J.D. Nichols and Pollock, 1994. Estimating the number of animals in wildlife populations. In Research and Management Techniques for Wildlife and Habitats (ed.)T.A. Bookhout. The Wildlife Society, Bethsda, Maryland. 215-253.

Madhya Pradesh Gazette, Part I, published on 8th February 1985.

Marques, F. F. C., Buckland, S. T., Goffin, D., Dixon, C. E., Borchers, D. L., Mayle, B. A. and Peace, A. J. (2001). Estimating deer abundance from line transect surveys of dung: sika deer in southern Scotland. Journal of applied Ecology.

Mathai, M.V. 1999. Habitat occupancy by tiger prey species across anthropogenic disturbance regimes in Panna National Park, Madhya Pradesh. M.Sc. Dissertation thesis, Saurashtra University, Rajkot, India. Pp. 61.

Mathur, V. B. 1991. The ecological interaction between habitat composition, habitat quality and abundance of some wild ungulate in India. Ph. D. Thesis. University of Oxford.

May, R.M. 1975. Pattern of species abundance and diversity. In Ecology and Evolution of Communities (ed.) M.L. Cody and J.M. Diamond. Harvard University Press.

McDougal, C. 1977. The Face of the Tiger. London, Rivington Books.

McDougal, C.W. 1975. The face of the tiger. Revington Books and Andre Deutsch. 180pp

Mech, L.D. 1983. Handbook of animal radio tracking. University of Minnesota Press.

Miquelle, D.G., Smirnov, E.N., Quigley, H.G., Hornocker, M.G., Nikolaev, I.G. and

Matyushkin, E.N. 1996. Food habits of Amur tigers in Silkhote-Alin Zapovednik and the Russian Far East, and implications for conservation. Journal of Wildlife Research, I(2), 138-47.

Mishra, H., 1982. The ecology and behaviour of chital (Axis axis) in the Royal Chitwan National Park, Nepal: with comparative studies of hog deer, sambar and barking deer. Ph. D. Thesis, University of Edinburgh.

Mueller-Dombois, D. and E. Ellenberg. 1974. Aims and methods of vegetation ecology. John wiley &Sons. New York.

Mukherjee, S., S.P. Goya.l and R. Chellam. 1994. Refined techniques for the analysis of Asiatic lion (Panthera leo persica) scats. Acta.Theriologica. 39(4): 425-430.

Neu, C. W., Byers, C. R., Peek, J. M.1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38(3): 541-545.

Nichols, J. D. & Karanth, K. U. (2002). Statistical concepts: Estimating absolute densities of Tigers using Capture-recapture sampling. In Monitoring Tigers and their Prey: A manual for researchers, managers and conservationists in Tropical Asia: 121-137.

Karanth, K. U. & Nichols, J.D. (Eds). Bangalore: Centre for Wildlife Studies.
Nichols, J.D. (1992). Capture-recapture models: Using marked animals to study population dynamics. BioScience 42:94-102

Nowell, K. & P. Jackson, 1996. Wild Cats: Status Survey and Conservation Action Plan. Gland, Switzerland, IUCN.

O'Brien, T.G., Kinnaird, M. F. & Wibisono, H.T. (2003). Crouching tigers, hidden prey: Sumatran tigers and prey populations in a tropical forest landscape. Anim. Conserv. 6: 31-139.

Otis, D.L., Burnham, K.P., White, G.C. & Anderson, D.R. (1978). Statistical inference from capture data on closed animal populations. Wildl. Monogr. 62:1-135.

Pabla, H.S. 1984. Panna National Park - Prospects and Problems, M.P. Forest Department.

Panwar, H. (1987 Project tiger: the reserve, the tiger and their future. In Tigers of the world: the biology, bio politics, management and conservation of an endangered species (Eds) R.L. Tilson and U.S. Seal. 110-117. Noyes Publication, Park Ridge, New Jersey.

Panwar, H. S. 1979. Population dynamics and land tenures of tigers in Kanha National Park. Proceedings of International Symposium on Tigers, New Delhi.

Panwar,H.S. 1982. What to do when you have succeeded: Project Tiger ten years later. In National Parks, Conservation and Development (eds.) Mcneely, J.A. and K.R.Miller). Smithsonian Press, Washington D.C.

Plumtre, A. J. (2000). Monitoring mammal populations with line transect techniques in African forests. Journal of Applied Ecology 37:356-368.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators. In Research techniques in animal ecology: controversies and consequences, eds. Boitani, L. and Fuller, T. K. Columbia University Press. 65-110pp.

Prater, S H, 1971. The book of Indian animals. Bombay Natural History Society, Bombay.

Prater, S. H. 1967 The book of Indian Animals. Bombay Natural History Society. Bombay.

Pulliam, H.R. 1988. Sources, sinks and population regulation. Am.Nat. 132:757-785.

Pulliam, H.R. and B.J. Danielson. 1991. Sources, sinks and habitat selection: a Landscape perspective on population dynamics. Am. Nat. 137:S50-S66.

Putman, R. 1988. The natural history of deer. Cornell University Press, New York.

Pyke G. H., H. R. Pulliam and E. L. Charnov. 1977. Optimal foraging: a selective review of theory and tests. Quarterly Review of Biology. 52:137-154.

Pyke, G. H. 1984. Optimal foraging theory: a critical view. Annual Review of Ecology and Systematics. 15:523-575.

Rabinowitz, A. 1989. The density and behaviour of large cats in a dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. Natural History Bulletin of the Siam Society, 37 (2), 235-51.

Rexstad, E. & Burnham, K.P. (1991). User’s guide for interactive program CAPTURE. Abundance estimation of closed animal populations. Fort Collins: Colorado State University.

Rodgers, W.A. and H.S. Panwar. 1988. Planning a wildlife protected area network in India. Vol. I & II, Wildlife Institute of India.

Sanderson, G. C., 1966. The study of mammal movements: a review. Journal of Wildlife Management. 30(1):215-235.

Sankar, K. 1994. Ecology of three large sympatric herbivore (chital, sambar, nilgai) with special reference for reserve management in Saris tiger Reserve, Rajasthan. Ph.D. thesis, University of Rajasthan, Jaipur.

Sankhala, K. 1977. Tiger: the story of the Indian tiger. Simon and Schuster, New York.

Sankhala, K.S. 1978. Tiger, Rupa, Delhi.

Sankhala, K.S. 1993. Return of the tiger. Lustre Press, New Delhi.

Schaller, G. B. (1967). The deer and the tiger. Chicago: University of Chicago Press.

Schaller, G. B. 1972. The Serengeti lion. University of Chicago Press, Chicago.

Seidensticker , J. 1976. Ungulate populations in Chitawan Valley, Nepal. Biol. Conserv. 10: 183-209.

Seidensticker, J. & Mcdougal, C. (1993). Tiger predatory behaviour, ecology and conservation. Symp. Zool. Soc. Lond. 65:105-125.

Seidensticker, J. (1997). Saving the tiger. Wildl. Soc. Bull. 25: 6-17.

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

Seidensticker, J. 1986. Large Carnivores and the consequences of habitat insularization: Ecology and conservation of tigers in Indonesia and Bangladesh. In Cats of the world: Biology, Conservation and Management, ed. S.D. Miller & D.D. Everett, pp. 1-41. Washington DC, National Wildlife Federation.

Seidensticker, J., Christie, S. & Jackson, P. (1999). Preface. In Riding the tiger: tiger conservation in human-dominated landscapes: xv-xix. Seidensticker, J., Christie, S. & Jackson, P. (Eds). Cambridge: Cambridge University Press.

Seidensticker,J.C. 1976. On the ecological separation between tigers and leopards. Biotropica 8:225-234.

Simberloff, D.S. and L.G.Abele. 1976. Island biogeography theory and conservation practice. Science 191:285-286.

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

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

Soule, M.E. 1986. Conservation biology: the science of scarcity and diversity. 584pp

Springer, J.T. 1967. Some sources of bias and sampling error in radio -triangulation. J. Wild. Manage. 43: 926-935.

Sunquist, M E, 1981. The social organisation of tigers (Panthera tigris) in Royal Chitwan National Park, Nepal. Smithsonian Contribution to Zoology. 336, 1-98.

Sunquist, M. E., Karanth, K. U. & Sunquist, F. (1999). Ecology, behaviour and resilience of the tiger and its conservation needs. In Riding the tiger: tiger conservation in human dominated landscapes: 5-18. Seidensticker, J., Christie, S. & Jackson, P. (Eds). Cambridge: Cambridge University Press.

Sunquist, M.E. and F.C. Sunquist. 1989. Ecological constraints on predation by large felids. In Carnivore behaviour, ecology and evolution (ed.) J. L. Gittleman. 283-301.

Tamang, K.M. 1982. Population characteristics of the tiger and its prey. Ph.D. thesis. Michigan State University. East Lansing.

Terbough, J. 1976. Island biogeography and conservation: strategy and limitations. Science 193:1029-1030.

Tester, J.R. and D.B. Siniff. 1965. Aspects of animal movement and range data obtained by telemetry. Transactions of the North American Wildlife and Natural Resources Conference, 30. 379-392.

Thapar, V. 1989. Tigers: the secret life. Elm Tree Books, London. 160pp.

Thapar, V. 1992. The Tiger's destiny. London, Kyle Cathie.

Thomas, L., Buckland, S. T., Burnham, K. P., Anderson, D. R., Laake, J. L., Borchers, D. L. & Strindberg, S. 2002-a. Distance Sampling. In Encyclopaedia of Environ metrics. El-Shaarawi, A. H. & Peigorsch, W. W. (Eds). John Wiley & sons. Pp 1: 544-552.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., and Pollard, J.H. 2002-b. Distance 4.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Thompson, W. L., White, G. C. & Gowan, C. (1998). Monitoring vertebrate populations. New York: Academic Press.

Vanak, A.T.F. 1997. Movement Patterns of Radio-Tagged tigers in Panna National Park, Madhya Pradesh. M.Sc. Dissertation thesis, Saurashtra University, Rajkot, India. Pp. 47.

Wemmer, C., J.L.D Smith and H.R.Mishra. 1987. Tigers in the wild: the biopolitical challenges. In Tigers of the world: biology, bio-politics, management and conservation of an endangered species (eds.) R.L.Tilson and U.S.Seal. 396-405.

Wikramanayake, E. D., Dinerstein E., Robinson J. G., Karanth K.U., Rabinowitz A., Olson D., Matthew T., Hedao P., Conner M., Hemley G. & Bolze D. (1999). Where can tigers live in the future? A framework for identifying high priority areas for the conservation of tigers in the wild. In Riding the tiger: tiger conservation in human-dominated landscapes: 255-272. Seidensticker, J., Christie, S. & Jackson, P. (Eds). Cambridge: Cambridge University Press.

Wikramanayake, E. D., Dinerstein, E., Robinson, J. G., Karanth, K. U., Rabinowitz, A. R., Olson, D., Mathew, T., Hedeo, P., Conner, M., Hemley, G. & Bolze, D. (1998). An ecology based method for defining priorities for large mammal conservation: the tiger as a case study. Conserv. Biol. 12: 965-878.

Williams, B. K., Nichols, J. D. & Conroy M. J. (2002). Analysis and management of animal populations. San Diego: Academic Press.

Wilson, K. R., & Anderson, D. R. (1985). Evaluation of two density estimators of small mammal population size. Journal of Mammalogy 66: 13-21.

Wright, B. 1996. The Tiger Poaching Crisis. CBI Bulletin. V4 (2): 23-28.

Zar, Jerrold H., (1984). Biostatistical Analysis (Second Edition). Prentice-Hall, INC. Englewood Cliffs, New Jersey 07632.

Appendix-I

Communities and Tiger Conservation:
A holistic approach to development in and around Panna Tiger Reserve

A Preliminary Report
June 2005

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COMMUNITIES and TIGER CONSERVATION : **A Holistic Approach to Development In and Around Panna Tiger Reserve**

Introduction

Tigers are the largest of the living wild felids. They are at the top of the food pyramid and can safely be depicted as the thermometers of any ecosystem. Since a healthy tiger population depends on a sound foundation underneath in the food pyramid, protection of tigers ensures health of their prey and of the ecosystem, which in turn ensures water regime and the quality of floral richness in a particular area. A healthy and functional system is more beneficial to local communities that sustain their livelihood on such forests than a poor quality and degraded forest habitat.

Anonymous but systematic records have reported a drastic decline in the tiger population over the last century. Poaching and habitat destruction are the two most significant factors responsible for this decline. In 1973, the then Prime Minister of India, Mrs. Indira Gandhi initiated an ambitious project to save the grandest of India's natural heritage, the tiger. Project Tiger was initiated with an objective of protecting tiger and its habitat and ensuring their long-term survival. Attempts were, and are still, made to provide protection to the tiger and its habitat through an extensive network of protected areas. This model had initial success but now is criticised for some of its serious fallouts: creating islands of protected areas without any corridors, alienating people from their ancestral resources and disputes over land use with the local inhabitants, these have created conflict with local communities. The protected areas have aimed at protecting our natural resources exclusively, in a way that involves little real interaction or bi-directional support to and from the people living around these areas. As a result of this exclusive approach, little has been gained long-term in terms of wildlife conservation. Rising conflicts with villages adjoining PAs is a cause for serious concern for both wildlife conservationists and anthropologists working with the communities in these areas. The alienated villagers become potential allies to individuals, organisations and corporates with vested interests in the natural resources and in many illegal activities.

Tigers are large territorial carnivores, which range widely and require large areas. Research has revealed that tigers have particularly large territories in Tropical Dry Forests such as in Panna National Park; they move great distances and their territories often extend beyond PA boundaries into unprotected tiger habitats dominated by a large human population. Lack of buffer areas, fragmentation and lack of corridors in forests result in an adverse situation for the tigers, as they are left with no space for young individuals to disperse. At the same time, the territorial population of breeding individuals face high risk when they foray out of the protected area in the routine course of their territorial movements. It is in these areas, outside the protected areas' boundaries, where conflict exists, which makes this population highly vulnerable to existing threats. From past experience of tiger populations being lost from several of its strongholds, it is evident that the isolation model has not adequately achieved its objectives; this is true of the tiger, and also of other species.

Habitat loss is a serious threat to tiger and associated biodiversity; it is critical to establish protected areas as safe havens. Protected areas can have many management objectives beyond biodiversity conservation, including community participation towards watershed development, sustainable livelihood, outdoor recreation and tourism, scientific research, and environmental education and awareness.

A Protected Area needs to be more than just the setting aside and guarding of a tract of land. Apart from management plans for protection of the fauna and flora, it is also essential that micro-plans are prepared for and with the communities residing at the periphery and inside the PAs, compatible with, and to ensure, protection of their biodiversity. Such plans need to address the various threats to the area and the biodiversity it supports, provide solutions for community needs and for their appropriate and sustainable development.

While environmentalists, biologists and wildlife conservationists play an important role in developing management/micro plans by addressing the ecological issues related to conservation, social scientists such as anthropologists, economists, and political analysts need to play an increasingly greater role in helping protected area managers address the social issues related to conservation. To ensure protected areas' success in conserving biodiversity, it is critical to understand the cultures and needs of the individuals and communities living inside and around the protected areas. Incorporation of communities as direct stakeholders in conservation can also extend conservation efforts beyond the borders of protected areas and has paid rich dividends in many parts of the world (Wells, 1996).

Panna Tiger Reserve presently encompasses 543 km2; in the pipeline is another approximately 200 km2 area of the Gangau Wildlife Sanctuary which is being added to the Tiger Reserve. Approximately forty seven villages are situated around the National Park and thirteen villages are still inside the National Park's boundaries. Villages inside the PA enjoy some privileges in terms of grazing, collection of minor forest products and restrained fuel wood collection. However, these villages are earmarked for relocation outside the PA. Some of the villages are already in the process of rehabilitation.

The villages at the periphery of the PA appear to be the most underprivileged, mainly because they do not have access to the forest resources and development benefits have rarely reached them. Due to this, the standard of living in these villages is generally low and inevitably forest resources are used to fill the gaps; a growing population increases the damage caused by such activities on the adjoining forests. Repressive measures alone by the management, without alternatives provided, cannot lead to lasting solutions. Instead, they create conflict which continues to grow to unmanageable proportions. A holistic approach empowering the local communities is required for conserving these forests while keeping in mind their economic, social and cultural development.

Community-based natural resource management can empower communities through the efforts to manage available resources. Such management is based on the premise that those who are most dependent on natural resources for their livelihoods have the greatest incentive to manage them responsibly, and that they often possess an intimate knowledge of their local resources. Where natural resources are important for livelihood, empowering communities to manage these will have enormous social, economic and environmental impacts. Involving communities in governance is an issue of direct relevance and can allow them to derive economic benefits from this improved management. It is important to generate alternate means of livelihood, reduce dependency of local communities on forests and make them active partners in conservation by channelling direct benefits.

To develop a model where communities engage in supporting the management of local forests, wildlife, fisheries and water resources, a detailed understanding of the dynamics, demography and socio-economic status of the communities is required, as well as some appreciation of the communities' own views and perceptions of the existing problems. Baavan initiated this present study in an effort to move towards such an understanding; the aim is to share the results of this survey, done with some participation of members of the local community, with the villagers so that a community conservation model can be developed with their active participation.

Area of interest

The 543 km2 of Panna Tiger Reserve in Madhya Pradesh is Tropical Dry Forest. It is situated between coordinates 24°15'-24°20' N and 80°00'-80°15' E with an altitude ranging between 200m and 550m. The terrain of the area is typified by extensive plateaus and gorges. The unusual 'step' topography gives the area three distinct levels: the Hinauta and Talgaon plateaus are the middle and upper levels respectively. The lowest 'step', the Ken river valley, splits the Reserve into two; steep slopes, cliffs and deep gorges separate the different plateaus and the river valley.

Panna receives an average annual rainfall of 1100 mm of which almost 60-70% falls between July and September. The area is lush green during and immediately after the monsoon; winters can be characterized from October to January when temperatures may go down to as low as about –0.7 0C. A dry summer season follows until the next monsoon. Water is a major limiting factor during the summers when temperatures can rise to 47oC. The water table is peculiarly low and a large number of borings are either failures or have dried up within short durations.

A large cattle population of about 9,500 and over 6,000 humans live inside the Tiger Reserve. A much larger population of livestock and humans (37,500 cattle and 34,500 humans) surrounds the Tiger Reserve, and depends largely on the forest for their daily requirement of fuel wood, grazing and on other minor forest produce. A monsoon, ‘rabi’, crop of wheat, gram or mustard is the most common cropping pattern of the area. This forced single crop is due to the lack of water for irrigation. Waged labour, minor forest produce (MFP) collection and dairy are the other main sources of earning a livelihood in most of the villages.

Seven villages were selected on the basis of their geographic location with respect to Panna National Park and proximity to the Hinauta village where the research base is situated. These villages are typically constrained as they are surrounded by National Park and Sanctuary boundaries. No space to grow and few available resources put these villages in a high conflict zone: their needs are sufficed only by illegal wood and MFP collection, grazing, and mining.

Socio-Economic Survey

Before initiating community-based conservation activities we considered it mandatory to collect baseline socio-economic data on the target villages. Such preliminary surveys are essential for successful and sustainable implementation of any developmental activity so that informed decisions are made by the community. Once information from the survey is collated, analysed and simplified, we plan to translate it into Hindi and share it with the community to help them also to have a more comprehensive understanding of the problems.

The thorough socio-economic survey of all inhabitants of seven villages has consumed a large amount of time but we hope it will help the communities to plan better. We aim for a larger participation over this planning process because we sincerely believe that such an approach will overcome some initial apprehension shown by the villagers during earlier meetings. The survey objective is to get a better insight into each village community’s composition and structure, their economic status, cattle strength, and dependency on the forests. Since the selected villages are just outside the park, they do not enjoy the usual perks of land use and grazing as villagers inside the park do. This has led to high amount of conflict because every activity which exploits natural resources, such as grazing, fuel wood and MFP collection, is termed illegal. Their resources are limited and legally they have no support for their high cattle populations, irrigation, fuel and other economic needs. The survey’s objective was to quantify activities that are based on natural resources and to gather information, which can help formulate appropriate action plans to reduce the conflict.

Information on basic demography parameters, employment, livestock population, cattle food, milk yield, firewood and its consumption, and minor forest produce was gathered from 602 households of seven villages. The following section provides information on these villages, after a simple preliminary analyses of the data:

Analysis

Population Structure and Composition

The survey was design to collect information on the available workforce, requirements of resources, community wise discrimination of available sources of employment.

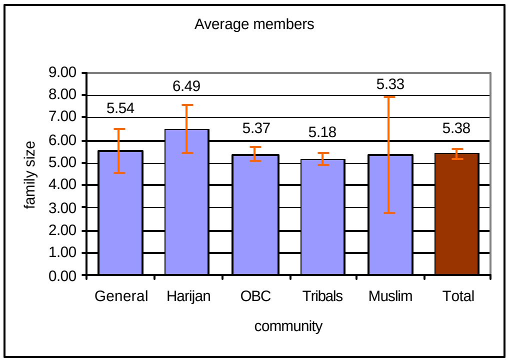


Figure. 1. Average family size in different communities in the surveyed seven villages

The total population of these seven villages is 3239 individuals in 602 families; the average family comprises 5 to 6 members. Overall population is close to unity with a slight bias towards males (1000 male: 953 female; this is better than the country average which is 1000:933). Family size varies slightly among different communities. The largest families are found in the Harijan communities, whereas Adivasis (Tribals) have the smallest families. The Muslim community showed a great variation: it had both smallest and largest families (Figure 1). Very similar trends were observed among the different villages with very little variation in family size (Figure 2).

Adivasis form the largest community (52%), followed by OBCs (Other Backward Castes) (30%) and Harijans (11%). General and Muslim communities together account for 7% of the total population of these seven villages. Umrawan, Madaiyan and Bador villages have the largest Adivasi population. Umrawan is an exclusively adivasi village. Bakchur comprises only of OBC community; and Kaimasan, which is a very small settlement on the road, has a majority of Harijans who are otherwise in a minority throughout the other six villages. Hinauta and Bador, the two largest villages,

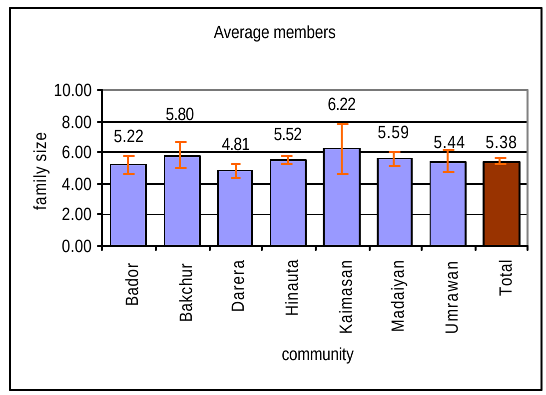
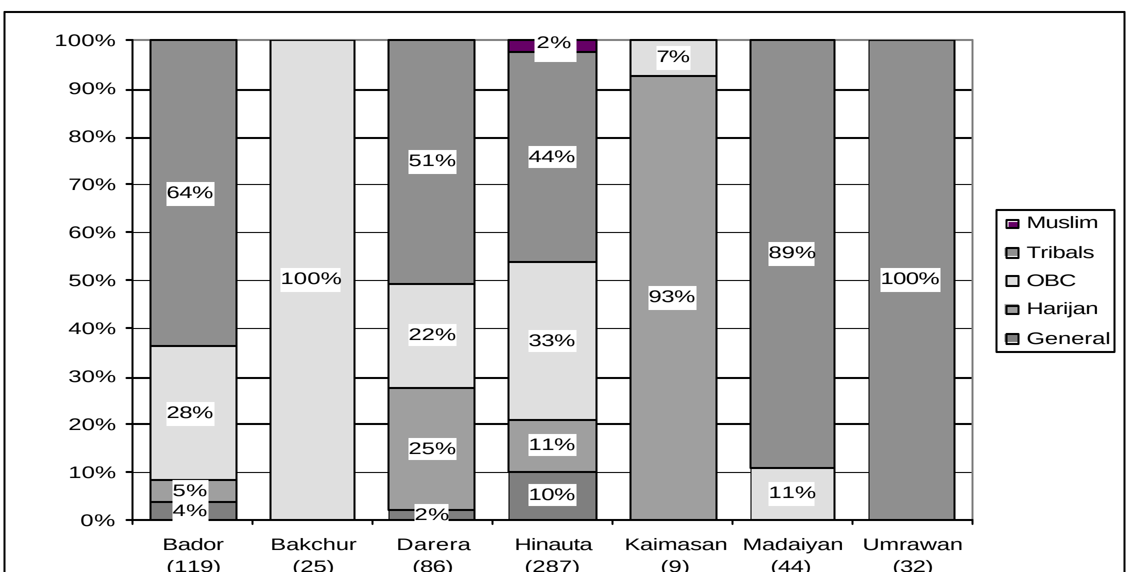


Figure 2. Average family size in the surveyed villages.



Community wise population distribution

Figure 3. Village wise population distribution in the surveyed villages.

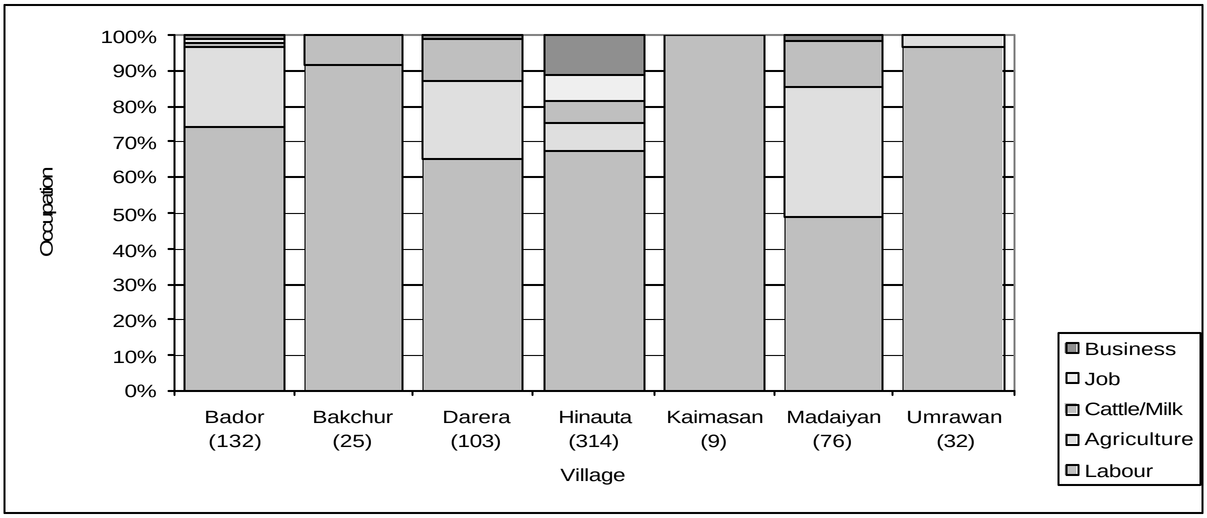
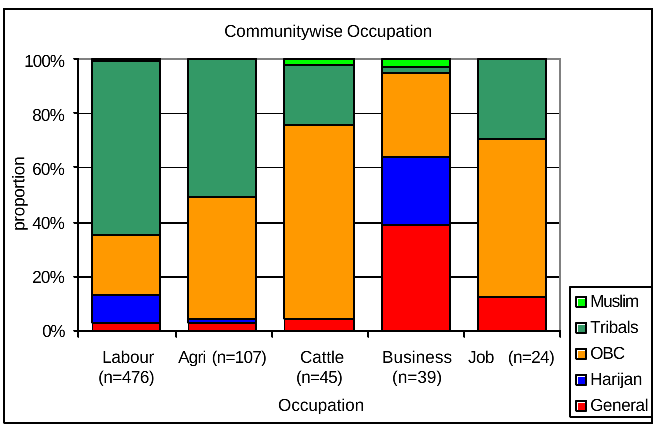


Figure 4. Village wise occupation in the surveyed villages.

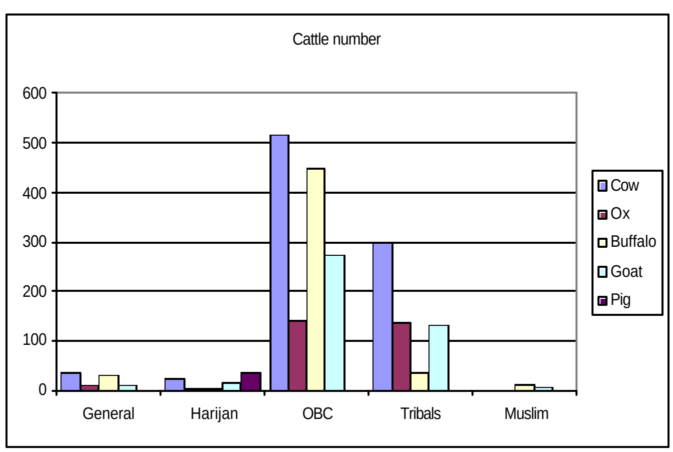
have a comparatively high mix of communities (Figure 3).



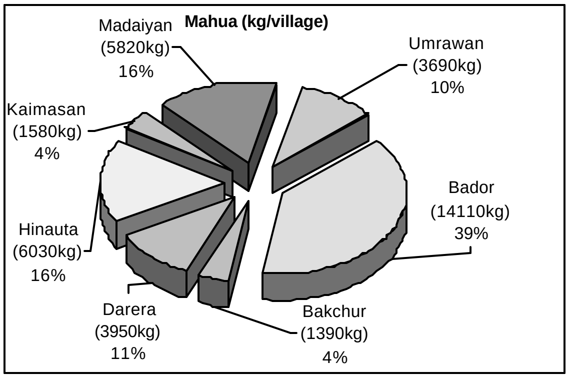
Community Economics

Labour is the predominant employment comprising of about 69% of the total working class. Hinauta, the largest village also has the largest number of people employed in business and labour. Contrary to a general impression, it is interesting to note from the results of this survey that a very small number of people depend on dairy for a living.

When occupations are looked into community wise, it is clear that the main occupation for Adivasis is labour and agriculture. A small population of Adivasi community is dependent on cattle rearing and government jobs. OBC, which are mainly comprised of Yadav community, are largely dependent on livestock rearing and dairy related occupations and agriculture. But most of the milk production is for local consumption. The rest of the population belonging to Harijan, Muslim and general caste are employed mainly in businesses and jobs, either for the government or the diamond mine.



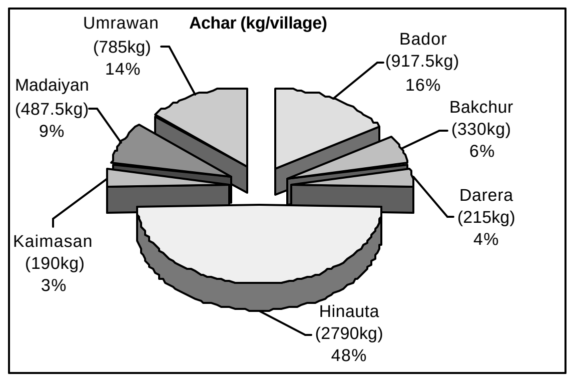
Settlements around forests have historically been dependent on those forests for their livelihood and sustenance. While setting aside these forests as national parks and sanctuaries, the difficulties caused by instantly cutting off people's dependence on them, needs to be recognised. Most people use fuel wood for cooking and for warming



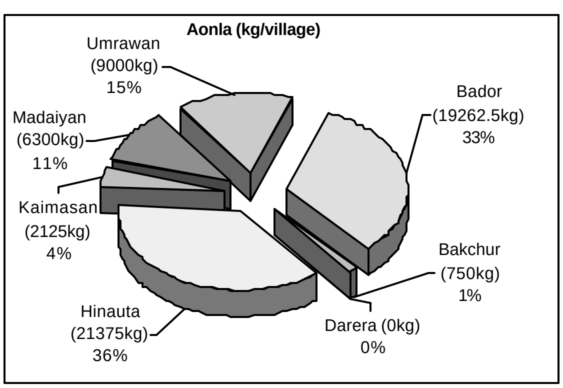
purpose despite the easy availability of cooking gas in some villages. Most households collect MFP and this constitutes a significant chunk of their annual income. Dependence on forests is extensive and the annual impact can be evaluated by the total biomass extracted annually.

Minor Forest Produce (MFP) is one of the prime sources of income for the population other than labour. Most of the households, up to 60% (361) of all the families surveyed (602), are involved in MFP collection. Mahua, Madhuca indica (used for brewing alcohol), Aonla/amla, Emblica officinalis (used for medicinal purposes and as a savoury) and Achar, Bucnania spp. (chirongi as dry fruits) are the main MFP collected from the Tiger Reserve and its neighbouring forests. The Adivasi community is mainly involved in MFP collection and to some extent the OBC (Figure 5). Aonla and Mahua are the two most important MFP items collected by them from the Tiger Reserve.

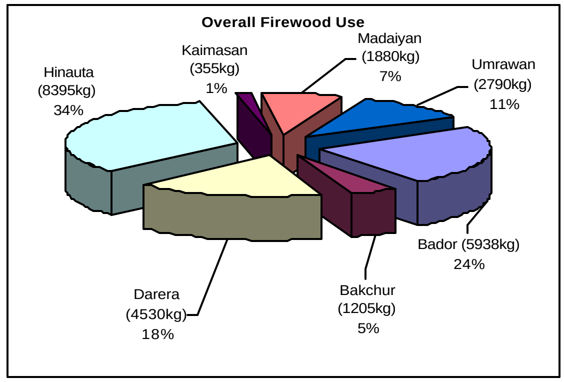
Achar, Mahua and Aonla are the primary non timber minor forest products extracted from the forest. It is estimated that over 5.7 tons of Achar is extracted from the forest during April and May each year. Mahua flowers, which are extracted in the months of March and April, add up to a massive 36.5 tons. Aonla is the least expensive of the three MFPs but it is extracted in mammoth quantity - 58.8 tons. The cumulative earning from MFP collected in all seven villages is INR 7,15,000.00 (About US$16,000.00).



If considered per family income (considering that 60% of families are mainly involved in MFP collection), this comes to $45 (approximately INR 2,000/- per family) which is a small amount; however the impact this collection causes in terms of damage and disturbance to the reserve is significant. It will be an important exercise to communicate this information to the local community to understand the problem in a cost-benefit context. The amount involved in MFP collection is not very large and if similar revenue can be generated through alternate sources it may be possible to greatly reduce the biotic disturbance within the park. It will be difficult to bring a complete stop to these activities but by providing alternatives and with an education awareness programme, its impact on the Tiger Reserve may be minimized.



Fuel wood, is the primary source of energy in the surveyed villages. More than 597 (99%) of the households use wood. In Hinauta, despite easy availability of cooking gas, only 44 families out of 287 use this alternate energy source. The impact of fuel wood demand on the forest is substantial as every week 25 tons of wood is used by the villages. Although the impact of each village is proportional to its population, it appears from the survey data that the community structure does affect fuel wood consumption. From the preliminary analysis it appears that the Adivasi community is using more wood per capita than any other community and are closely followed by harijans. This in turn affects the overall impact of a particular village on the forests. This needs further analysis and exploration to determine why there is higher consumption among these communities; then appropriate activities can be planned to minimize the impact on the Tiger Reserve. The over all impact of a particular village on the forest has two co-variates, viz. population size and community structure. Our approach to mitigate this problem has to be judiciously designed to address the issue both at a population and community level. Further analysis is underway for assessment of these complex associations.



BIOGAS- an alternative to Fuel-wood

Biogas is a clean and cheap fuel that contains 55% to 70% of flammable Methane gas (CH4). It is produced from cattle dung (gobar) through the process of decomposition in a specially designed digester unit, which is called Gobar-Gas or Bio-Gas plant. As a bi-product of this process, the productiveness, as manure, of the decomposed cow dung is increased up to approximately one and half times.

Production (m^3/day)	Cow dung required (kg/day)	Animals required per day		Family size
		Stall fed	Open grazing	
1	25	2-3	4-6	3-4
2	50	4-6	10-13	5-8
3	75	7-9	14-18	8-12
4	100	10-12	20-25	12-16

Benefits of Bio-gas plant

Apart from providing fuel and rich manure the introduction of Biogas plants to the local community will release women and children from the pressure of (illegal) collection of fuel-wood from the Tiger Reserve and from preparing dung cakes. By removing smoke from the kitchen, it thus also reduces the risk of eye and lung ailments. Therefore, not only is it environmentally friendly but a healthy and clean alternative to smoky fuel-wood. It also saves a substantial amount of cooking time. If a Bio gas plant is connected with the sewage system of a house, it can improve the overall sanitation of the village. Besides cooking and illumination, the gas can also be used to run irrigation pumps.

Unit Type and Capacity

Discussions with families who have used or are using bio-gas plants have led us to conclude that the floating model or KVIC model is the better one to use. Though this model costs more initially than the Dinbandhu model, which is more commonly promoted by the government, it is found to be more successful in producing the gas on a regular basis. There are several problems associated with the Dinbandhu model, one of which is the inconstant supply of gas. Because the chamber where the gas is collect is fixed and small, after 30 to 40minutes of use the pressure declines, affecting the supply of gas to the burner. On occasions there is not even enough pressure to use the burner and the users have to wait until the pressure builds up again. This causes interruptions in cooking and is not

Unit capacity (m^3)	NABARD authorized unit cost		Subsidy amount	
	Dinbandhu model	Floating model (KVIC)	SC\ST	General category
1	5820	9500	3500	1800
2	7960	11500	3500	1800
3	9605	13000	3500	1800
4	11515		3500	1800
5 or higher	n.a.	n.a.	3500	1800

appreciated by the user. Another, not uncommon, problem is the appearance of cracks in the chamber causing a leak; this is more likely to occur where the masonry work is of poor quality. On the other hand in the floating model pressure remains constant throughout, until all the gas is utilized. Moreover, at times the plant can continue to produce gas for couple of days even when dung is not added or forgotten by the user. The floating chamber is either made of metal or more recently by fibreglass material, which lasts for many years - on average 8-10 years - with very little maintenance. Its only disadvantage is the initial cost and a larger space requirement; even so we find it to be the more successful model. A comparison cost of different sizes is provided in the table.

Nutritious constituent	Bio fertilizers	Local fertilizer
Nitrogen	1.5-2.0%	0.5-1%
Phosphorous	1%	0.5-0.8%
Potassium	1%	0.5-0.8%

Networking with NGO, Individuals and Govt. Organisations

In the last seven months, several informal meetings were organized with local villagers with an objective of bringing them together. This exercise was useful in constituting a committee in Hinauta village. Several rounds of discussion took place between members of Baavan and the village communities. The objective of conducting many such meetings was to develop a relationship of trust between the two groups before plunging into concrete activities. While we succeeded in answering some of the queries made by the villagers, it was also encouraging to find them volunteering to take up responsibilities. Since any community development activity should have representation from all the communities within the village, we encouraged them to choose representative members within themselves. The final group was formed through democratic interaction and discussions and with proportional representation of different communities.

Visit to Chitrakoot

One of the first activities undertaken under this project was in relation to cattle rearing and milk production; after several discussions held with villagers, the village committee of Hinauta nominated a group of representatives whom we took on a visit to Chitrakoot near Satna (in M.P.) where the Govansh Vikas Evom Anushandhan Kendra, Arogya Dham, Deendyal Research Institute is situated.

The following activities were observed and explained by the experts in details:

1. Importance of Stall feeding

2. Indigenous cattle breed improvement
3. Vermicompost
4. Biogas as an ultimate source of energy
5. Preparation of other compost using cow dung, urine and weeds (such as lantana, ipomoea and other herbaceous materials)

Villagers saw and discussed the merits of the ten different breeds of cows and bulls which were properly managed in the research centre. It was a day long visit which helped the villagers to understand the importance of bovine economy. It also helped in the selection of cattle breeds suitable for the area. The idea was to explore improved and more productive animal husbandry practices and to introduce villagers to the concept of stall feeding of cattle for better dairy production with the objective of reducing/removing the livestock pressure on the park. The visit also served to educate ourselves and them on how local breeds can also produce more milk with very little investment; villagers were also introduced to the numerous means of utilising the by-products that can make them economically secure with a reduced number of cattle. Discussions with scientists from the institution led to a better understanding of the benefits of stall-feeding and how an improved management of fewer cattle can enhance their gross income.

Similar meetings were also held in other target villages, where an introduction to the organization and its objectives were explained to the villagers. The response of the villagers was welcoming but at the same time they were a bit apprehensive about any such ventures. It was evident from the discussions with them that this apprehension is a fallout of their bitter experiences with similar previous initiatives that had eventually failed in absence of proper research and follow-up actions. It was also observed by us that part of their apprehension was due to the imposing nature of government policies; rather than based on community need and the realities of the field situation, most of the earlier initiatives had a top-down approach. Such impositions does not encourage participation and fails to generate required enthusiasm. Such imposed actions will eventually lead to failure of what might otherwise be a brilliant concept. The overall experience and feedback from these meetings with the villagers was encouraging, as more members of the villages wanted to visit Chitrakoot to see for themselves the potential of improved production of dairy products from the local breeds and the techniques developed by the organisation there. In view of the enthusiastic reaction, we plan to take a few more such tours for other villages.

Visit to Tara Gram

Tara Gram is an organizational setup situated near Orchha, in Tikamgarh district, part of a well known national NGO, "Development Alternatives". Tara Gram works at the community level for employment generation and empowerment of poor communities. They function as a hub with spokes of an efficient social network. The main objective of our visit was to collect information on biogas. We also learned about various activities that are being conducted in the field of alternate energy sources. Tara Gram has a range of activities aimed at generating employment and energy with an entrepreneurship approach. Different sections within Tara Gram comprise of charcoal production from waste wood, electricity generation from ipomoea (weed) and other biodegradable waste, production of hand-made paper (recycled paper), biogas production for domestic use from cow dung and other biodegradable waste, providing low cost illuminating and production of energy efficient cooking stoves (chulhas), preparing and marketing a range of confectionaries such as pickles, jams, marmalade, sauces and chips from locally available fruits and vegetables. It was found that while biogas was successful in some villages, detailed discussions with their programme staff highlighted the point that to make it a successful venture, consistent maintenance support for a few years is essential. The social network of Tara Gram is also involved in water conservation works, which include designing and building check-dams to cater for water requirements and mass plantations to serve a two-pronged purpose of raw material for various developmental activities.

The visit to Tara Gram opened up various possible avenues that were not known to us, and also stimulated ideas of other possible activities, which may be undertaken. The visit and discussions with their staff was an eye-opener and educational. With their vast experience in and around Panna Tiger Reserve, their willingness to associate with our community based developmental project was encouraging. We hope to incorporate their experience and expertise in initial building and maintenance of the bio-gas (KVIC model) and improved Chulhas (fuel-wood stove).

Meeting other NGOs:

Baavan has met and interacted with a number of other NGOs and organisations working locally in related fields; Unnati and ‘Action for Food Production’ (AFPRO) Gwalior were two of these. Through them we were able make some very useful contacts, which can be tapped when required in future. The district office of Madhya Pradesh Agro Industry Ltd in Panna also provided us access to technical information needed for building biogas plants, right from the installation stage to its maintenance and to efficient productive methods that are indispensable for its success in remote areas.

Information gathered about the support this organisation can provide in installation, maintenance, training and more importantly financial support to such an activity is crucial in expanding our activities in these villages with their help. We are still in the process of contacting several other organisations working on dairy related activities. One such organisation is related to cheese production so that its possibility can be assessed in detail.

The Zila Panchayat Chief Executive Officer’s (CEO) response to our initiatives was very warm and he showed keen interest in our objectives and promised his support in making this project a reality. He even assured financial support in the installation of biogas plants in the villages. His support shall be crucial in assuring the holistic development of the villagers. The newly elected President of Zila Panchayat was also very keen to give a helping hand and assured a full cooperation with the organization in its pursuit.