

**ECOLOGY OF WILD PIG (*Sus scrofa*)  
AND HUMAN-WILD PIG CONFLICT IN AND AROUND  
RANTHAMBORE TIGER RESERVE, RAJASTHAN.**

**Thesis submitted to  
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**For the Degree of  
Doctor of Philosophy  
in  
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(Zoology)**

**By**

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**Under the supervision of  
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**Certificate**

I have great pleasure in forwarding the thesis of Mr. Kuldeep Singh Barwal entitled "Ecology of wild pig (*Sus scrofa*) and human-wild pig conflict in and around Ranthambore Tiger Reserve, Rajasthan" for the acceptance for the degree of Doctor of Philosophy in Wildlife Science (Zoology). The thesis embodies original findings of the research work on wild pigs and the interpretation of facts. The research work carried out by Mr. Kuldeep Singh Barwal under my supervision has not been submitted in part or full to any other University/Institution for the award of any degree.

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## Summary

The wild pig, *Sus scrofa cristatus* Linnaeus, belongs to Order Artiodactyla, Family Suidae, Subfamily Suinae and Suborder Suiformes. The race found in India is *Sus scrofa cristatus*. The wild pig is one of the most widely distributed terrestrial mammals. It has always been associated itself with man, and successfully utilises the human altered landscape. The wild pig is Schedule III species of Wildlife Protection Act, 1972. The Indian subcontinent is represented by a single widely distributed genus (*Sus*) with four subspecies. They are the domestic pig (*Sus domestica*), common wild pig (*Sus scrofa cristatus*), Andaman wild pig (*Sus scrofa andamanensis*) and Nicobar wild pig (*Sus scrofa nicobaricus*).

Wild pigs are gregarious. A sounder of wild pig constituted of adult females, sub-adult males, yearlings and piglets. Adult males move in all male groups. Old boar is usually solitary or moves with a companion. Herds or sounders of varying size are seen, but they are usually of 6-20 individuals. Wild pig is a generalist species and is admirably adapted to range of habitats such as forests, secondary thickets, woodland and grasslands in which they roam in small bands (sounders) of varying number of individuals. The wild pig is essentially a forest dwelling animal preferring to remain in shade. It prefers thick vegetation as it provides protection from predators. Shade of trees and shrubs is preferred as it aids in thermoregulation. Access to water and shade is important as wild pig must drink regularly, since it has no sweat glands.

They are considered to be diurnal by some scientists and to be nocturnal by others. Wild pigs spend most of their inactive daylight hours in characteristic day beds. Nest building is one of the most overt behavioural indications of farrowing. Wild pigs throughout their distribution ranges in world are omnivorous and opportunistic feeders. Wild pigs occupy a wide variety of habitats from semi-desert to tropical rain forests, temperate woodlands, grasslands and reed jungles, and often venturing into agricultural land to forage. After rainy season, they are commonly seen in crop fields. No animal is more destructive to crops than pigs. They have always been associated itself with man, and successfully utilises the human altered landscape. The species is known for its biological and ecological adaptability. They live on crops, roots, tubers,

fruits, insects, snakes, offal and carrion. Wild pigs are prolific breeders and apparently breed throughout the year. The reproductive activity in pigs tends to be seasonal and positively correlated with the relative availability of food or climatic factors. Wild pigs notoriety as a crop pest is universal. They cause extensive damage to agricultural crops and utilize the agro-ecosystem for food resource and shelter. Besides agricultural crops, they cause damage to ground vegetation, orchards, forest plantations and possibly act as carrier of some infectious diseases.

There is no systematic study on the ecology and behaviour of wild pigs especially with respect to agricultural crop damage and economic losses in man-altered protected areas-village interface situations. There is paucity of information on wild pigs from Indian sub-continent; the available information is fragmentary. Further the research findings have little or no application in India due to different environmental, socio-cultural and agricultural practices. So the study on ecological and management considerations in Ranthambore National Park will provide a basis for developing an action plan to mitigate the problem effectively and on a long-term basis.

The **Chapter 1** deals with Introduction of the wild pig study, its significance and objectives. The **Chapter 2 and 3** include the review of literature and the study area respectively.

In **Chapter 4**, the spatial and temporal distribution of wild pigs in context of habitat attributes in and around Ranthambore National park has been presented. Wild pig is a generalist species and is admirably adapted to range of habitats such as forests, secondary thickets, woodland and grasslands in which they roam in small bands of varying number of individuals. Wild pigs live in grass or scanty bush jungle, sometimes in forest and quite commonly in high crops. Wild pigs can thrive as readily in plains as in the mountains, in swamps as well as relatively dry steppes, in remote areas as well as in densely populated areas. Space use of wild boar depends on season, food availability and anthropogenic disturbances. This would help in management of habitats by wild pigs, developing conservation plan for the species and evolving mitigation strategies for human-wild pig conflicts on the long term basis.

To study spatio-temporal distribution of wild pigs in relation to habitat attributes in Ranthambore National Park, direct sightings of wild pigs were made, and locations of

indirect evidences such as diggings and faecal matter during the surveys and along line transects were recorded. For the quantification of landuse pattern and vegetation, 45 linear transects in different land use and vegetation types encompassing pig habitats were used. Line transects were laid in different habitat types in proportion to their availability. Reconnaissance of the areas to get an idea of the cover types, terrain and landuse pattern etc. was done and also to develop interpretation key. Forty five linear transects were laid covering the representative landuse cover and vegetation. Pre-designed formats were used to record information on terrain, soil, canopy cover, shrub cover, shrub height, stand height, ground cover, number of each tree, shrub and herb species etc. Information on availability and utilization of different habitat categories was collected along the transects. The data on habitat utilization was also collected by making observations at waterholes and by quantifying digging signs.

The group size of wild pigs varied from solitary animal to 52 individuals, and it also showed variation from season to season. Wild pigs were found distributed all over the national park as well as in peripheral areas, and sighted throughout the year. Lone pigs were sighted 169 times and constituted 21.39% of the total observations. The group size of 3-10 individuals was sighted maximum times. Large group of 27-34 individuals were rarely seen. Group size of wild pigs was also found to vary in different seasons. Wild pigs found to occur mostly in small and medium sized groups, and larger groups were sighted less and less. In monsoon, large groups of wild pigs were also encountered along with sighting of small groups. In summer, generally small groups of wild pigs were encountered most.

Wild pigs were found distributed in different landuse and vegetation types, namely, *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest, Water bodies and Agriculture. All these habitats were differentially used by wild pigs throughout the year. Distribution or sightings of wild pigs in different habitats were found to vary in winter, monsoon and summer seasons. Based on diggings and presence of faecal matter, wild pigs were found distributed all over the national park and in peripheral areas.

Wild pigs were used different habitat variable like terrain, canopy cover, aspects, distance from road, distance from water bodies, distance from village and use of

elevations. Various terrain types such as flat, medium slope and gentle slope were found to be differentially used by wild pigs. The use of slope by wild pig was found to be significantly different among the seasons and the gentle slopes were used significantly high by the wild pigs in comparison in all seasons. Distribution based on sighting of wild pigs showed much variation in their use of medium dense, open and sparse canopy types. They preferred medium dense and open canopy much more than sparse canopy. Wild pigs were found to use different aspects based on their sightings; they used different aspects viz. East, North, Northeast, Northwest, South, Southeast, Southwest and West to varying extent. Distribution based on sighting of wild pigs showed use of areas at variable distance from the road. They were generally found to use areas within 1 km from the road more than areas used at 2 km distance from the road. Distribution based on sighting of wild pigs showed almost no variation in distance from the water bodies in different seasons. Likewise, distribution of wild pigs showed much variation in relation to distance from villages. They were found to use different elevations in the study area. Distribution of wild pigs was highest at an elevation from 351 to 400m in winter, monsoon and summer seasons.

In **Chapter 5**, methods for capturing and handling wild pigs were developed and evaluated. Physical and chemical restraint techniques for wild animals are essentially required for research and management purpose. Wild pigs are often trapped for ecological studies and eradication efforts. Trapping of feral pigs has long been used as a control measure and has been useful to capture animals for research and for the game meat export. There are two main live trap designs that are useful for capturing feral pigs: panel and silo traps. Both types of trap are made of steel mesh and incorporate a one-way entrance. Wild pigs captured in both box and panel traps are usually physically restrained. Different drug combinations and dosages are used for immobilization of wild pigs.

For capturing wild pigs, planning of capture procedures, designing and fabrication of traps, trapping protocol, selection of capture sites, setting of panel traps, bait preparation and pre-baiting to habituate wild pigs were essentially required and undertaken. Several trap designs: the silo trap, the drop-gate trap, the panel trap and the box trap are used for capturing pigs. But panel traps are preferred more because of their portability and ease of construction. Panel traps were fabricated by using steel

mesh panels of 1.5 m high and 2.5 m breadth with a mesh size of 10 cm x 10 cm. The steel mesh with a small grid size of 50 x 75 mm or 50 x 100 mm was used for fabrication. The panel traps were set in Rajbagh and Guda, and the bait comprising of fermented maize, groundnut, gram and molasses was provided inside and outside for capturing wild pigs. The fermented bait was increasingly attracting the wild pigs and in such a way, wild pigs were slowly habituated to visit these traps. A total of 153 wild pigs of varying age classes ranging from <5 kg to 80 kg were captured without a single capture-related mortality in Rajbagh and Guda during 2007-2008.

A combination of drugs like Xylazine hydrochloride, Telazol and Succinyl chloride were used for capturing of wild pigs in Kundal, Rajbagh, Malik Talab, Patwa Bawari and Guda from 2008 to 2009. Seven free-ranging wild pigs, two males and five females, were captured successfully by using this combination of drugs. Reverzine was mainly used as antidote. All wild pigs were continuously monitored until full recovery was evident. All wild pigs immobilized and captured were handled carefully and rapidly to avoid injuries and minimize stress. The recovery phase was followed through visual observations.

The **Chapter 6** deals with the study of the ranging pattern of wild pigs based on radio-telemetry. To study the habitat use, movement, activity pattern, home range, interaction among the individuals and other socio-biological aspects, wild pigs need to be radio collared. Many studies on capture and radio-collaring of wild and feral pigs were carried out in Australia and outside India. These studies on wild and feral populations in other areas have yielded important information on habitat preferences, home range traditions and a better understanding of life history strategy in this animal

The study on capture and radio-collaring of wild pigs was conducted from April 2008 through June 2010 in Ranthambore National Park. For radio-collaring of wild pigs, Rajbagh, Guda, Kundal, Patwa Bawari and Malik Talab areas were selected for capturing wild pigs in free ranging situation. The VHF radio-collars of 150-151MHZ frequency range were used. For mounting radio-collars on wild pigs, well designed harness made up of nylon polymer mix were used. Direct observations were also made on the habitat use and activity pattern of other non-collared wild pigs during August 2005 through June 2010. We sighted 6069 wild pigs, and recorded their point

of locations, time, habitat use and activity etc. within the protected area and in peripheries of the park. But the data obtained from the radio-collared animals was only used for studying the ranging pattern of wild pigs.

During 2008, the home range of Kundal female 1 was 14.3 km<sup>2</sup> and Rajbagh female 2 was 0.5 km<sup>2</sup> by using 100% MCP. Among the animals collared in 2009, the male in Lakarda showed a home range of 18.5 km<sup>2</sup>. The female 3 in Patwa Bawari and female 4 in Rajbagh showed home ranges of 24.3 km<sup>2</sup> and 6.5 km<sup>2</sup> respectively. The Guda female 5 collared in peripheral area of the park showed home range of 21.5 km<sup>2</sup>. The home ranges of the female in Patwa Bawari were 8.8 km<sup>2</sup>, 2.0 km<sup>2</sup> and 4.4 km<sup>2</sup> in winter, monsoon and summer seasons respectively, which were much smaller than the annual home range of 24.3 km<sup>2</sup>. Larger area was covered by this wild pig during winter than monsoon and summer season. The home ranges of the female in Rajbagh were 4.3 km<sup>2</sup>, 3.3 km<sup>2</sup> and 0.8 km<sup>2</sup> in winter, monsoon and summer seasons respectively, which were also smaller than the annual home range i.e. 6.5 km<sup>2</sup>. The area covered by this wild pig was more during winter as compared to areas covered in monsoon and summer. The home ranges of the female in Guda were 15.9 km<sup>2</sup>, 2.0 km<sup>2</sup> and 6.3 km<sup>2</sup> in winter, monsoon and summer seasons respectively, which were also smaller than the annual home range of 21.5 km<sup>2</sup>. Several management and ecological implications could be drawn from this study. Small, compact and sedentary home ranges with stable seasonal centres of activities and extensive home range overlap showed that a small area of the habitat types had sufficient biological productivity and physical components to meet the maintenance needs of wild pigs.

The **Chapter 7** deals with the assessment of the nature and extent of human-wild pig conflicts: Qualitative and quantitative assessment of crop damage by wild pigs in different seasons. The wild pig is one of the most widely distributed large mammals. It has always been associated itself with man, and successfully utilises the human altered landscape. Agricultural crop depredation by wild animals is a major problem in many parts of India, and wild pig is one such species causing extensive damage. Wild pigs raid crops and utilise the agro-ecosystem for food resource and shelter. The wild pigs notoriety as a crop pest is universal. Damage to the agricultural crops by wild boar in peripheries of forest areas has become a problem of severe nature in the recent past.

Besides agricultural crops, it causes damage to ground vegetation, orchards, forest plantations and possibly acts as carrier of some infectious diseases. As a result, there has been increasing trend in the human-wild pig conflict in and around protected areas throughout the country. Now people have developed antagonistic attitude towards the wild pigs and which is adversely affecting the conservation efforts for endangered species are also badly affected. Despite local efforts to control the wild pigs, it continues to remain a problem animal. The propensity of wild pigs to overcome deterrents is a behavioural adaptation, about which very little is known. So it is important to understand the behaviour of wild pigs to use agro-ecosystem, nature and extent of human-wild pig conflict and assess qualitatively and quantitatively the damage to agricultural crops in and around Ranthambore National Park.

A reconnaissance survey was conducted in and around the National Park and information on the nature and extent of human-wild pig damage problems was collected from the villages. Incidences of human casualties by wild pigs and agricultural crop damage problem were evaluated based on the information collected from the office record of forest department, questionnaire survey of the villages and interview of the victims or their families and analysis of human casualty cases. Field managers were also contacted to know about the gravity of the problem. For assessment of damage to rabi and kharif crops, eighty eight 'control' plots and eighty eight 'un-control' plots of 2m x 2m dimension each were randomly laid in crop fields of six villages. The crop yield difference between 'control' and 'un-control' plots was calculated to know the extent of losses to different crops.

Out of 90 villages located in the periphery of the park, 41 villages were surveyed to collect information on human-wild pig conflict from 236 respondents. Most of these villages were located within two kilometres from the park boundary and they were reported to have severe crop damage problem. Some of the worst affected villages due to wild pigs were Indala, Khatuli, Padara, Jaitpur, Mai, Kushalpura, Chhan, Halonda, Ulliyana, Anda and Shyampura. A total 13 human casualties were caused by wild pigs in nine villages during 2005-2009. Wild pigs accounted for human injuries only; there were no death cases. They were responsible for injuring 8 males, and 5 females in these villages. Seven human casualties occurred in the age group of 41-50 years.

Maximum casualties occurred between 0801-1200h. Wild pigs were responsible for maximum human casualties in crop fields.

The main crops grown in these villages were wheat, maize, gram, mustard, bajra, jowar, chilli, til, groundnut and urad. Wild pigs caused severe damage agricultural crops due to extensive feeding activity. Crop fields which were located in close proximity of forests were badly affected. Wild pigs were found to cause extensive damage by uprooting plants with their snout and trampling. Crops most affected were gram and wheat. According to 236 respondents, the mean percent damage to agricultural crops by wild pig was reported to be 37.8% in peripheral villages. Damage to wheat, maize, gram, mustard, bajra, jowar, chilli, til, groundnut and urad crops as reported by respondents, was of varying extent. Damage to groundnut crop as reported by 53 respondents ranged from 30-80%. The extent of crop damage showed variation in villages located at varying distance from the park boundary. Villages situated within 2 km from the park boundary, loss to wheat crop due to wild pigs ranged from 20-60%. Damage to gram and bajra crops ranged from 25-70% and 20-80% respectively in villages situated within 2 km from the park boundary. According to 79 respondents, damage to jowar crop ranged from 20-100% in villages situated within 2 km, and the mean percent damage to jowar crop was 32.9. Wild pigs showed strong preference for all phenological stages of groundnut, urad, bajra, gram and wheat crops. Damage to these crops was mainly due to feeding, digging, trampling, crushing and wallowing activities of wild pigs. There was marked monthly variation in the extent of damage to wheat and gram crops by the wild pigs. The mean losses per bigha to grains/seeds of wheat, mustard, gram, bajra, groundnut and urad crops due to various activities of wild pigs were estimated to be 56.64 kg, 9.9 kg, 53.49 kg, 105.3 kg, 84.6 kg and 9.56 kg respectively in all six villages. Various mitigation strategies to reduce attacks on farmers and crop damage by wild pigs are suggested.

In **Chapter 8**, the use and efficacy of power fence was evaluated in controlling crop damage caused by wild pigs. Traditionally, wild pigs have been kept out of cultivations by scaring them away or restricting them with barriers. Scaring wild pigs with flash lights, fire, fire-crackers, crop protection guns, stone slings etc may effectively deter them sometimes. Most forms of effective barriers for wildlife such as trenches, rubble wall or conventional fences, are expensive to construct and maintain.

A power fence is purely a psychological barrier. Power fence is a relatively new control technique and not fatal for animals and only restricts their movements. Power fencing is most effective and safe to animals and to humans. If properly constructed and maintained, it can effectively keep most of the animals out. Power fencing system provides an economic and a practical solution to achieve maximum protection through effective control of animal trespass. In this study, we developed the pig-proof power fences by construction of fence line around the crop fields in Jaitpur village situated on the boundary of Ranthambhore National Park, and evaluated their efficacy in reducing crop damage. We compared the extent of wild pig crop-raiding in the fenced and adjacent unfenced areas.

The power unit had a solar panel, a 12 volt power battery, and an energizer to provide current to 1.5 km length of the two fences. An energizer is the heart of the system and powered by lead acid batteries of 12 volt. It is device which converts low voltage to pulses of high voltage, but of low current thereby making the shock harmless in terms of physical damage. We erected the electric fence as per the designs specified in June 2006 when the fields were prepared for sowing crops. A fence design with posts at an interval of 8 meters and GI wires at the height 15, 37.5, 62.5, 100 and 135 cm was tested. Another design with posts at an interval of 8 meters and GI wires at the height 15, 37.5, 62.5, 100, 135, 165, 195 and 225 cm was also constructed. The pig-proof fence was 4.5 feet in height with five strands; the first and third strands were connected to earthing, and the rest three i.e. 2<sup>nd</sup>, 4<sup>th</sup> and 5<sup>th</sup> strands were live strands. The pig and nilgai-proof fence line was constructed along the forest boundary and crop fields, and it was 8.5 feet in height with 8 strands. The 1<sup>st</sup>, 3<sup>rd</sup> and 5<sup>th</sup> strands were connected to earthing system, and the rest five strands i.e. 2<sup>nd</sup>, 4<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> were live wires. The fences were monitored regularly by walking along the perimeter to evaluate their effectiveness. Both the fences were maintained properly. We recorded high range of voltage (7.9-8.1 KV) at the energizer point. Average output voltage of the main fence i.e. nilgai-pig proof fence ranged from 5.5 to 6.5 KV. The voltage of small pig-proof fence was slightly on the lower side i.e. 5.2 to 6 KV. The voltage at 1000m fence length was higher than at shorter distances, which might be due to good earthing system. Overall the fences were found effective against pigs and nilgai.

Finally recommendations are made for management of wild pigs and mitigation of human-wild pig conflicts in villages situated in and around Ranthambore National Park. Suggestions to check mixing up of wild and domestic pigs to avoid genetic hybridization between them for long-term conservation of wild pig populations are also made.

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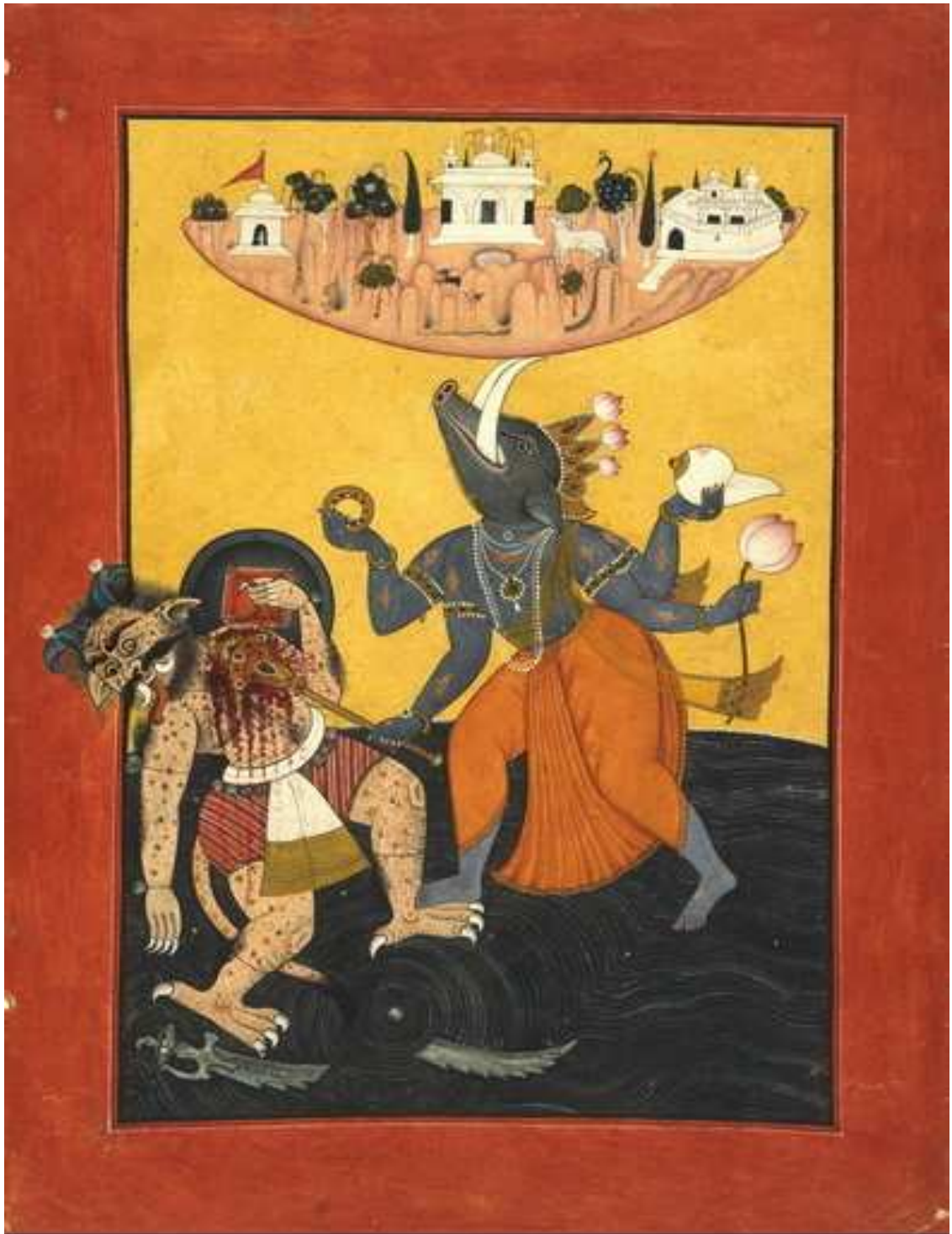
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## Varaha Avatar

(*Sus scrofa* Linnaeus, 1758)

Races in India: *cristatus* Wagner. Andamans: *andamanensis* Blyth. Nicobars: *nicobaricus* Miller. Ceylon: *cristatus* Wagner

# Chapter 1

## Introduction

The wild pigs are ungulates native to Eurasia. Several different words in English identify different types of pigs eg. boar - an adult male pig, sow - an adult female pig, piglet or farrow - a juvenile pig, shoat - a young pig between 100 to 180 lb (50 to 90 kg), gilt - an immature female pig, barrow - a castrated male pig, hog - synonym for wild pig in the United States; in its original sense it means a castrated boar and swine - synonym for pigs (plural).

### 1.1 Physical characteristics

The length of body and head varies from 90 to 180 cm, length of tail varies from 30 to 40 cm and body weight ranges from 50-200 kg. The wild pig has distinct sparser coat and fuller crest or mane of black bristles reaching from the nape down the back. The colour of the animal is black mixed with grey, rusty brown and white hairs. The young are brownish and grown up pigs are grayish in colour. New born wild pigs are brown with light or black stripes on its back. The head is very strong and used in fighting, digging and bulldozing vegetation. An elongated head with an abruptly truncated mobile snout ending in a flat disc having the nostrils is distinct in pigs. Pigs and peccaries are similar in having a remarkable organ adapted to rooting in the soil - the snout disc or rhinarium. The tip of the snout is flattened and supported by cartilage, a tough pad for pushing into even quite hard ground. The upper edge of the disc is at right- angles, or even at an acute angle to the top of snout, so that the loosened soil is most easily pushed aside by an upward motion of the head. The lower edge runs without a break into a mucous membrane of the mouth. The nostrils are centered in the disc where they are well placed to detect potentially edible items but can be closed so that soil does not enter the nasal passages. The snout is moved by special muscles located just in front of the eyes, so that fine rooting movement is possible.

The dental formula of adult pigs is 3.1.4.3 in each jaw, giving a total of 44 teeth. The rear teeth are adapted for crushing. In the male the canine teeth form tusks, which grow continuously and are sharpened by constantly being ground against each other. The wild pigs have incisor teeth in the upper jaws. Their molar teeth when unworn are capped with small hillock-like columns. The tusks (canines) are well developed in the males. The lower tusks grow as long as 32 cm. on the outside curve. Both the upper and lower tusks curve outwards and project from the mouth. As they are not ruminants, their stomach is much less complex and consists of a single chamber. Their feet are narrow and have the bones of the four toes complete. The petty toes are completely developed but do not touch the ground while walking. The cannon bones are not developed in the feet; the bones which fuse to form the canon bone in true ruminants remain distinct in these animals.

Wild pigs are hoofed animals. They walk on the tips of special toes, the hoofs. Cloven-hoofed animals walk on a central pair of hoofs, but many also have an outer pair of dewclaws on each foot. These are a little farther up the leg than the main hoofs, and similar in structure to them. Most even-toed ungulates (such as sheep, goats, deer, cattle, bison and pigs) have two main hooves on each foot, together called a cloven hoof. Most of these cloven-hoofed animals also have two smaller hoofs called dew-claws a little further up the leg, these are not normally used for walking, but in some species with larger dew-claws (such as deer and pigs) they may touch the ground when running or jumping, or if the ground is soft.

In some species (such as cattle) the dewclaws are much smaller than the hoofs and never touch the ground. In others (such as pigs and many deer), they are only a little smaller than the hoofs, and may reach the ground in soft conditions or when jumping. Some hoofed animals (such as giraffes, pronghorns and modern horses) have no dewclaws. In some so-called 'cloven-hoofed' animals such as camels, there are no hooves proper – the toe is softer, and the hoof itself is reduced to little more than a nail. Cloven-hoofed mammals have 4 toes: two cleaves (at the front) and two dew claws (at the rear). Unlike most deer, wild pigs leave 4 clear imprints, as in the **Plate 1 and 2**. This is because their gait (and the fact that their dew claws are located lower down on the leg than those of deer) results in the dew claws touching the ground.

Hence, most wild pigs leave dew claws imprints, whereas deer usually do not. Most deer leave just two slots (left by cleaves). This type of hoof prints are probably left by a young wild pigs as the front two claw marks are pointed and narrow. Those of adult boars are broader and more rounded.

## 1.2 Evolution and systematics

The wild pig (*Sus scrofa cristatus*) belongs to the Order Artiodactyla, Family: Suidae, Sub-family: Suinae and Sub order: Suiformes. The taxonomic classification of wild pig is as follows:

Order	Artiodactyla
Sub-order	Suiformes
Super family	Suoidea
Family	Suidae
Sub-family	Suinae
Genus	<i>Sus</i>
Species	<i>scrofa</i>

Pigs belong to the mammalian order Artiodactyla, the even-toed ungulates. There are three major lineages or clades- the Suiformes, tylopoda and pecora-each rank as sub-order. Of these, the Suiformes are the only non-ruminants. The tylopoda are the camels and llamas, and the pecora are the deer, giraffes, cattle, goat, antelope, and their relatives. In many ways, the Suiformes are the most primitive of the three. The stomach is less complex than in ruminants, many teeth are present and they are low crowned and bunodont, the unguligrade condition of the lombs is less advanced and, in one family, the female make nest. These are some generalizations which indicate the primitive nature of some Suiform artiodactyls. Within Suiformes, there are three living families: Hippopotamidae (hippopotamuses); Dicotylidae (peccaries) and Suidae (pigs).

The Suiformes underwent an early Tachytic evolution phase during Eocene and Oligocene periods. Some of these families appear to be akin to the evolutionary line of the later forms, while others are abortive evolutionary lines. The forms that occurred during Oligocene are comparable to the modern pigs and peccaries. It is probable that from the genera similar to the European *diliochoerus* and American *perohoenus*, new world peccaries were evolved, while the old world suids evolved from the forms similar to the *palaechoeras* of the European lower and middle Pliocene. The evolution of the pigs from the beginning has shown moderate increase in size, a great lengthening of skull, retention of four toed feet and a complicated dentition. The existing genera of pig tribe are also known in fossil condition, *Sus* itself goes back as far as the upper Miocene. *Sus erymanthius*, the erymanthine pig is known from the beds of that age in Greece, England and Germany (Tiwari, 1985).

### 1.3 Distribution

Wild pigs are widely distributed. They occur in Europe, North Africa, Asia, Sumatra, Japan and Taiwan. They range in nearly the whole of India, Burma and Tenasserim, Siam, and part of the Malay Peninsula. It is very common in Ceylon. Pigs were introduced into North America. Semi-wild pigs live in North and South America, Australia and New Zealand.

The Suidae is an old world family with a very wide distribution which includes wild, domestic and feral pigs (Graves, 1984). Whereas peccaries and hippos are limited to North America and Africa respectively and pigs (Suidae) are the only representative of the Suinae in India, with two sub-genera viz. *Sus*, the wild pig and *Porcula*, the pygmy hog (Prater, 1980). One hoofed mammal widely transported, introduced world-wide, and left to multiply was the pig, *Sus scrofa* Linnaeus (1758). Whether it was introduced in its wild, domestic or feral states, the pig often has adapted remarkably well and in a relatively short period of time to a new environment by establishing breeding populations. Examples of firmly established populations can be seen on both continents and islands. Outside the continental land mass of North America feral pigs have become well established on Santa Rosa, Santa Cruz, and Santa Catalina islands, California (McKnight, 1964); on Ossabaw and Cumberland

islands, Georgia (Smith *et al.*, 1980 and Singer, 1981); on Horn and Gulf islands, Mississippi (Baron, 1980) on Robert island, Canada (Smith and Hawkes, 1978) in West Indies (Wiewandt, 1977) and in Latin America (Petrides, 1975). In the Pacific region: Santa Cruz Floreana and San Salvador of the Galapagos islands (British Admiralty, 1943 and Kruska and Rohrs, 1974); Australia (McKnight, 1976; Tisdell, 1979; 1980a,b; McIntosh and Pointon, 1981); New Zealand (Wodzicki, 1950); Marianas (Wheeler, 1979); Swain, Tokelau islands (Kirkpatrick, 1966); Hawaiian islands (Tomich, 1969 and Kramer, 1971); on several coral islands (British Admiralty, 1943) and many other Pacific islands (British Admiralty, 1943, 1944 and 1945a,b). Feral populations in these areas have radically different histories, but typically they originate from domestic stock, which have turned feral.

The natural geographic distribution of *Sus scrofa* is more extensive than that of any other large mammal, extending from Iberia to the Japanese islands and Java. It is only mammal to have been brought into domestication more than once at independent sites, probably in the Middle East, Southeast Asia, and Far East. Transported by man, it is now virtually cosmopolitan, occurring on all continents except Antarctica and on many oceanic islands. Wild animals are elements of natural ecosystems for the maintenance of which they have an important contributory role. Not for nothing have wild pigs been called the “gardeners of the forest”.

The Eurasian wild pig is widespread and locally abundant to potentially at risk. The Eurasian wild pig has one of the widest geographic distributions of all terrestrial mammals, and this range has greatly expanded by human agency. The species occurs in pure wild or barely modified feral form on all continents except Antarctica, and on many oceanic islands. It is ancestors of most (but not all) ancient and modern domestic pig breeds, and there is evidence to suggest that it was independently domesticated in several different parts of its range, including Southeast Asia, the far East and Asia minor. As a wild form, it has constituted a primary resource of subsistence hunters since the earliest times, and it is one of the most important targets for recreational hunting wherever it remains sufficiently abundant. Over hunting and change in land use have resulted in the fragmentation of its range and its extermination throughout the British Isles, Scandinavia, parts of North Africa, and relatively extensive parts of its range in the (former) U.S.S.R. and northern Japan.

Nevertheless, the species remains widely distributed and is often locally abundant. As a result of its depredation on crops it is regarded as a pest in many countries, where it remains unprotected outside designed wildlife reserves, or is managed as a game animal.

*Sus scrofa* is one of the most widely distributed terrestrial mammals, and has by far the largest range of all Suiformes. It occurs throughout the steppe and broadleaved forest region of the Palaearctic from Western Europe to Soviet Far East, extending southward as far as North Africa, the Mediterranean basin and the Middle East, through India, Indo-China, Japan (including the Ryukyu China), Taiwan and the Greater Sunda Islands of Southeast Asia. Population East of Bali is probably all introduced. It has been extinct in the British Isles since sometimes in the 17<sup>th</sup> century, despite attempted introductions of new stock from Europe (Harting, 1880). It is also extinct in southern Scandinavia, over extensive portions of its recent range in west-central and eastern parts of the (former) Soviet Union (Heptner *et al.*, 1961), and in Northern Japan (Chiba, 1964, 1975). The species was last reported in Libya in the 1880s, and it became extinct in Egypt about in about 1902 (Hufnagl, 1972).

The wild pig is present in almost all bio geographic regions of India excepting the alpine zone, deserts and trans-Himalayas (Prater, 1980). The wild pig occurs throughout India except the desert region of Rajasthan where it has almost disappeared during recent times (Prakash and Ghosh, 1980). Its high degree of adaptability has led to this wide distribution. It is a veritable crop pest and has been known to raid crops since historic times.

#### **1.4 Sub-species**

*Sus scrofa* is the antecedent of the overwhelming majority of domestic and feral pig populations. In its native form it has one of the largest ranges of any wild ungulates and, together with its domestic and feral derivatives; it has one of the most extensive distributions of all mammals. In different part of this range it is naturally sympatric with at least congeners (*S. sylvanius*, *S. barbatus*, and *S. verrucosus*), though it or its derivatives have been introduced by human agency into areas supporting all others

(formerly allopatric) congeners (*S. celebensis*, *S. cebifrons*, and *S. philippensis*) and non-congeners (*Potamochoerus*, *Hylochoerus*, *Phacochoerus* and *Babyrousa*), as well as the New World tayassuids (*Tayassu* and *Catagonus*). Where introduced populations have become naturalized and abundant they are generally regarded as environmental pests, as well as posing threat of disease contagion and or genetic contamination to native suids, including endemic populations of this species.

*Sus scrofa* has been studied extensively in Europe, North Africa, and in the former U.S.S.R. and much comparable research has been conducted on the introduced, mostly feral population in the U.S.A., Australia, and New Zealand (Bridermann, 1990). Available data indicates that basic diploid number of 38 chromosomes (similar to domestic pigs) is found in eastern and Southeast Asian population, but this number decreases by robertsonian translocations over the species's extensive range such that the continental European populations have only 36 chromosomes (Bosma *et al.*, 1984). Eurasian wild pigs are also markedly variable in size, pelage and some other characters, and an enormous number of subspecies, and several different species, have been described. However, in a major review of the genus *Sus*, Groves (1981) argued that many of these named forms were synonymous or, in some cases were actually naturalized feral or hybrid (with *Sus celebensis*) populations. Groves accordingly recognized only 16 subspecies, including a previously under scribed form, *Sus scrofa davidi*, from Pakistan and northwestern India. Groves and Grubb have distinguished four 'subspecies groupings', based on both geographic and morphological criteria, which are as follows:

- i. Western races of Europe (*scrofa* and *meridionalis*), North Africa (*algira*) and the Middle East (*lybicus*), extending at least as far as Soviet Central Asia (*attila* and *nigripes*).
- ii. Indian races of the sub-Himalayan region from Iran in the west (*davidi*) to north India and adjacent countries as far east as Burma and West Thailand (*cristatus*), and south India and Sri Lanka (*affinis* and subsp. *nov*).

- iii. Eastern races of Mongolia and the Soviet Far East (*sibiricus* and *ussuricus*) Japan (*leucomystax* and *riukiuanus*), Taiwan (*taivanus*) to Southeast China and Vietnam (*moupinensis*).
- iv. Indonesian race (or banded pig) from the Malay Peninsula, Sumatra, Java, Bali and certain offshore Islands (*vittatus*).

### 1.5 Suidae

The family Suidae comprises four genera and it has worldwide distribution. The palaeartic and oriental regions have wide distribution of genus *Sus*. The Ethop a region is represented by 3 genera, the open savannah pig (*Phacochoerus*), forest hog (*Hylochoerus*) and the river hog (*Potamochoerus*). The oriental region also has the genus *Babyrousa*.

The names and world distribution of Suidae are shown below:

Genus	Common name	Distribution
<i>Sus</i>	Wild pig, Eurasian wild pig	Europe, Asia, northern Africa
<i>Sus</i>	Feral pig	America, Oceania etc.
<i>Potamochoerus</i>	Bush pig	Africa (south of Sahara)
<i>Phacochoerus</i>	Wart hog	Africa
<i>Babyrousa</i>	Babirussa (deer-pig)	Celebes (Indonesia)

The world distribution of Suidae and their main habitats are given below:

<b>Species</b>	<b>Habitat</b>
Pygmy hog	Woodland grassland (India, Nepal, Bhutan)
Wild pig	Tropical and temperate woodlands of Eurasia, Equatorial forests
	i. Monsoon forests
	ii. Mediterranean forests
	iii. Scleroph forests
	iv. Taiga (partly)
	v. Riverine forests
Babirusa	Tropical rain forest (Indonesia)
African bush pig	Riverine forests
Wart hog	Savanna

There are 4 species of genus *Sus*. They are *Sus scrofa* (wild pig), *Sus barbatus* (beared pig), *Sus verrucosus* (javan warty pig) and *Sus salvanius* (pygmy hog). *Sus scrofa* has the largest number of subspecies and varieties and it also has largest population of all these subspecies.

There are several sub species of *Sus scrofa* and it has a wide distribution world over.

<b>Sub-species</b>	<b>Distribution</b>
<i>Sus scrofa scrofa</i> (Linnaeus, 1758)	France, Germany, European Russia
<i>Sus scrofa cristatus</i> (Wagner, 1839)	India, Sri Lanka
<i>Sus scrofa leuomystax</i> (Temminck, 1942)	Japan
<i>Sus scrofa andamanesis</i> (Blyth, 1858)	Andaman island (India)
<i>Sus scrofa barbarus</i> (Selater, 1860)	Morocco, Algeria
<i>Sus scrofa tairanus</i> (Swinhoe, 1863)	Formosa
<i>Sus scrofa libycus</i> (Gray, 1808)	S. W. Asia Minor
<i>Sus scrofa moupensis</i> (Milae-Edwards, 1871)	S. China
<i>Sus scrofa anigripes</i> (Blanford, 1875)	Russian Taraistan, Afghanistan
<i>Sus scrofa meridionlis</i> (Forsyth, 1882)	Sardinia
<i>Sus scrofa ussuricus</i> (Heude, 1888)	Southern china, Hainan
<i>Sus scrofa chirodontus</i> (Heude,1888)	Eastern Siberia, Manchuria
<i>Sus scrofa coreanus</i> (Heude, 1887)	Korea
<i>Sus scrofa jubatus</i> (Miller, 1906)	Indochina, Thailand
<i>Sus scrofa attila</i> (Thomus, 1912)	Transylvania, Caucasus N. Iran
<i>Sus scrofa castilianus</i> (Thomus, 1912)	Southern Spain
<i>Sus scrofa falzeeini</i> (Matschke, 1968)	Poland

The species *Sus scrofa scrofa* has been introduced by man in places like Australia, New Zealand, North and South America and Oceania.

## 1.6 Chronology of Indian wild pig

The Indian sub continent had six species of wild pig during the early geological times they are as follows:

Forms	Period	Locality in India and other continents
<i>Sus scrofa</i>	Recent	Indian subcontinents and Eurasia
<i>Sus punjabiensis</i>	Early Pleistocene	Siwaliks
<i>Sus sivalensis</i>	lower Pleistocene	Siwaliks
<i>Sivachoerus</i> sp.	Plio-pleistocene-pliocene	Siwaliks
<i>Sonitherius</i> sp.	Ploicene	Siwaliks
<i>Anthracoelium</i> sp.	Mio-pliocene-Oligocene	Siwaliks, Europe

At present Indian region has only two species that is *Sus scrofa* and *Sus salvanius* (Prater, 1980; Tiwari, 1985 and Ramdas, 1987).

The wild suids are found in a diverse array of habitats ranging from semi-arid environments and temperate woodlands to tropical rainforests and swamps. They also often take advantage of agricultural lands. They occupy altitudes ranging from sea level to over 13,000 ft (4,000 m). Habitat selection is dictated by the availability of energy-rich foods, climactic extremes, and predation pressure. Some species may occupy a range of habitat types as long as they have adequate food resources (e.g., wild boar), whereas others specialize on a particular habitat (e.g., pygmy hog). Forest type, elevation, and forest age have been found to influence habitat selection in some populations of wild boar. It has been suggested that wild pigs play an important role in forest diversity, regeneration, and structure through their depredation of seeds and young saplings. Studies of the effects of wild pigs on the environment have had varying results. Wild pigs may increase or decrease forest species' richness, negatively impact regeneration of trees, remove competitive vegetation such as

weeds, and decrease soil macro-invertebrate populations. There is also evidence the Eurasian wild pigs will take advantage of acorn caches created by small mammals.

The suids can be divided into two groups in terms of territoriality or home range use. The African suids are generally more sedentary than other wild pigs, occupying small territories or home ranges that may overlap. The other suids are also more or less sedentary, but changing ecological conditions may cause these species to roam in search of better places to forage, sometimes over long distances. Whether territorial or not, areas occupied by wild suids tend to have several features in common. Resting places are one such feature, and these tend to take the form of nest sites or burrows. Most wild suids construct nests for farrowing, whereas others build nests for protection in bad weather (e.g., *P. larvatus*), but some construct nests all year round (*S. salvanius*). Most wild suids make nests of varying complexity and structure, using vegetation. Nests may be used year round or seasonally. Warthogs often occupy burrows dug by aardvarks (*Orycteropus afer*) and do not build their own nests. Wild suid home ranges also include tree trunks, rocks, or anthills that are used as spots for rubbing and scratching the body. These home ranges also include sources of shade and water, as well as mud wallows. These features are of critical importance as some suids do not have functional sweat glands for cooling the body.

## **1.7 Indian wild pig**

### **1.7.1 Local names**

Hindi *suar*, *barba*, *bad janwar*, *bura janwar*; Marathi *ran dukkar*; Tamil *punni*; Kannada *hundi*; Malayalam *kartu punni*; Burmese *wet*.

## **1.8 Body size**

The Indian wild pig (*Sus scrofa cristatus*) is a large, heavily built animal. The body weight of wild pig ranges from 50-200 kg. A young pig weighs from 50 to 90 kg. A well-grown male stands up to 36 in (90 cm) high at the shoulder level and weighs

about 200 lb (90 kg). The female is smaller than male and weighs around 65 kg. The length of body and head of wild pigs varies from 90 to 180 cm and length of tail varies from 30 to 40 cm. The record measurement of lower tusks is 12 in (32.1 cm) on the outside curve.

## **1.9 Life span**

The life span of wild pig is about 15-20 years. Whereas the life span of a domestic pig tends to be 10-15 years.

## **1.10 Appearance and adaptations**

The race found in India is *Sus scrofa cristatus*. The wild pig is Schedule III species of Wildlife Protection Act, 1972. The Indian subcontinent is represented by a single widely distributed genus (*Sus*) with four subspecies. They are the domestic pig (*Sus domestica*), common wild pig (*Sus scrofa cristatus*), Andaman wild pig (*Sus scrofa andamanensis*) and Nicobar wild pig (*Sus scrofa nicobaricus*). The typical feature of wild pig is its elongated movable snout ending in a flat disc like surface supporting the nostrils. The upper canines grow upwards and outwards. The most distinct difference between the Indian pig and its counterpart in Europe is its grayish black coat which is sparsely covered with hairs. It has a full crest or 'mane' of black bristles rising from the nape of its neck and running to its hind quarters. The wild pig being omnivorous, it eats variety of food such as roots, tubers, bulbs, fruits, insects, mollusks, offal, carrion and even the remains of tiger and other wild animals kills (Mason, 1883; Brander, 1923; Krishnan, 1972; Johnsingh, 1978; Prater, 1980; Tisdell, 1982; Seshadari, 1986 and Ramdas, 1987).

The wild pig is essentially a forest dwelling animal preferring to remain in shade. It prefers thick vegetation as it provides protection from predators. Shade of trees and shrubs is preferred as it aids in thermoregulation. Access to water and shade is important as wild pig must drink regularly, since it has no sweat glands. Therefore it has difficulty in regulating the body heat unless it wallows in wet ground or moist

places during hot weather. Death due to heat coma is possible if there is no water and shade available during the hot conditions. The wild pig has the adaptability and can survive in a wide climatic range and conditions. It occurs in low lands as well as in high altitude regions. It can withstand snow and low temperature and thrive well in tropics. With surface water and shade, the wild pig can survive in low rainfall and high temperature areas (Tisdell, 1982; Tiwari, 1985; Ramdas, 1987 and Blouch, 1988).

The wild pig has moderate vision but other sensory organs are well developed. The sense of hearing and smell, which are well developed, helps them to avoid predators. Local movement in wild pig is common. Under environmental stress, it migrates to long distances and thus it aids in its survival. The home range is not permanent and exclusive. The range of sows tends to be 5-30 km and that of a boar about 50 km. The boar is more mobile and known to move far of distances for forage and mating opportunities (Prater, 1980; Tisdell, 1982; Fadeev, 1981; Baber and Coblenz, 1986 and Dardaillion, 1986).

### **1.11 Social organization**

Wild pigs are gregarious. A sounder of wild pig constituted of adult females, sub-adult males, yearlings and piglets. Adult males move in all male groups. Old boar is usually solitary or moves with a companion. Herds or sounders of varying size are seen, but they are usually of 6-20 individuals, though aggregations of over 100 have been reported (Prater, 1971; Legakul and Mcneely, 1977 and Briedermann, 1990). Group size of wild pigs varies with respect to locality, seasons and climatic conditions. A group of 10-15 animals is common, a large group of 40-50 animals in wet season is not uncommon (Brander, 1923; Santiapillai and Chambers, 1980 and Ramdas, 1987).

The basic social unit is a nucleus of one or more females and their last litters. Animals peripheral to this comprise of sub-adults from previous litters, and adult male (s) during the mating season. However, the latter tend to stay in relatively close contact with 1 or 2 female groups at other time of the year, and sub-adult males or mixed sex

groups of sub-adults may also form long term associations (Spitz and Janeau, 1990). The dynamics of the basic group include the isolation of the pre-parturient female, her re-entry with young ones, entry of nulliparous females and the arrival of adult males with the simultaneous departure of sub adult animals (Spitz, 1986). In contrast to its domestic derivatives, reproductive activity in *Sus scrofa* tends to be seasonal and positively correlated with the relative availability of principal food stuffs or related climatic factors. However social organization may also play a role in modulating the timing of reproductive events, since furring is often synchronized among females in the same social groups, which suggests a mechanism for synchronizing the onset of oestrous (Spitz, 1986).

Wild pigs live in a family party that has a territory of 10-20 km<sup>2</sup> but in the autumn, family groups come together to form herds of up to 50 females and young ones. The group is known as a sounder, led by an older sow, and its members feed, rest and sleep together. The young male forms a bachelor group but the older male remains solitary, joining with females in the autumn mating season. Once mated, male will once again live alone. They are normally most active in the early morning and late afternoon, though they become nocturnal in disturbed areas, where activity usually commences shortly before sunset and continues through the night. A total 4-8 hours are spent foraging or traveling to feeding areas.

## **1.12 Habitat**

Wild pig is a generalist species and is admirably adapted to range of habitats such as forests, secondary thickets, woodland and grasslands in which they roam in small bands (sounders) of varying number of individuals. The size of sounder seems to be a function of the carrying capacity of the habitat (Pine and Gerdes, 1973). Wild pigs live in grass or scanty bush jungle, sometimes in forest; after the rains, quite commonly in high crops.

### **1.13 Activity pattern**

The wild pigs are considered to be diurnal by some scientists and to be nocturnal by others. The species is known to be active in early morning and evening and resting in shade during the hottest part of the day. In areas where hunting is significant, it hides in shade during the day and becomes nocturnal, feeding during the night (Hone and O’Gardy, 1980 and Ramchandra *et al.*, 1986). Wild pigs exhibit some of the activities which are very specific to its suborder. These are as follows:

#### **1.13.1 Digging and de rooting**

The pigs are characterized by rooting behaviour which is facilitated by their associated cranial features including an elaborated rhinarium, elongated snout and hypertrophy of the nuchal muscles and areas of attachment (Graves, 1984). Plant roots, tubers and rhizomes thus dug out supplement their dietary requirements and also make them naturally more fit to survive in a habitat which is shared by sympatric herbivorous species to which these underground vegetable matters are unavailable. De rooting can be of various intensities and depends on the learning of individuals. It has been observed that the intensity of digging by sub-adults and young ones are more intense and narrow than that of adults. They graze more or less in large areas and dig after sensing potential food. This behaviour is attributed to the experience of the adult pigs in finding out the hidden food as compared to the young ones who are inexperienced. This habit can lead to damage of potential food plants or may cause shift in plant succession influencing the regeneration of certain plant species and changing habitat condition for itself as well as other resident herbivores (Everitt and Alaniz, 1980).

#### **1.13.2 Wallowing**

Wild pigs lack sweat glands and have sparse hair coat. They do not tolerate a wide range of temperature. Therefore, thermoregulation is a major component of their ethogram (Dellmeir and Friend, 1991). Wild pigs like to live near mud wallows in

which they will spend many hours. This wallowing is an important activity, helping to remove parasites and protect the sensitive skin from the harmful rays of sun. Wild pigs wallow for a short duration or just long enough to plaster their skin with mud as a protection against flies (Eisenberg and Lockhart, 1972) or to get rid of ecto-parasites (Conely *et al.*, 1972) or for thermoregulation during the hot dry season (Eisenberg and Lockhart, 1972 and Graves, 1984). Usually immediately after wallowing, they rub their sides, snout or the anal portion probably to get rid of parasites sticking to skin even after wallowing (Graves, 1984).

### **1.13.3 Nesting and resting sites**

Wild pigs spend most of their inactive daylight hours in characteristic day beds (Graves, 1984 and Fradrich, 1971). They construct temporary sleeping nests of considerable size or use burrows dug by other mammals (Fradrich, 1971). The beds are often made at the base of trees besides logs or other protected areas on an exposure where the pigs can warm up (Conley *et al.*, 1972). Dens are not used during winter but in hot weather, more elaborate beds are made in cool and shady places (Stegeman, 1938; Conley *et al.*, 1972 and Graves, 1984). Resting places are normally occupied by more than one individual because pigs, unlike most of other Artiodactyles (except the hippos) belong to 'contact type' of animals (Fradrich, 1971 and Conley *et al.*, 1972).

Nest building is one of the most overt behavioural indications of farrowing. Excavating shallow oblong areas, slightly larger than their bodies by rooting and filling up this bed with grasses, leaves, stems and other plant material gathered by mouth and carried to the nest site is the common method of nest building (Covacevich, 1972). It was observed in domestic swine that nest building behaviour is primarily instinctive and can be observed in sows with no previous farrowing experience (Dellmeir and Friend, 1991).

#### **1.13.4 Scavenging**

Wild pigs have been observed feeding on kill remains of dholes five times; three times in the presence of the pack itself (Johnsingh, 1978). Nevertheless, wild pigs are ecologically separated from other scavengers by their mode of feeding on other herbaceous material such as grasses, roots, tubers, fruits etc. (Conley *et al.*, 1972).

#### **1.14 Food habits**

Wild pigs throughout their distribution ranges in world are omnivorous and opportunistic feeders (Fradrich, 1971, Martin, 1975 and Sweeney *et al.*, 2003). The wild pigs occupy a wide variety of habitats from semi-desert to tropical rain forests, temperate woodlands, grasslands and reed jungles, and often venturing into agricultural land to forage. After rainy season, they are commonly seen in crop fields. No animal is more destructive to crops than pigs. They have always been associated itself with man, and successfully utilises the human altered landscape (Fadeev, 1981 and Erkinaro *et al.*, 1982). Being a resilient and fast breeding animal, it is capable of expanding and establishing its population in new areas (Erkinaro *et al.*, 1982 and Ahmed, 1991). The species is known for its biological and ecological adaptability (Tisdell, 1982 and Ramdas, 1987). They live on crops, roots, tubers, fruits, insects, snakes, offal and carrion. The stomach and fecal matter analysis indicated that vegetable matter, fruits, seeds, roots and tubers, constituted about 90% of the diet (Spitz, 1986). The consumption of invertebrates and small vertebrate prey may be a necessary component of the diet, since a study of free-ranging domestic pigs in Papua New Guinea revealed that the pigs fed ad-libitum lost weight when denied earthworms (Rose and Williams, 1983). Wild pigs search for food mainly at dawn and dusk, rooting amongst the leaf litter and damp soil of open woodlands with its toughened snout. It has a keen sense of smell and will eat almost anything. Its main diet consists of plant material but it can increasingly gobble up any animals it can catch. They feed in the early morning and late in the evening and, where much disturbed, chiefly at night.

A study on the Indonesian wild pig, *Sus scrofa vittatus* in the Ujung Kulon national park indicated that these animals were predominately frugivorous, feeding on about 50 species of fruits, especially *Ficus* species, and they were important seed dispersal agents (Pauwels, 1980). An analysis of the stomach contents of wild pigs in West Malaysia revealed that sugarcane, tapioca and rice were the commonest food items, but usually more than one type of food had been eaten, even where a single cultivated crop was abundant (Diong, 1973). Other items commonly consumed by these pigs included soil, earthworms, roots and other vegetable matter, and in mangrove areas, molluscs, crabs and other arthropods and even fishes. Wild pigs have also occasionally been reported to predate on larger vertebrates such as deer fawns and tethered goats (Hoogerwerf, 1970). Feeding is generally a social activity; even solitary males may join feeding groups, which also provides an opportunity for display and other agonistic behaviors (Beuerle, 1975).

### **1.15 Reproduction**

Wild pigs are prolific breeders and apparently breed throughout the year. The reproductive activity in pigs tends to be seasonal and positively correlated with the relative availability of food or climatic factors. In central India, the majority of young ones are born in two periods, shortly before and shortly after the rains. In tropical countries such as Sri Lanka, peak estrous activity has been recorded during the wettest months i.e. November and December (Santiapillai and Chambers, 1980). However, social organization may also play a role in modulating the timing of breeding activities, since farrowing is often synchronized amongst females in the same social groups, which suggests a mechanism for synchronizing the onset of estrous (Spitz, 1986).

Among all the wild pigs species with exception of *Sus domesticus*, the *Sus scrofa* is by far the most widely maintained and bred in captivity, though general perceptions about the relative abundance of this species has resulted in diminished interest in its propagation. Many zoos, particularly in Western Europe, have therefore disposed of their stocks of these animals, mostly to 'wild boar breeding farms', which have escalated in number to meet growing demands in the gourmet meat markets and for

commercial diversification. In addition, increasingly restrictive quarantine and other veterinary regulations pertaining to the international movements of all live suids have made it extremely difficult to establish new breeding programs.

### **1.16 Domestication of wild pigs and their uses**

The earliest domestication of the wild boar is uncertain but it probably came about during the period when men settled down and began farming rather than hunting. Wild pigs do not like being herded, but they readily take to life in a sty or house. It is likely that pigs were domesticated from local races, thus producing domestic pigs of various sizes.

The Chinese pig was domesticated by the first neolithic farmers in about 3000 B.C. and was descended from the wild *Sus vittatus*, a fatter and shorter-legged type than the European *Sus scrofa*. The Neapolitan pig from Italy was said to have been of Siamese ancestry and bred from the Asian pig *Sus indicus*. Both these pigs were crossed and re-crossed with the native European wild boars. The Siamese pig or 'tonkey' pig, as it was known, was also introduced into Britain in the eighteenth century together with a variety of other foreign types of pigs. All these imported pigs were cross-bred with the European wild boar for nearly a century. The Berkshire pig was the first of the good looking early breeds and was used to cross-breed with local types to produce many regional strains.

The pigs have been bred for its flesh (pork) and fat. Its bristles have been used for making brushes and the hide for all sorts of leather goods. The bones are crushed to powder for bone meal fertilizer. However, over the centuries, the domestic pigs have been put to quite a few other uses. It has been used for sacrifices in Roman times among the armies. There was a strange custom of swearing an oath on a pig or a piglet. Pigs have also been used for pulling carts.

In Ancient Egypt, pigs were used for treading in corn, their sharp hoofs making holes of the correct depth for the seeds to germinate. Perhaps strangest of all, in medieval England, they were trained as pointers and retrievers for illegal hunting in areas like

the New Forest. This came about because the commoners, living in the New Forest, were forbidden to keep large dogs; they could only keep dogs capable of passing through King Rufus' stirrup, an iron stirrup 26.3 cm high by 11.3 cm across.

### **1.17 Threats**

Habitat destruction and hunting pressure, either for food, sport or in reprisal for crop damage, are the major threats to this species, particularly in areas near human habitation. Illegal hunting of wild pigs is reported from in and around protected areas and managed forests in the Indian subcontinent (Chauhan, 2004). Wild pig has been one of the most important target species for recreational hunting. Over-hunting and changes in the landuse pattern have resulted in the fragmentation of its range and its extermination throughout the British Isles, Scandinavia, parts of North Africa, and many parts of its range in the Russia and northern Japan (Chauhan, 2004). Wild pig (*Sus scrofa vittatus*) populations declined drastically as a result of increased hunting pressure, particularly for commercial purposes (Diong, 1973). Nevertheless, the species remains widely distributed and is often locally abundant.

### **1.18 Human-wild pig conflict**

Wild pigs notoriety as a crop pest is universal (Tisdell, 1982). They cause extensive damage to agricultural crops and utilize the agro-ecosystem for food resource and shelter. Presently the wild pig populations are fragmented and relatively isolated all over. Some of these isolated populations became locally overabundant and depend upon agricultural crops especially in and around protected areas or managed forests for a major part of their food requirement. Besides agricultural crops, they cause damage to ground vegetation, orchards, forest plantations and possibly act as carrier of some infectious diseases.

### **1.19 Human mythology - Role of wild pigs**

The ancient ties between man and wild pig have undergone considerable changes in the course of time and development. The modern man's interest in the wild pig is many ways. To the agriculturalist, the wild pig is a pest requiring control, while sporting hunters find the species to be an important hunting asset. Some European and far-east countries value the wild boar as an economic resource for game meat industry. In Islamic countries, the wild pig is regarded as unwanted and useless animal with no redeeming quality. Wherever the wild pig was introduced, it posed a threat to the native flora and fauna (Braton, 1975; Tisdell, 1982 and Lacki and Lancia, 1986).

In India, the wild pig and man relationship is primeval. It is well documented in the ancient Hindu scriptures, where Demi Gods and mythological forms are associated with it. Similarly the species has been described in earlier scriptures also (Rao, 1957 and Hasting, 1961). Hunting of wild pig has been reported throughout the historic times (Anon, 1890; Brander, 1923 and Ali, 1927). Varaha (Sanskrit: **वराह**) is the third Avatar of the Hindu god Vishnu in the form of a boar. He appeared in order to defeat Hiranyaksha, a demon who had taken the Earth (Prithvi) and carried it to the bottom of what is described as the cosmic ocean in the story. The battle between Varaha and Hiranyaksha is believed to have lasted for a thousand years, which the former finally won. Varaha carried the Earth out of the ocean between his tusks and restored it to its place in the universe. Vishnu married Prithvi (Bhudevi) in this avatar.

### **1.20 Conservation**

Generally few, if any, practical measures have been taken in any country for the specific purpose of conserving wild populations of any subspecies of *Sus scrofa*, except in the sense of maintaining stock levels for hunting, particularly for sport hunting. Thus Genov *et al.* (1991) reported a gradual increase of the wild boar population in Bulgaria in the late 1950s following legal measures to regulate hunting and because of the reintroduction of animals from breeding farms in the north-east

Balkan Range and Sredna Gora of the country. Even in this instance, however, other factors may also be operating, since similar increases in the local wild pig populations in Spain, France, Switzerland, Czechoslovakia and eastern Russia have been described by Sáez-Royuela and Tellería (1986). They simply attributed this trend to a progression to a more temperate climate and, hence, progressively milder winters to benefit to these animals. Local wild pig populations are also reported to be increasing in numbers in several countries as a consequence of the spread of Islam. For example, the north-west African race, *Sus scrofa algira*, although extinct in Libya, is thought to be expanding in neighboring Algeria where it is designated a game animal, but as the meat is now seldom eaten in this country, hunting pressure has been greatly reduced since colonial times (Kowalski and Rzebik-Kowalski, 1991). These authors also cite earlier reports of wild boars hybridizing with domestic pigs, but the latter are no longer kept in Algeria. *Sus scrofa riukiuanus* has been included in the IUCN Red List since 1982, where its vulnerable status reflected a widespread concern about the environmentally destructive development of the Ryukyu Islands and the growing number of threats to the ecosystems and endemic species of Iriomote and other islands in this region. In 1978, these concerns led to the passing of a resolution at the 14<sup>th</sup> IUCN General Assembly in Ashkhabad, which called upon the government of Japan to take immediate steps to ensure the conservation of Iriomote Island and its endemic taxa, and for the subsequent designation of the whole of the Nansei Shoto Region, often referred to as the 'Galápagos of the East' on account of the high percent endemism of its fauna and flora, as a bio-geographical priority region in the world conservation strategy. In 1982, the 'Nansei Shoto Conservation Project' was launched by WWF-Japan, with initial emphasis being placed on the conduct of wildlife and socio-economic surveys on Iriomote and Amami Oshima (Obara, 1984a, b).

Of all wild pigs species, *Sus scrofa* is by far the most widely maintained and bred in captivity, though general perceptions about the relative abundance of this species has resulted in diminished interest in its propagation. Many zoos, particularly in Western Europe, have therefore disposed of their stocks of these animals, mostly to wild boar breeding farms, which have escalated in number to meet growing demands in the gourmet meat markets and for commercial diversification. In addition, increasingly restrictive quarantine and other veterinary regulations appertaining to the international movements of all live suids, has made it extremely difficult to establish new breeding

programs.

On the contrast, since these animals are most easily acquired in their countries of origin, local stocks are most likely to be pure-bred and, hence, most valuable for research and conservation purposes. In this situation, priority should be given to the establishment of national or regional breeding programmes for each of the rarest subspecies, especially *Sus scrofa riukiuanus*. As a general rule, *Sus scrofa* is both highly adaptable and highly resistant to a variety of degradative processes, and may thrive under conditions of habitat modification and hunting pressure which have devastated other forms of wildlife. In addition, most subspecies are well represented in protected areas in their relatively extensive ranges. Nonetheless, there are reasons for concern about a number of distinct populations of *Sus scrofa*, of which the Ryukyu pigs are undoubtedly the most seriously threatened. Indeed, *Sus scrofa riukiuanus* is the only subspecies of *Sus scrofa* to be included in the IUCN Red List of Threatened Animals (IUCN, 1990), where it has been accorded the status of 'Vulnerable' since 1982. But it is already thought to be 'Endangered' on at least four of the six islands in the Ryukyu chain which constitute its entire extremely restricted range. This particular form is also the most distinct by far the smallest subspecies with an average adult male body weight of only about 45 kg (Barber *et al.*, 1984). It is therefore of some interest as a potential genetic resource, as well as being one of the principal 'flagship' animals for increased conservation activity in the crucially important Nansei Shoto Region. For all of these reasons, the recommendations are mostly focused on the immediate and longer-term management requirements of this taxon (Oliver *et al.*, 1993).

### **1.21 Significance of study**

- i. There is no systematic study on the ecology and behaviour of wild pigs especially with respect to agricultural crop damage and economic losses in man-altered protected areas-village interface situations. The research conducted in India so far includes only few ecological parameters, and they are not management oriented. There is paucity of information on wild pigs from Indian sub-continent; the available information is fragmentary.

- ii. The research findings have little or no application in India due to different environmental, socio-cultural and agricultural practices. Wild pig a widely distributed and an important prey species for large carnivores in India, has not been the subject for an intensive study so far. The present study aims at ecology of wild pig and human-wild pig conflict in the Ranthambhore National Park, Rajasthan.
- iii. Human-wild pig conflict has been increasing and now attained to serious levels in most of the man-altered protected areas-village interface situations. A few studies conducted on pigs include some ecological aspects. The proposed study is entirely different and focuses on management of wild pigs. No work has been done on developing pig capture techniques and radio-collaring of pigs in our situations, which would help management of this species. Consequently, the conservation efforts for the species are badly affected.
- iv. The environment, socio-cultural and agricultural practices in India are different from Europe, Australia and America, thus studies conducted elsewhere has little or no application.
- v. Construction of rubble or stone wall or digging of trenches for wild pigs is very expensive. Terrain, local development, crop pattern makes the above mentioned control measures very difficult. Pig bombs are illegal and dangerous and should never be used. Trapping and snaring for contraception and using species-specific cost-effective barriers to control the wild pigs has a wide applicability and seem to have the potential to develop as effective management tool to control the wild pigs. The success of this operation can help in reducing the crop depredation and thus mitigating human-wild pig conflicts.
- vi. The study: ecological and management considerations, will provide a basis for developing an action plan to mitigate the problem effectively and on a long-term basis.

## **1.22 Objectives**

The aims of the present study on wild pigs in Ranthambore National Park, Rajasthan are:

1. To study the spatial and temporal distribution of wild pigs in context of habitat attributes.
2. To develop and evaluate capture and handling methods for wild pigs.
3. To study the ranging pattern of wild pigs based on radio-telemetry.
4. To assess the nature and extent of human-wild pig conflicts: Qualitative and quantitative assessment of crop damage by wild pigs in different seasons.
5. To evaluate the use and efficacy of power fence in controlling crop damage caused by wild pigs.
6. To recommend strategies for management of wild pigs and mitigation of human-wild pig conflicts.

**Plate 1: Imprints of two cleaves and two dew claws of wild pigs.**



**Plate 2: Imprints of two cleaves and two dew claws of wild pigs.**



## Chapter 2

### Review of literature

#### 2.1 General

The origin of *Sus scrofa* appears to have occurred in south-east Asia (Larson *et al.*, 2005), where the greatest diversity of the entire genus *Sus* exists (Groves, 1981 and Lucchini *et al.*, 2005). This was followed by an initial dispersal into India and then subsequent radiations into East Asia, and then progressive spread across Eurasia into Western Europe (Larson *et al.*, 2005). This progression is consistent with the morphological data, with wild boar increasing in size somewhat to the north, and more significantly decreasing to the west (Groves, 1981; Mayer and Brisbin, 1991; Kusatman, 1992 and Mayer *et al.*, 1998). *Sus scrofa* is currently the most widespread species in the family Suidae (Groves, 1981; MacDonal and Frädriich, 1991 and Oliver *et al.*, 1993).

The wild boar, *Sus scrofa cristatus* Linnaeus, belongs to Order Artiodactyla, Family Suidae, Subfamily Suinae and Suborder Suiformes. The race found in India is *Sus scrofa cristatus*. The wild pig is one of the most widely distributed terrestrial mammals. It has always been associated itself with man, and successfully utilises the human altered landscape (Fadeev, 1981 and Erkinaro *et al.*, 1982). Being a resilient and fast breeding animal, it is capable of expanding and establishing its population in new areas (Erkinaro *et al.*, 1982 and Ahmed, 1991). The species is also known for its biological and ecological plasticity (Tisdell, 1982 and Ramdas, 1987).

Wild pigs are very intelligent and secretive. In addition, these animals are adaptive ecological generalists, capable of exploiting a wide variety of geographic locations, habitats and forage resources (Prater, 1965; Rolls, 1969; Eisenberg, 1981 and Land Protection, 2001). They occupy a wide variety of habitats, from semi-desert to tropical rain forests, temperate woodlands, grasslands and reed jungles; often venturing onto agricultural land to forage. Wild pigs raid crops and utilises the agro-

ecosystem for food resource and shelter. Wild pigs are normally most active in the early morning and late afternoon, though they become nocturnal in disturbed areas, where activity usually commences shortly before sunset and continues throughout the night. Frädrieh (1974) further observed that wild pigs were more difficult to study than other ungulates because of their intelligence, shyness and vigilance combined with an acute sense of smell and hearing.

Behavioural sex differentiation is the apparent cause for the sexual dimorphism observed in this species (Herring, 1972). The males were found to be on average between 4.5% and 9.2% larger than the females in various dimensions. Henry (1970), Sweeney (1970), Barrett (1971) and Belden and Frankenberger (1979) found similar percent differences between the sexes in the body dimensions of adult wild pigs from different locations in the United States. However, some studies (Brisbin *et al.*, 1977 and Henry, 1970) found these differences not very significant between the sexes in adult animals. Adult boars and sows also differ in their general physical appearance. In overall proportionate body size, males have a larger head and higher shoulders than females. In their general lateral appearance, boars also have a more angular overall profile of their back compared to sows. The permanent canines or tusks of male wild pigs are significantly larger than those in females. In addition, the shapes of these teeth differ markedly between the two sexes (Mayer and Brisbin, 1988). Boars further have the presence of a lip curl (i.e., the opening in the lips that allows the protrusion of the adult canines) and external genitalia (i.e., the scrotal sac and the preputial bulb). Adult males have enlarged canines, which visibly protrude from the mouth. In contrast, females have a more rounded profile to their back, equally high shoulders and hips, an insignificant to very slight lip curl, and no readily-apparent external genitalia (i.e. with the exception of the vaginal papilla under the base of the tail). The canines of even adult sows only slightly protrude from the mouth. Mature sows may also have visibly distended mammary glands and teats.

The frequency of coat coloration patterns varies among wild pig populations. Solid black is often cited as the most common pattern (Sweeney and Sweeney, 1982). Coat colour can vary considerably between different regions, but in a sample of 2604 pigs from the northern South Island, the predominant colour (77%) was black (Clarke and Dzieciolowski, 1991).

Most wild pigs did not last more than six to eight years of age in the wild (Barrett, 1978 and Conley *et al.*, 1972). The maximum life span for most wild pig populations was estimated to be 9-10 years of age, with exceptional instances of individuals reaching 12-14 years (Henry and Conley, 1978; Jezierski, 1977 and Dzieciolowski *et al.*, 1992). Wild pigs were typically an r-selected species with a high reproductive potential (Geisser and Reyer, 2005).

Review of literature reveals that classical and applied scientific investigations on the wild pigs are by and large confined to Europe, North America, New Zealand and Pakistan. Lot of information is available on ecological and behavioural aspects from these countries. American literature on feral pigs (*Sus scrofa*), mostly deals with distribution, morphology, ecology, habitat, feeding and foraging impact on native flora and management aspects (Matschke, 1967; Barrett, 1970, 1978; Pine and Gerdes, 1973; Bratton, 1975; Wood and Roark, 1980; Baber and Coblenz, 1986, 1987 and Anderson and Stone, 1993). Occurrence, migration, ranging pattern, habitat use, feeding habits, mortality, reproduction, hunting and management of wild pigs have been reported by many European authors (Fedyushin, 1964; Miroslav, 1965; Rakov, 1970; Mackin, 1970; Fadeev, 1973, 1975, 1981; Jezierski, 1977; Andrzejewski and Jezierski, 1978; Genov, 1981; Erkinaro *et al.*, 1982; Kratochoil *et al.*, 1986; Daradaillon, 1986, 1988 and Gerard *et al.*, 1991).

Australian literature pertains to the impact of feral hogs on the native flora, agriculture, animal husbandry and management (Giles, 1978; Griggs, 1981; Pavlov *et al.*, 1981; Pavlov and Hone, 1982; Tisdell, 1982; Woodall, 1983 and Mcilory, 1983). There is paucity of information on wild pigs (*Sus scrofa cristatus*) from Indian sub-continent; some general information is fragmentary (Anon, 1890; Mason, 1893; Brander, 1923; Ali, 1927; Morris, 1929; Rao, 1957; Schaller, 1967; Santaipillai and Chambers, 1980; Prater, 1980; Tiwari, 1985; Shafi and Khokar, 1986; Ramachandran *et al.*, 1986; Ramdas, 1987 and Ahmed and Samant, 1989). Aspects of man and wild pig interaction in the Western Ghats of south Maharashtra were briefly studied by Ahmed (1991).

Hampton *et al.* (2004) found based on genetic data that breeding boars were significantly heavier than non-breeding boars. The most reproductively successful

boars in that study were large individuals, weighing more than 90 kg, which also moved further (>30 km) to secure breeding opportunities. Similar findings suggesting that larger boars disperse further to secure paternity were also reported by Saunders and Kay (1991), Caley (1997) and Lapidge *et al.* (2004). Competition between males ranged from posturing and display to actual combat (Barrett, 1978). Kurz and Marchinton (1972) observed two types of antagonistic interactions between feral boars. The first type occurred before establishment of dominance between the two males and consisted of a head-on charge followed by circling, pushing, and attempts to slash each other with their tusks. Interactions between boars that had already established dominance lasted only a few seconds, often consisting of only a few lunges by the dominant boar (Kurz and Marchinton, 1972). They also observed a large boar attack and drive off a smaller boar attempting to breed an estrous sow. Male-male fighting among wild pigs has also been described by various other authors (e.g. Barrette, 1986; Beuerle, 1975; Poncins de, 1914 and Frädriich, 1974).

A small proportion of wild sows in California (Baber and Coblenz, 1986), Great Smoky Mountains National Park (Johnson *et al.*, 1982) and Texas (Springer, 1977 and Taylor *et al.*, 1998) produced multiple litters annually. No incidence of more than one litter per year was reported for hybrid sows in Tennessee (Henry, 1966). On Santa Catalina Island, adult sows produced an average of 0.86 litters per year (Baber and Coblenz, 1986). However, Barrett (1978) observed that wild sows at Dye Creek Ranch produced an average of two litters per year.

Although not as gregarious as other ungulates (e.g. Bovidae), wild pigs are by their nature social animals. This statement is based on the fact that the species is typically found in groups composed of two or more individuals. Within wild pig populations, the basic social unit is the sow and her litter (i.e. the family group). Males were usually solitary, except when participating in breeding groups; however, groups of two or more mature boars do occur (Kurz, 1971; Sweeney *et al.*, 2003 and Hughes, 1985).

Wild pig group sizes, two or more animals, found to vary greatly among populations, but typically average from 3 to 9 and range from 2 up to 30 or more individuals (Eisenberg and Lockhart, 1972; Duncan, 1974 and Barrett, 1978). Most of these were

composed of single or multiple family groups (Barrett, 1978; Eisenberg, 1981 and Dardaillon, 1988). Multiple family groups were organized around two or three reproductively mature highly-related females and their litters, and contained up to three generations of related animals, including sub-adults from previous litters (Barrett, 1978; Spitz, 1986; Lapidge *et al.*, 2004 and Spencer *et al.*, 2005).

Multiple paternities were also found to be tolerated within the same group (Lapidge *et al.*, 2004 and Spencer *et al.*, 2005). The size of wild pig groups in an area varied depending upon season, habitat and predation (Dardaillon, 1988 and Eisenberg and McKay, 1974). Fernández-Llario *et al.* (1996) reported that group size reached a maximum during the peak farrowing season. Diong (1982) also recorded that wild pig population with higher reproductive success form larger family groups. Very large groups i.e. up to 100+ animals of wild pigs were seen (Prater, 1965, Lekagul and McNeely, 1988). Such groups could occasionally be observed in situations of a concentrated attractant (e.g. food resources such as agricultural crops, waterholes in arid areas or during dry seasons). These oversized groups were typically only temporary localized phenomena and did not persist beyond the immediate site of the attraction (Frädriich, 1984).

Although solitary sightings can include either sex or any age class of wild pig, most are composed of mature boars. Most studies reported that adult males comprised from 70 to 90% of the solitary wild pig sightings (e.g. Challies, 1975; Baber, 1977; Saunders, 1988 and Braza and Alvarez, 1989). In contrast to these findings, Singer *et al.* (1978) reported that adult males made up only 13.5% of those sightings. The reason for that apparent inconsistent observation was not provided. Solitary mature sows were uncommon and thought to be usually consisted of pregnant sows about to give birth (Baber, 1977). Also uncommon, solitary immature pigs were probably either orphaned, temporarily separated from their family group, or in the process of dispersing from their family group.

Wild boars *Sus scrofa* have a social organization based on female groups that can include several generations of adults and offspring, and are thus likely matrilineal. However, little is known about the degree of relatedness between animals living in such groups or occupying the same core area of spatial activity. Also polygynous

male mating combined with matrilineal female groups can have strong influences on the genetic structure of populations. They used microsatellite genotyping combined with behavioral data to investigate the fine-scale population genetic structure and the mating system of wild boars in a multi-year study at Chanteauvillain-Arcen Barrois (France). According to spatial genetic autocorrelation, females in spatial proximity were significantly inter-related. However, they found that numerous males contributed to the next generation, even within the same social group. Based on their genetic data and behavioral observations, wild boars in this population appeared to have a low level of polygyny associated with matrilineal female groups and infrequent multiple paternities. Mortality due to hunting was reported to facilitate the break up of what historically had been a more predominantly polygynous mating system, and likely accelerated the turnover of adults within the matrilineal groups (Poteaux *et al.*, 2009).

## **2.2 Habitat**

Wild pigs were found to occupy and exploit a wide variety of habitats (Eisenberg, 1981). The general habitat requirements for this species over most of its range included reliable and adequate seasonally available forage resources (e.g. mast production during the fall and winter months) and daily access to well distributed water, shade and escape cover on a year round basis (Pullar, 1950; Wodzicki, 1950; Pine and Gerdes, 1973; USDA, 1981; Baber and Coblenz, 1986; Barrett, 1982 and Choquenot *et al.*, 1996). Given those attributes, wild pigs can thrive as readily in plains as in the mountains, in swamps as well as relatively dry steppes and in remote areas as well as in densely populated areas where they actually thrive close to civilization. Such habitats can range in elevation from sea level up to 4000 m above msl (Nasimovic, 1966 and Frädrieh, 1974, 1984).

Wild pigs are comfortable on flat to very steep terrain. However, these animals did not tend to inhabit deserts, high mountain areas with substantial winter snowfall, or intensive agricultural areas where cover was scarce (Waithman, 2001). Throughout its range, the wild pig had shown a preference for riparian and wetland habitats (e.g. forested swamps, bottomland hardwoods, emergent marshes, sloughs, stream and

river drainage corridors) as well as mesic upland hardwood forest (e.g. Kurz, 1971; Graves, 1984; Saunders and Kay, 1996; Caley, 1997; Laurance and Harrington, 1997; Mitchell and Mayer, 1997; Dexter, 1998; Friebel and Jodice, 2009 and Sparklin 2009). Other habitats such as pine/conifer forest, arid scrub brush, chaparral, grasslands were utilized, but typically only on a temporal basis. With respect to the sexes, Spitz and Janeau (1995) found that females showed a preference for denser habitats than males, which spent more time in the open. Wild pigs were found regularly modifying their habitat use within their home range based on climatic conditions and the availability of food and water (Kurz and Marchinton, 1972; Wood and Brenneman, 1980; Baber and Coblenz, 1986; Choquenot *et al.*, 1996 and Dexter, 1998). Abrupt or seasonal changes in habitat use by wild pigs in an area were often found to be related to food availability and dietary shifts (Sweeney, 1970; Kurz and Marchinton, 1972; Graves and Graves, 1977 and Barrett, 1978).

The daily activity patterns of wild pigs vary by locations. Frädriich (1974) stated that because man nearly always and everywhere exercises influence on wild pig populations, it is difficult to regard them as either diurnal or nocturnal. Both Kurz and Marchinton (1972) and Wood and Brenneman (1977) reported that wild pigs were largely diurnal. Gundlach (1967) further observed that in relatively undisturbed areas, wild pigs seemed to trend toward diurnal activity. However, intense hunting pressure or human activity during the day would drive pigs to become more nocturnal in their activity patterns (Stegeman, 1938; Hanson and Karstad, 1959; Choquenot *et al.*, 1996; Waithman, 2001 and Pei, 2006). Wild pigs in California, which were almost exclusively nocturnal during summer, were most active on moonlit nights (Waithman, 2001).

### **2.3 Ranging pattern**

Home range over periods of time found to be dependent on food availability, population density, reproductive activity, quality and interspersions of habitat, season, climatic conditions, disturbance by humans and social organization (Conley *et al.*, 1972; Kurz and Marchinton, 1972; Pavlov, 1980; Crouch, 1983; Hughes, 1985 and Choquenot *et al.*, 1996).

Wild pigs exhibit home range behaviour in that the movements of these animals are generally restricted to a defined area over an extended period of time. In general, wild pigs showed a general trend toward sedentary habits; however, depending upon ecological conditions, these animals might roam about widely in search of better forage conditions (Frädriich, 1974; Giles, 1980 and Pavlov, 1980). In addition, periodic irregular shifts in home range occurred within this species (Barrett, 1978 and Wood and Brenneman, 1977). The home range size in wild pigs is variable. Typical home ranges in this species found to cover an area of about 10 km<sup>2</sup> and were also found up to one to nine km in length on a side (Kurz, 1971 and Saunders, 1988). However, home ranges as large as 154 km<sup>2</sup> had been reported (Maillard and Fournier, 1995). The home range size was determined by a mixture of factors including the absolute and spatial availability of food, water and escape cover, body weight, and the local density of pigs (Singer *et al.*, 1981; Diong, 1982; Saunders, 1988; Caley, 1993; Massei *et al.*, 1997 and Saunders and McLeod, 1999). In Australia, the home ranges of feral pigs in a wide range of habitats found to vary from 1.4-43 km<sup>2</sup> for males and 1.5-19.4 km<sup>2</sup> for females (Choquenot *et al.*, 1996). For example, wild pigs inhabiting arid shrub-scrub and woodland areas with poor food supplies showed notably larger home ranges than did pigs occupying mesic forested environments with ample forage resources. Home ranges in wild pigs typically found to increase in size from daily to seasonal, and then to aggregate annual areas utilized. In addition, Gaston *et al.* (2008) reported that intense hunting pressure caused wild pigs to decrease their home range in an attempt to avoid the hunters.

Boars showed larger daily, seasonal and overall home ranges than sows (Choquenot *et al.*, 1996). Sterner (1990) reported that home ranges for boars were 2.5 to 4 times larger than those for sows. There was also greater variation in the male home ranges compared to female home ranges. In contrast to this, Saunders and McLeod (1999) reported that, when the effect of body mass was taken into account, there were no sexual differences in the home ranges of wild pigs. Kurz (1971) noted that boars were given to making excursions beyond their established home range boundaries and then return; sows typically did not exhibit this behaviour. Home ranges of boars and sows were also found to overlap extensively between and within the sexes. This was found true of the overall range as well as core areas (Baber and Coblenz, 1986 and DEFRA,

2004). However, Adkins and Harveson (2007) reported that range overlap was higher within than between the sexes in wild pigs. Barrett (1971) and Saunders (1988) both found that the home ranges for barrows i.e. neutered males were similar to those for females. Kurz (1971) reported that sows appeared to reduce their home range approximately one month before farrowing. Singer *et al.* (1981) reported that sows could also significantly reduce their home ranges when nursing their young. Barrett (1978) further observed that sows with young less than 3 weeks old rarely moved more than 0.5 km from their farrowing nest location. Sparklin (2009) observed that adult sows used a small portion of their home range from immediately before until approximately two weeks after farrowing.

The shapes of a wild pig's home range were described as ranging from being generally circular to elongate (Singer *et al.*, 1981 and McIlroy, 1989), and were determined by the local terrain, floral and habitat cover and available resources. Singer *et al.* (1981) also reported that home ranges were generally more circular in summer than in winter. Kurz (1971) reported that there was a tendency for wild pig home ranges to be bordered by man made or natural topographic features e.g. rail road tracks and streams. The use of the area encompassed by the home range was localized or patchy, with the different parts of their home range being connected by a network of paths which were regularly used (Hanson and Karstad, 1959; Barrett, 1971 and Frädriich, 1974). One or more core areas, each approximately <1 km<sup>2</sup> in size, existed within a wild pig's home range. Core areas typically found to contain preferred resting areas. The core areas of males were more scattered within the entire range and less intensively used than those of females (Boitani *et al.*, 1994). Sparklin (2009) found that family groups used well-defined core areas within the social unit's home range. These core areas were located in dense thickets in both pine uplands and hardwood bottoms.

Seasonal variations have also been recorded in the home range sizes for wild pigs; although these differences are not consistent and vary depending upon the same suite of factors that generally determine home range size. According to Boitani *et al.*, (1994) seasonal home ranges for wild boar in Italy were smallest when food was abundant. Singer *et al.*, (1981) reported that summer home ranges for wild pigs in the Great Smoky Mountains National Park did not differ significantly from the winter

ones. However, these authors did note that home ranges in that location did increase significantly during one winter period when the mast crop failed. Sterner (1990) also reported that seasonal differences in home ranges for the wild pigs were not evident on Santa Cruz Island, California. Kurz (1971) stated that summer and fall home ranges in western South Carolina were smaller than the winter-spring ranges. Both Crouch (1983) and Hughes (1985) found that the spring home ranges were smallest for both sexes. However, these studies showed that the fall home range was the largest for males, while the summer data were the largest for the females. The larger fall home ranges for males might be the consequence of increased movements by these boars in search of sows in estrous. Periodic shifts in home range were also recorded for wild pigs (Hughes, 1985).

Home range size in feral pigs was determined by the abundance of food, and it was found correlated with both body weight and population density (Saunders, 1988 and Caley, 1993). The only new studies over the last decade of what feral pigs in New Zealand ate confirmed their need for protein in their diet for breeding and growth (McIlroy, 1990). The diet of 30 pigs shot on sub-antarctic Auckland Island during the winter of 1996 (Coleman and Parkes, 1997) was different from that of 33 pigs shot there in spring 1989 (Chimera *et al.*, 1995). Feral pigs in the northern part of the South Island bred throughout the year (McIlroy, 1989 and Dzieciolowski *et al.*, 1992). McIlroy (1989) estimated the density of pigs in a heavily hunted area near Murchison at about 3-8 pigs per km<sup>2</sup>, compared with 12-43 per km<sup>2</sup> in a lightly hunted area with abundant food and cover nearby. Dzieciolowski *et al.* (1992) estimated an exponential rate of increase of 0.90, based on reproductive rates and the age structure of harvested individuals. This level was very high compared with the rates of 0.25-0.78 for pig populations in Australia living in good conditions or recovering from control operations (Giles, 1980; Hone and Pedersen, 1980; Caley, 1993; Saunders, 1990 and Choquenot, 1998).

The radio telemetry studies in southern France indicated that wild pigs generally traversed between 2 and 15 km per night. However, the home range estimates for adult females and adult males over a 2-3 month period varied from 500-1,000 ha and 1,000-2,000 ha respectively. During the same period, sub-adult pigs covered an area of 500-5,000 ha. Movements over long distances (50 to 250 km) were also recorded in

Europe, but the reasons of these movements had yet to be studied (Spitz, 1986). The research conducted so far in India includes few ecological and behaviour aspects of wild pigs. For the first time, this study on home range, ranging and activity pattern using radio-telemetry method, feeding ecology and behavioural aspects of wild pigs was conducted in Ranthambore National Park.

Pigs are very mobile animals and their home ranges are not fixed in locality. Under stress they may disperse to considerable distances. In Australia, feral pigs were found to move 20 km in 48 hours when they suffered from food shortage (Auld and Tisdell, 1986). This mobility could mean that it was uneconomic for an individual landowner or controlling agency to control a pig population because animals destroyed were soon replaced by pigs moving in from adjacent properties. In Hawaii, snaring was used to control pigs within 600-800 km<sup>2</sup> fenced enclosures.

Wild pigs are generally not territorial. As recorded previously, there is extensive range overlap both between and within the sexes. In general, no defence of an exclusive area by either sex over time is typically reported. In fact, Kurz (1971) reported extensive range overlap among mature males in his study area. The one exception to this behaviour might be a few uniquely dominant males. Boitani *et al.* (1994) reported that large adult boars could be territorial, and they maintained exclusive home ranges during the breeding season in winter. Conley *et al.* (1972) also recorded the existence of anecdotal evidence to support territorial behaviour in large males.

## **2.4 Feeding ecology**

Wild pigs (*Sus scrofa*) were found to be omnivorous and generally opportunistic in their food habits (Sweeney *et al.*, 2003). These animals made efforts to maximize the intake of a preferred food resource when it was encountered. This adaptability could occasionally result in abrupt and radical seasonal changes in diet observed as new forage species became available (Barrett, 1978). Subsurface herbaceous materials (e.g. roots, tubers, bulbs etc.) were widespread and important staples in wild pig diets throughout their distribution. In general, wild pigs preferred fleshy roots or corms or

woody roots (Howe *et al.*, 1981). The use of agricultural crops as a forage resource by wild pigs varied, ranging from nothing up to 71% of the plant material consumed (Genov, 1981a and Irizar *et al.*, 2004). Like plants and fungi, animal material (i.e. invertebrates and vertebrates) was consumed year-round (Scott and Pelton, 1975). In spite of being omnivorous, wild pigs were mostly herbivorous in their food habits; however, they did prey on a broad range of animal species (Barrett, 1971; Diong, 1973; Wood and Barrett, 1979 and Giles, 1980). This variously included egg, larval or immature, and adult forms of these different animals as well as the remains or carcasses of many of these species. One of the most significant impacts of this type of wild pig foraging was the predation of the eggs and hatchlings of reptiles and birds. It was suggested that food habits studies of wild pigs could under represent the percentage of animal matter in the diet (Hahn *et al.*, 1998 and Loggins *et al.*, 2002). Rapid digestion of soft tissues often caused animal matter to be overlooked when an analysis of stomach contents or feces was conducted (Klaa, 1992; Fournier-Chambrillon *et al.*, 1995 and Schley and Roper, 2003). Unless exoskeleton, bones, scales, feathers, hairs, or remains were present, documentation might not occur. The presence of animal matter in the diet of wild pigs was reported to be due to more availability and accessibility rather than prey selection (Klaa, 1992). Throughout their range, the diet of wild pigs varied by season. This variation was primarily a function of availability and abundance of local plant and animal communities (Klaa, 1992 and Sjarmidi *et al.*, 1992). According to Coblenz and Baber (1997), pigs were extreme generalists. Forbs were the major food, with grasses, fruits and invertebrates consumed in small amount.

The Middle Ebro Valley was a semi-arid area in northeast Iberia, and wild boars were found to feed mainly on crops, particularly, maize in this area. Other elements of the diet of agricultural origin included wheat, barley, and alfalfa, which were the alternatives to maize in the period between harvest and seeding, which was found the basis of seasonal changes in diet. Results indicated that wild boar actively selected maize crops and consumed wheat in proportion to its abundance; barley and alfalfa fields were damaged less than expected based on their abundance (Herrero *et al.*, 2006).

In New Zealand, their annual diet comprised of 71.9% plant material and 28.1% animal material, the proportions were similar in all seasons. The fruits of tawa (*Beilschmiedia tawa*), hinau (*Elaeocarpus dentatus*) and supple jack (*Ripogonum scandens*) together made up of one-third of the diet of pigs. These were taken seasonally, comprising 60% of their food in autumn, 42% in winter and 25% in summer. The other major plant foods were the roots of supple jack, the fronds and stems of tree ferns (*Cyathea* spp.), and the rhizomes and roots of bracken (*Pteridium esculentum*); the first two foods were taken mainly in spring and summer. Earthworms and vertebrate carrion, especially the carcasses of brushtail possums (*Trichosurus vulpecula*), were the main animal foods eaten. It was suggested that periodic fluctuations in pig numbers might be associated with yearly differences (Thomson and Challies, 1988).

Vegetable foods occurred more frequently in the diet than animal foods, and also constituted the bulk of the food ingested. Overall, there were four major vegetable food categories: mast, roots, green plant matter and agricultural crops. Depending on the study area, wild boar always consumed at least one energy-rich plant food such as acorns, beechnuts, chestnuts, pine seeds, olives, cereal grains or other crops. The number and types of agricultural crops consumed varied between study areas but crops represented an important component of wild boar diet throughout its Western European range. Among animal foods, insects, earthworms, birds and mammals were eaten most consistently but the diet also included amphibians, reptiles, gastropods and myriapods (Schley and Roper, 2003).

The plant materials comprised 25.2% of the total mass, 16% was animal mass and 0.8% mud and 58% garbage matter. Wheat leaves dominated in the samples collected in December 2005 until March, when wheat grains became the major part of diet until July. Maize first appeared in the diet in March and was present until June. A small quantity of tree bark and leaves of *Zizyphus* (ber) were also present, while *Mesquite* was heavily consumed in June and July. Several grasses and weeds appeared prominently in the diet in August up to November. Garbage matter was present in the stomach throughout the year. In conclusion, the diet of wild boars in Islamabad comprised of a significant amount of plant food (Hafeez *et al.*, 2008).

Wild pig was found to be an important wild prey in the diets of carnivores (Bagchi *et al.*, 2003). Cannibalism or predation of wild pigs by other individuals within that same population was documented to occur (Barrett, 1971 and Wennrich, 1976). Such intra-specific predation would be primarily directed at immature animals. The most likely instance would involve the predation of unattended newborn piglets by adult boars.

## **2.5 Digging activity**

Rooting activity was found to vary in different forest types (Laurance and Harrington, 1997). Digging was a reliable indicator of presence of wild pigs. Wild pigs could be secretive in their behaviour and shift their activity patterns to avoid being readily observable by humans (Goulding, 2003). The presence of these animals in an area might therefore not be verifiable by the direct observations of either animals or their physical remains. However, the presence of wild pigs in an area could be readily identified from the field signs of these animals (Mayer and Brisbin, 1991 and Goulding, 2001). The most common and evident field sign created by wild pigs was rooting. This was the first field sign noted when the escaped wild boar began to establish themselves in southern England in the mid to late 1980s (Goulding, 2003).

Rooting was simply the result of wild pigs foraging for food located in either the leaf litter or below the surface of the ground. These foods included hard and soft mast, newly emergent tips of shoots, roots, tubers, bulbs, rhizomes, subterranean fungi, both adult and larval invertebrates, and even some smaller vertebrate species. Wild pigs used their snout to excavate soil in a forward pushing and scooping motion. The feet were infrequently used in a pawing motion to supplement the snout actions. Rooting was done by all wild pigs, regardless of sex or age. However, although piglets were found to start rooting from their first day of life, adult wild pigs was found responsible for most of the rooting in a large forested area of the Netherlands (Groot Bruinderink and Hazebroek, 1996). Rooting was done year-round in search of food (Barrett, 1971 and Belden and Pelton, 1975). The scats or droppings of a wild pig could vary widely depending on the material that was eaten and the size of the animal that produced it. In general, most droppings were irregularly shaped lumps approximately 3-7 cm thick

and 7-22 cm in length (Anon., 2003). The colour might vary from light brown to black, and had a purplish hue when fresh (Goulding, 2003).

Wild pigs frequently rub their body against either natural or manmade objects. The function of this behaviour was found to provide comfort, remove excess mud, remove hairs and mechanically rid the body of ectoparasites (Conley *et al.*, 1972 and Graves, 1984). Because of the need to cool themselves and get relief from external parasites and biting insects, wild pigs were found to wallow. Wallowing behaviour occurred round the year (Belden and Pelton, 1976 and Stegeman, 1938); however, it was especially pronounced in the summer months (Crouch, 1983 and Stevens, 1996). Wild pigs were found to rub their body against trees, rocks and or other immovable objects. Tree rubs were often found near trails that these animals used regularly (Barrett, 1971 and Waithman, 2001), especially those near wallows (Stegeman, 1938).

## **2.6 Invasive species**

Anderson and Stone (1993) regarded feral pigs as ‘currently the most pervasive and disruptive alien that influenced on the unique native forests of the Hawaiian Islands. Pigs were found to damage to forests by eating or uprooting tree seedlings as well as other plants with palatable leaves or stems, including ferns and some orchids. They were found to break open tree-fern trunks in search of starch (Griffin, 1977). A secondary but very significant impact resulted from consumption of the fruits of some species of invasive weeds such as guava by pigs; the seeds passed through the gut and droppings, thus spread those weeds far more rapidly.

Pigs were also found to impact on large native invertebrates such as earthworms and land snails by destroying their habitat, and eating their eggs, juvenile growth stages or adults (Meads *et al.*, 1984). Pigs were found to be very effective predators of both surface- and burrow-nesting seabirds. Moors and Atkinson (1984) concluded that pigs probably also ate the eggs and young ones of other surface-nesting seabirds such as albatrosses, shags and boobies, but adequate documentation was lacking. In addition to their impact on native wildlife and native plant and animal communities, pigs adversely affected agricultural crops, including sugarcane. They were also found to damage planted forests by digging up young trees and eating their roots (McIlroy,

1990). They were reported to have the potential to spread diseases to other animals, both domestic and native, and were reputed to facilitate attacks on trees by the dieback disease caused by the fungus, *Phytophthora cinnamomi* (Auld and Tisdell, 1986).

Wild pigs were also found to widely implicated in the declines and extinctions of numerous native species of flora and fauna worldwide (e.g. Bratton, 1974; Roots, 1976; Wiewandt, 1977; Tisdell, 1982; Lever, 1985; Oliver and Brisbin, 1993; Cuthbert, 2002 and LaPointe, 2006). In fact, the Species Survival Commission of the World Conservation Union (IUCN) listed these animals as being among the 100 worst invasive alien species from around the world (Lowe *et al.*, 2000). Feral pigs were reported to have an adverse effect on native flora (Bratton, 1975 and Howe *et al.*, 1981). Impacts caused by the rooting of wild pigs were found varied and depending on the local situation, impacts were viewed as either detrimental or beneficial (Tisdell, 1982).

There has been no scientific research published on the activities of the free-living wild boar currently present in England. The only English literature available was related to the farming of wild boar for meat (Booth *et al.*, 1988 and Kyle, 1995), the integration of wild boar with forestry (Brownlow, 1994) and their possible re-introduction into the British Isles (Yalden, 1986 and Howells and Edwards-Jones, 1997). However, European wild boar populations, particularly in Italy, France and Poland, were studied in some depth as had feral pig populations in Australia and America. This literature was reviewed to determine the current state of knowledge on wild boar and feral pig populations. The origin and genetic purity of the many wild boar populations throughout the native range of animals remained unclear. Wild boar were always favoured as animals for hunting and they were introduced into numerous localities and countries for this reason (Singer, 1981; Tisdell, 1982 and Boitani *et al.*, 1994). Some localities might have already supported wild boar populations of their own, thus populations were often genetically mixed. For example, the genetic polymorphism seen in many wild pigs from interbreeding with feral pigs was believed to affect the phenotypic and ecological characteristics of certain Italian wild boar populations (Apollonio *et al.*, 1988; Boitani *et al.*, 1995 and Paolo and Marina, 1988).

Feral pigs (*Sus scrofa*) were found widespread in New Zealand but they were generally considered to be a minor, whose numbers were limited by recreational hunting. However, there was increasing concern about their potential for transmitting diseases such as foot and mouth disease. Despite this, there were only two studies on the ecology of feral pigs in New Zealand (Wodzicki's, 1950), Auckland Island (Challies, 1975) and in North Canterbury (Martin, 1975).

In Veluwe area of Netherland, the study was carried out on the dietary habits and it was found that density dependence was for the decrease in mast consumption from autumn to winter (Groot Bruinderink and Hazerbroke, 1994). Wood and Roark (1980) studied food habits of feral hogs in coastal South Carolina. Fruits, herbage and roots were the most important types of food, although relative importance of these categories varied seasonally. Most of the workers reported that ingestion of animal matter by feral hogs was frequent, but that composed of minor portion of the diet.

Wild pigs or their feral derivatives were widely distributed by humans, and significant populations now found to occur on all continents except Antarctica (Oliver and Brisbin, 1993). Where they were not native, wild pigs were often the subject of a variety of management efforts aimed at eradicating or controlling populations to minimize ecological or economic damage (Hone, 1990a; Sterner and Barrett, 1991; Anderson and Stone, 1993 and Barrett, 1993) differing management approaches, developing accurate and cost effective methods for enumerating sizes and assessing densities were important for hunting and eradication efforts, and had implications for agricultural and ecological damage (Hone, 1990b; Caley, 1993; Choquenot, 1995; Sweitzer, 1998 and Katahira *et al.*, 1993).

Wild pigs in the North and Central Coast regions of California were found to be closely associated with the availability of permanent water and oak woodland habitats (Waithman *et al.*, 1990). The density of wild pig populations could respond rapidly to changes in forage availability (Barrett, 1978 and Schauss *et al.*, 1990). Differences in population density between years were attributed to changes in the density of young pigs, coincident with a mast-seeding year of dipterocarp trees in 1996. Two factors likely accounted for the extremely high pig densities were local extinction of natural

predators (mainly tigers and leopards) and an abundant year-round food supply of African oil palm fruits from extensive plantations bordering the reserve (Ickes, 2001).

## **2.7 Breeding biology**

Wild pigs are prolific breeders and apparently breed throughout the year. Normally, the wild pigs are sexually mature at 18 months of age, but a male will not usually mate until male attains about four years of age. The dominant male is generally solitary and joins the sounder during breeding season (Graves, 1984). Boars and sows are known to collect in large assemblies when pairing. They congregate in a circle, the master boars remain in the centre. The sows in a group usually come in the oestrous simultaneously a phenomenon known as oestrous synchronization (Eisenberg and Lockhart, 1972). During the autumn mating season, the male joins a herd of females and fights any male who challenges his position. Fighting boars use their tusks to slash at shoulders of each other. Despite their thick skin and coarse layer of hairs on the shoulders, deep wounds are sometimes inflicted. The wild pig and feral pig crosses and conceive successfully. After mating, the boar leaves the herd, taking no part in rearing the young. After breeding, the big boars live alone or in company of another of equal size or with one or two sows.

After a gestation period of 112-115 days, normally a litter of 4-6 piglets is born in the spring. Sow usually litter once a year, but instances of two litters per year are also recorded. In Western Europe, litter size is usually between 4 and 7 piglets (Briedermann, 1990). Harrison and Bates (1991) reported occurrence of 5 and 7-10 piglets per litter as being usual in Iraq and Armenia respectively. The litter size peaks when the sows are 2-3 year old and drops down as the sow grows old. The piglets are born with stripes and these help to camouflage them in the undergrowth. Their coats become a dull and dun colour at about six months of age, and they will stay with their mother until at least the next litter is born. When young ones attain one year age, their coats turn into a rich black-brown colour and they reach full size at 5-6 years of age. The mother has 8-14 teats and each piglet can have a teat to suckle. The first piglets born choose teats near head of their mother so that they have a better chance of attracting her attention and are less likely to be trodden on. The young ones are

suckled for about 12 weeks before they are completely weaned onto food which they find while rooting around with their mother.

The breeding sow builds a farrowing nest of plant material, which is compact having water repellent quality. The nest is built in a hollow depression on ground and is covered with plant material such as twigs, leaves, grass etc and this roofing of plant material gives the nest dome like appearance. The nest protects the piglets and keeps them warm and dry since the piglets are born with very little hairs on their body. The mother shelters them in a heap of grasses or branches which she builds before littering. The piglets join the sow after a week and take solid food after about a fortnight, but their main source of food is milk for three months. The litter stays in the nest for about 10 days and then the family moves off, joining up with previous litters. The piglets have brown coat with lateral dark stripes which is characteristic of the wild pigs (Santiapillai and Chambers, 1980; Prater, 1980; Baber and Coblenz, 1986; Dardaillion, 1986 and Ramdas, 1987).

Annual recruitment into the total population depends on reproductive rate i.e. the number and prolificacy of females, and juvenile mortality; both of these factors may be influenced by the availability of food and other external factors (Spitz, 1986). Juvenile mortality averages around 15% in the first three months in Western Europe, though between 50% and 75% mortality have been reported within one year of age (Jezierski, 1977 and Briedermann, 1990). These mortality rates are thought to be highly dependent on external factors like predation and climatic hazards, at least in wilderness areas (Spitz, 1986).

Among all the wild pigs species with exception of *Sus domesticus*, the *Sus scrofa* is by far the most widely maintained and bred in captivity, though general perceptions about the relative abundance of this species has resulted in diminished interest in its propagation. Many zoos, particularly in Western Europe, have therefore disposed of their stocks of these animals, mostly to 'wild boar breeding farms', which have escalated in number to meet growing demands in the gourmet meat markets and for commercial diversification. In addition, increasingly restrictive quarantine and other veterinary regulations pertaining to the international movements of all live suids have made it extremely difficult to establish new breeding programs.

## 2.8 Capture and handling

Pigs were either trapped or caught with the help of dogs. Weld mesh panel traps were used near fresh signs of pig activity e.g. rooting, tracks and faeces and baited with carrion, bread, fruit, vegetables and grain for capturing pigs (Boreham, 1981). Trapping success was poor because birds and brushtail possums (*Trichosurus vulpecula*) often ate the bait and sprung the traps. Immobilization of pigs with an intramuscular injection of Ketalar (Ketamine hydrochloride) 15 mg per kg body weight followed by an equal amount of Rompun (Xylazine hydrochloride) was to minimize the adverse side effects of Ketalar. Unlike this combination (Baber and Coblenz, 1982), the 1:1 mixture of both drugs was found ineffective in remote areas of rain forest in the Haleakala National Park, Maui (Anderson and Stone, 1993).

The only requirements that a trap designs could achieve were that pigs might be able to enter relatively easily, and after the door was shut, the animals could not be able to escape (Caley, 1999). Panel traps consisted of three or more connected panels or sections were frequently used. Typically, the panels were welded with metal frames (e.g. galvanized pipes) covered with welded or woven wire. Whichever the construction, the openings in the wire mesh or spaces between wooden boards were small enough to prevent small piglets from escaping, especially near the bottom of the panel. The panels or sections were typically 3 to 5 m in length and 1.5 to 2 m in height. The door was a separate framed component connected to the ends of two of the panels or built into one of the panels or sections. Doors could be almost any design (e.g. drop, hinged or funnel or squeeze). Triggers normally included either root or trip-wire designs. The panels were connected together through a variety of means (e.g. pull pin metal hinges, metal hose clamps, cable ties, wire or rope). The advantage of panel traps was the combined versatility of sturdiness and configuration options. Designs for the construction of panel traps for wild pigs were recommended by Belden and Frankenberger (1977), Giles (1977), Sweitzer *et al.* (1997b) and Caley (1999).

Trapping was found to be a very effective way to reduce numbers of wild pigs where they were either present at low to moderate densities or concentrated in small areas (Giles, 1977; Caley, 1999 and Vernes *et al.*, 1999). The varieties of baits were used to

trap wild pigs effectively. The best bait to use in a specific area could be regionally dependent. Whatever bait could be chosen; it needed to be readily recognized by and attractive to the local animals, cheap to purchase, easily handled and have a long life in the trap (Giles, 1973). Because of the pig's highly-developed sense of smell, the use of baits with increased odours could increase the trap harvest (Seamark, 1999).

Wild pigs were trapped in modified panel traps baited with fermented corn (Switzer *et al.*, 1997a). Immobilized or trapped pigs with a combination of Telazol and Xylazine hydrochloride was done (Switzer *et al.*, 1997b), and blood was collected through jugular puncture. The body mass and age through dental formulas classified them into piglets of < 8 months, sub-adults with 8-18 months, adults >18 months (Matschke, 1967). The procedure for handling captured feral hogs required the use of an immobilizing drug to reduce the potential for injury to the researchers as well as to the animals. Zurowski and Sakowicz (1965) made 27 observations on the use of Succinyl choline chloride in Poland and concluded that the European wild hog (*Sus scrofa*) had a high tolerance for the drug. Matschke and Henry (1969) made 92 observations on European wild hogs in Tennessee and concluded that the effects of Succinyl choline chloride were highly variable and that tolerance had been overestimated by (Zurowski and Sakowicz, 1965). Based on 182 observations of 151 feral hogs injected with a liquid preparation of succinyl choline chloride at the rates from 0.46 to 1.20 mg/kg live body weight, they believed that it was a reasonably safe and effective drug, although response was variable in this animal (Wood *et al.*, 1977).

Switzer *et al.* (1997a) used Telazol 3.3 mg/kg and Xylazine hydrochloride 1.6 mg/kg to immobilize wild pigs. This drug combination was safe and effective for rapidly immobilizing animals of weight ranging from 34 to 170 kg. A portable modified steel mesh panel trap was developed to reduce injuries that wild pigs suffered when captured in simple square panel traps. Heart rates, respiration rates, and body temperatures were all lower for animals immobilized with Telazol and Xylazine HCl compared to relatively few animals that were restrained for immobilization with Ketamine HCl and Xylazine HCl. They captured an average of 2.5 pigs per trap night, and in 343 captures only 11 animals were injured. There were no capture-related mortalities. Also the trap was efficient at capturing multiple-animal groups, and there was no difference in the mean size of pig groups captured using a top-hinged gate.

Safe and effective traps and restraint techniques were found to be important because of the need to capture and handle study animals with a minimum of stress and injury (Peck and Simmonds, 1995 and Thompson, 1995). Two primary trap designs used for capturing these animals were box traps (Foreyt, 1979; Schauss, 1980 and Sterner, 1990) and panel traps (Hone, 1984 and Lukins, 1989). Box traps were constructed of either wood slats or fencing around a pipe or wood frame. Panel traps were square or rectangular traps made of pre-fabricated steel mesh panels wired together and held in place with steel fence posts. A trap design that allowed for the capture of multiple animal groups could help reduce costs of trapping (Waithman, 1982). Both panel and box traps were effective at capturing multiple wild pigs (Hone, 1984; Baber and Coblenz, 1986; Lukins, 1989 and Choquetot *et al.*, 1993), but panel traps could be used to capture larger groups than box traps (Waithman, 1982). Although box traps might require little labor after initial assembly, it could be difficult to transport these into remote areas with limited road access. Disassembled panel traps can be readily carried into remote areas, but require more labor for reassembly.

Minimizing stress associated with capturing and handling of animals is another consideration in trap design. Painful trapping and handling procedures could have adverse physiological consequences including weight loss, increased systemic concentrations of stress hormones, and capture myopathy (Boever, 1986; Kreeger *et al.*, 1990, 1991 and Kaufman and Kaufman, 1994). Safety and animal welfare considerations are especially important for wild pigs because they are aggressive when confined in traps and can injure themselves in attempts to escape. Wild pigs captured in both box and panel traps were usually physically restrained for processing, or temporarily restrained to administer hand injections of Ketamine HCl and Xylazine HCl to immobilize them for processing (Baber and Coblenz, 1982). Physically restraining pigs to hand inject this drug combination is necessary because the recommended immobilization dose of 15-20 mg/kg Ketamine HCl and 15-20 mg/kg Xylazine HCl requires a large total volume of drugs, which is difficult to administer using pole syringes or darts.

In general, wild pigs were regarded everywhere as a pest and were therefore heavily hunted to keep their numbers in control. This drove these animals to adopt a nocturnal

activity pattern and frequently seek shelter in heavy, dense cover, making behavioural studies difficult if not impossible to conduct (Frädriich, 1974). In spite of those challenges, a number of behavioural studies of free-ranging wild pigs were carried out since that time (Barrett, 1971; Baber, 1977; Van Vuren, 1984; Dardaillon, 1988; Saunders and Kay, 1996; Caley, 1997 and Fernández-Llario, 2004).

## 2.9 Human-wild pig conflict

Wild pigs raid agricultural crop fields in groups and feed on variety of crops. Damage to *Triticum aestivum*, *Oryza sativa*, *Zea mays*, *Saccharum officinarum*, *Arachis hypogea*, *Cicer arietinum*, *Brassica compestris* and *Sorghum vulgare* varied from 5-30% across the country (Chauhan, 2004). *Eleusine coracona*, *Phaseolus radiatus*, *Glycine max*, *Sesamum indicum*, *Lens esculenta* and *Ipomoea batatas* showed insignificant damage i.e. only 5-8%. Damage was very high in crop fields close to forest areas (Chauhan and Rajpurohit, 1996, 1998). Crop raiding was observed generally during night. Almost all phenological stages were fed upon by wild pigs, but the early tender stage and crop maturation stage when grain panicles were highly susceptible to damage.

Occasionally wild pigs attack on people and cause injury due to mere confrontation. Human casualties by wild pigs are widespread in different parts of the country (Chauhan and Rajpurohit, 1996, 1998). Most of these cases occurred inside forests and resulted in to severe injury. As a result, there has been increasing trend in the human-wild pig conflict in and around protected areas, managed forests and human settlements throughout the country. Despite of this fact, management of this species hitherto has not been attempted in India because the information available on ecology and behaviour is inadequate for management of this species. This task has become even more difficult and challenging in situations where people's interests come in way of wildlife needs. Consequently, the conservation efforts for the endangered species are adversely affected everywhere.

In India, no animal is more destructive to agricultural crops than wild pigs and it is impossible to make a plea for its protection (Prater, 1980). In the Pul-i-Khumri district

of Afghanistan, decrease in the numbers of wild pigs was due to the draining of marshlands for agricultural purposes and hunting by Europeans in the 1950's (Hassinger, 1973). But they were still numerous in other adjoining districts where they increasingly raided crop fields and caused serious damages during the crop harvesting time. In many parts of Perak and Johore in West Malaysia, wild pigs (*Sus scrofa vittatus*) populations declined drastically as a result of increased hunting pressure, particularly for commercial purposes (Diong, 1973). Nevertheless on account of extensive damage caused to a variety of crops, including sugarcane, tapioca, rice and coconut by wild pigs, they are still included in the Agricultural Pest Ordinance, 1977 in Malaysia. Lay (1967) also reported occurrence of damage to crops by wild pigs in Iran, which brings great wrath upon them from the local farmers. In Pakistan, the expansion of the sugarcane industry during 1960-1970 brought about local increase in the numbers of wild pigs, *Sus scrofa davidi* (Shafi and Khokhar, 1986). They were found to cause considerable damage in the cane fields, which led to more and more use of poison baits by farmers for killing the pigs. The environment, socio-cultural and agricultural practices in Europe, Australia and America are different, and accordingly the conflict mitigation strategies were developed in these countries.

In India, farmers employ different crop protection measures to protect their crop from wild pigs. Crop damage is generally contained by lighting fire at some places in crop field, and guarding crop fields sitting on elevated platforms or watch tower during nights with light. They manually guard their farms, use ingenious noise making devices, fire crackers and even guns to create psychological fear to scare away wild pigs from farms (Ahmed, 1991). At times pig bombs are also used illegally to eliminate wild pigs. Despite local efforts to control wild pigs, it continues to remain a problematic animal. The propensity of wild pigs to overcome deterrents is a behavioral adaptation, about which very little is known. Wild pigs getting used to firework bluff is again a behavioral adaptation acquired after learning that the noise is not physically harmful. This aspect of behavior makes it a difficult animal to manage. There is no empirical data that can help us understand how wild pigs develop behavioral adaptation, which enable it to use agro-ecosystem despite crop protection measures. According to Mackin (1970), Andrzejwski and Jezierski (1978) and Genov (1981), the damage to crops increases when there is less natural food available in

forests and artificial feeding of wild pigs can reduce crop damage. Hone and Atkison (1983) reported use of fencing to control feral pig movement. Poisoning campaign was adopted to eliminate wild pigs in the sugarcane area of Pakistan (Shafi and Khokhar, 1986). Reduction in feral pig density by snaring has been reported by Anderson and Stone (1993) and Choquenot *et al.* (1993). Development of trapping technique to manage wild pigs has the potential to develop an effective applicable management tool.

Wild pigs are well known globally for depredation of and damage to almost any commercial crops (Tisdell, 1982 and Mapston, 2004). For example, in Poland, 70% of crop damage caused by game animals was due to wild pigs (Mackin, 1970). Kristiansson (1985) estimated that only 5-10% of crop damage by wild pigs was due to actual consumption, the balance was due to trampling. In some cases, rooting around the base or root mat of larger plants (e.g. banana and apple trees) could cause damage through undermining (Tisdell, 1982). Wild pigs could feed on most life stages of an agricultural crop, from seeds through mature plants (Mapston, 2004). However, most of the depredations occurred when the crops were nearly mature (Stevens, 1996).

Agricultural depredations by wild pigs encompass a variety of resources including grains and cereals (e.g. wheat, sorghum, barley, hay, rye, oats, millet, maize and rice), vegetables (e.g. potatoes, yams, squash, turnips, rutabagas, beets, cassava, lettuce, cabbage, beans, peas, soybeans and artichokes), fruits (e.g. pumpkins, grapes, blueberries, pineapples, avocados, bananas, apples, various *citrus* species, water melons, cantaloupes and coconuts) and other crops (e.g. cotton, linseed, sunflower, peanuts, almonds, oilseed or rapeseed, groundnuts, pecans, clover, thyme, basil, oil palms, sugar cane, rubber seeds) (Diong, 1973; Tisdell, 1982; Brooks *et al.*, 1988; Stevens, 1996; Devine, 1999; Schley and Roper, 2003 and Mapston, 2004). Not all crops were equally impacted. For example, Pavlov (1980) showed that feral hogs in Australia had a preference for certain types of grain. Wheat and oats were preferred over rye and barley (DEFRA, 2004). Crop losses typically varied depending upon location and season. Crop depredation by wild pigs in some countries (e.g. France, Italy, Luxembourg and Poland) was so significant that the governments reimbursed farmers to compensate them for these losses (DEFRA, 2004).

In India, traditions and cultural and religious attitudes towards wild animals make local people more tolerant towards wildlife, despite the damage to crops and livestock it causes. Orthodox Hindus for instance consider monkeys to be sacred animals, revered and protected. This religious belief and traditional attachment to monkeys greatly influences people's perception of the conflict, resulting in its partial acceptance (Imam *et al.*, 2002). In Sariska Tiger Reserve, many species of wild herbivores blamed for crop raiding were nilgai (*Boselaphus tragocamelus*) and wild boar (*Sus scrofa*), while other species as sambar (*Cervus unicolor*), chital (*Axis axis*), common langur (*Presbytis entellus*), rhesus monkey (*Macaca mulatta*) and parakeets (*Psittacula krameri*) were also accounted for the damage. Nilgai were usually found to raid crops in the evening and tend to favour the degraded edges of forest villages. Wild boar instead, acts at night, while other ungulates such as sambar and chital are usually confined to forest cores. The data on crop damage revealed the annual crop losses varied according to the type of crop grown, in fact the annual loss for chickpeas (*Cicer arietinum*) were 10-27% per hectare (ha), maize (*Zea mays*) 12-24% per ha, mustard (*Brassica campestris*) 10-27% higher than wheat (*Triticum vulgare*) 6-14% and pearl millet (*Pennisetum typhoideum*) 6-15% per ha. The percentage ranked so broadly as distance between reserve boundary and household survey varied from 0-3 km and in general, the depredation increased with closer proximity to the reserve (Sekhar, 1998).

The problem of crop damage by nilgai, blackbuck and wild boar was widely reported from Rajasthan ( Rajpurohit, 1993), Haryana (Chauhan and Sawarkar, 1989, Chauhan and Singh, 1990 and Singh, 1994), Maharashtra (Indurkar *et al.*, 1994; Mankadan and Rahmani, 1994 and Sinha and Jha, 1994), Madhya Pradesh (Chandra, 1994; Dwivedi, 1994; Singh, 1994 and Rajpurohit and Chauhan, 1996, 1998). Jeyasingh and Davidar (2003) in Southern India identified wild pigs as major crop pest in paddy crops.

Crop raiding can reduce farmer's tolerance towards wildlife. Despite higher human population densities in rural areas, and more rapid conversion of forest to farmland, much less is known about crop raiding in Asia than in Africa. Actual crop pests and their patterns of crop raids were identified from farmland in and around Kerinci Seblat National Park, Sumatra.

## 2.10 Threats

Habitat destruction and hunting pressure, either for food, sport or in reprisal for crop damage, are the major threats to this species, particularly in areas near human habitation. In many other non-Islamic countries or local communities, wild pigs often constitute the single most important game animal to subsistence and recreational hunters. Sport hunting accounts for about 30% to 50% of animals heavier than 20 kg in southern France, though this figure may be as high as 50% to 75% in some heavily populated countries, where hunting remains largely or wholly uncontrolled (Spitz, 1986). For example, the wild pig population inhabiting the 25,000 ha of broadleaved woodlands around Monticiano in Italy, has apparently been able to sustain its numbers despite an annual hunter-kill rate of about 50% of the population (Devitt, 1984).

According to figures produced by the Japanese Environment Agency, a total of 12,79,453 wild pigs were harvested in Japan between 1970 and 1989 (incl.), of which 1,083,858 (85%) were taken by hunters, and the remaining 195,596 were destroyed as crop pests during the closed season. The great majority of these animals are *Sus scrofa leucomystax* from the main islands of Honshu, Shikoko and Kyushu, and this subspecies is evidently able to withstand high levels of harvesting to judge from contemporary reports of marginal expansions in the overall range of this subspecies (Hanai, 1982 and Takahashi, 1980). However, these totals do not differentiate between the numbers of *Sus scrofa leucomystax* and those of *Sus scrofa riukiuanus* from the three small islands of Amami Oshima, Tokuno Shima and Kakeroma Jima, which are also included in these figures. As indicated before, the latter subspecies is declining rapidly in numbers on these islands, and on the neighbouring island of Okinawa, largely as a result of over-hunting (Barber *et al.*, 1984). This conclusion is also borne out by official figures on the annual harvest of *Sus scrofa riukiuanus* from two other islands, Iriomote and Ishigaki, in the Ryukyu chain between 1965 and 1981, which indicate a downward trend in the numbers of these animals (Yasuma, 1984) and a marked increase in the amount of effort required by local hunters to obtain smaller catches (Hanai, 1982). Nonetheless, according to these figures an average of 530 and 190 wild pigs were still being taken annually on Iriomote and Ishigaki respectively; of which slightly more than 50% were killed as agricultural pests.

Moreover, it is certain that these totals are a serious underestimate, perhaps by as much as 50-100% of the actual numbers killed, since many hunters operate without licenses and do not declare their catches (Barber *et al.*, 1984 and Yasuma, 1984).

Due to its depredations on agricultural crops, it is regarded as a pest in many countries and remains unprotected outside wildlife reserves or is managed as a game animal. Though actually referring to wild pigs in India, it is evident that 'No animal is more destructive to crops and in cultivated areas, it is impossible to make a plea for its protection' (Prater, 1971). It may find popular support in many other countries. In the Ryukyu Islands, South Japan, the endemic *Sus scrofa riukiuanus* is actively regarded as an environmental pest, and bounties are paid to farmers for killing them by the Japanese government, despite the fact that this taxon is recognized internationally as being seriously threatened throughout (Hanai, 1982; Takahashi, 1980 and Yasuma, 1984). In various places in Indonesia, most notably in Java, deliberate attempts have been made in the past to eradicate wild pigs altogether by means of organized shooting and poisoning campaigns. However, despite many thousands of wild pigs being destroyed in this way, it is clear that this has had little lasting effect on these animals (Hoogerwerf, 1970).

The Ryukyu pigs are also threatened by genetic contamination through contact with free-ranging domesticates. On Ishigaki Island, interbreeding with domestic pigs has been so prevalent that it is doubtful if the remaining wild stock can be considered genetically pure (Obara, 1982). Moreover, it is unlikely that this problem will be confined to Ishigaki, given that the meat from wild and domestic hybrids is popular and local farmers will continue to produce it. Indeed, ino-buta have been farmed commercially on Iriomote for many years, often in poorly controlled conditions. As a result, feral ino-buta have become established on the adjacent, smaller islands of Sotobanare and Uchibanare, and it is claimed that a number of these animals have crossed onto Iriomote at low tide; thereby posing a further, serious threat to the remaining wild stock there (Yasuma, 1984; Takahashi and Tisdell, 1992). Similarly, Genov *et al.*, (1991) reported that the traditional practice of rearing 'domestic' pigs in semi-wild conditions in Bulgaria has resulted in their hybridizing with the wild boar populations in the eastern and north-eastern parts of the country.

The main threat to the survival of the Monticiano population in Italy, lies not so much with the high annual hunter-kill rate but with the fact that the genetic integrity of the native population has been seriously compromised by the introduction of Central European boars after the World War II, which have interbred with these animals. Indeed, the introduction of non-native wild pigs, by hunting interest groups in the belief that these were more desirable because of their larger size and reputed greater fecundity, has been so widespread in Italy that the only surviving pure-bred native stock is thought to be in the presidential reserve in Castel Porziano, near Rome (Devitt, 1984).

## **2.11 Diseases**

Wild pigs are also susceptible to a variety of highly contagious diseases which can decimate their populations. Santiapillai *et al.*, (1991) referred to a catastrophic crash in the wild pig population owing to an outbreak of swine fever during 1989 in Ruhuna national park, Sri Lanka, but the population apparently recovered. Many wild pigs are also reported to have died during an outbreak of disease in the Kanto region on Honshu Island, Japan during 1877 (Yanagida, 1913).

It is possible that this was hog cholera, contracted from domestic pigs which were imported to the region at that time (Chiba, 1975), and this may have been one of the factors contributing to the extirpation of *Sus scrofa leucomystax* throughout the north of their range on this island. An outbreak of severe skin disease, tentatively identified as sarcoptic mange on Iriomote Island, which was first noted in 1976, had spread throughout the Island by 1980, and infected up to 83% of the *Sus scrofa riukiuanus* population according to hunter-killed samples (Yasuma, 1984).

## **Chapter 3**

### **Study area**

#### **3.1 Introduction**

Ranthambore Tiger Reserve (RTR) named after a great monument of history, bravery, culture and natural beauty, the majestic 'Fort of Ranthambore' is one of the globally acclaimed high priority conservation areas, supporting a population of the critically endangered tigers. Besides, it also supports enormous faunal and floral diversity. The Reserve is situated in the Rajasthan state in western (Rajasthan) India. It is the one of the first nine Tiger Reserves taken up in the country in 1973 for the conservation of tigers. It is situated at the confluence of the Aravali Hills and the Vindhyan plateau in eastern Rajasthan. The Chambal River in the South and the Banas River in the North drains the Ranthambore National Park. Six man-made reservoirs and many perennial streams add to the beauty of the national park.

#### **3.2 History**

Ranthambore National Park was the hunting ground of the Maharajas of Jaipur. This region under the control of the Rajput King Hamir was annexed by Ala-ud-din Khilji's army in AD 1301. The history of Ranthambore reached the pinnacle of its glory when Emperor Akbar captured it in 1569 AD. He also took over the control of the fort from the Rajputs. This event has been recorded in the miniature paintings of the Akbarnama. The fort was transferred to the Kachwaha rulers of Jaipur later and remained under their control till 1949 when Jaipur was made the part of Rajasthan. The region is played host to several hunting parties organized in this region for dignitaries. One such party was organized in honor of Queen Elizabeth II and Duke of Edinburgh in 1949. The former rulers of Jaipur first felt the need to preserve the area. In 1955, Ranthambore became a game sanctuary and was among the first few protected areas in India. In 1984, Ranthambore Sanctuary acquired the status of a

National Park covering almost 400 sq km of area. It was declared as one of the first nine Tiger Reserves in India, with the inception of Project Tiger in 1972.

### **3.3 Physical attributes**

#### **3.3.1 Location and extent**

Ranthambore Tiger Reserve lies between latitudes 25<sup>0</sup>41' N to 26<sup>0</sup>22' N and longitudes 76<sup>0</sup>16' E to 77<sup>0</sup>14' E. The reserve is situated in south eastern part of Rajasthan in Sawai Madhopur and Karauli districts of Rajasthan, India. Ranthambore Tiger Reserve is located on the Western bank of river Chambal. The other river Banas divides the reserve into two parts, the north eastern part being the Keladevi Wildlife sanctuary. The total area of Ranthambore Tiger Reserve is 772.63 km<sup>2</sup> falls in Sawai Madhopur district and the in Karauli district 621.84 km<sup>2</sup>. Ranthambore National Park covers an area of 392 km<sup>2</sup>. The total area of the Ranthambore Tiger Reserve is 1,394.47 km<sup>2</sup>, which includes the adjoining protected areas Kaila Devi Sanctuary (672 km<sup>2</sup>) and the Sawai Man Singh Wildlife Sanctuary (242 km<sup>2</sup>) and 40 km<sup>2</sup> of Qualji game sanctuary.

#### **3.3.2 Topography**

The physiography of Ranthambore Tiger Reserve includes undulating terrain with rolling hills of low to moderate height traversed with perennial rivers and several streams. The altitude ranges from 244 m to 507 m above sea level (asl). The terrain of RTR is mostly rugged and hilly. The hills to the north-west of fault are typical Gwalior and lower Vindhyan and are characterized by ridges on one side and gentle slope on the other side. This Gwalior and lower Vindhyan tract are highly undulating except for a few small plateaus like Salawata ki dang, Rann ki dang and Mandook, and some small valleys like Kachida, Anantpura, Berda, Lakarda and Malik Talab. The highest point of this tract is Gazella peak, 507 m asl. The lowest altitude of this tract is 244 meters above sea level (asl) at Bodal village.

### **3.3.3 Drainage pattern**

Streams flowing in northern tract form the catchment of the Banas and streams flowing in southern tract drain directly in the Chambal. Streams facing sharp ridges contain water for almost throughout the year, as the folded impervious rocky strata beneath does not permit the water to percolate. The hills on south west of Great boundary fault are Upper Vindhyan. The sand stone beds of these hills are particularly horizontal and form extensive table lands known as 'Dangs' like Indala ki Dang, Dang Dood Bhatt and Karauli Dang, etc. These Dangs rise abruptly from flat ground above a mass of crumbling shale where inclined sand stone forms continuous strike ridges along deep, long and narrow gorges of eroded shale. These gorges are locally known as 'Khohs'. The Khohs are cool and retain moisture even in the hot summer and are heaven for wild life of this dry and parched area. These Khohs are the main wildlife areas. In the Keladevi sanctuary particularly, the gorges are very long and wide, in some areas extending up to 10 km in length, up to 0.5 km wide and as deep as 100 meter or more. In this tract one hill range starts from Qualji, runs in north-east direction and goes up to Sawta. The hill range passes through Sawai Man Singh and Sawai Madhopur sanctuaries.

### **3.3.4 Geology and edaphic characteristics**

The area includes the confluence of the ancient Aravalli system with Vindhyan system, where in the later are brought against the former at the Great Boundary fault. It has a unique geomorphology. The Vindhyan system is characterized by flat topped hills. The soil of the RTR is formed by the Aravalli, Gwalior and Vindhyan system of rocks. The Aravalli system rocks cover a small portion on the north-west side of the reserve while Gwalior and Vindhyan systems share most of the RTR. A part of the terrain comprises of pre-Cambrian Igneous, Metamorphic and Sedimentary rocks belonging to pre-Aravalli-Vindhyan system. Pre-Aravalli rock units are made up of Quartzite, Mica Schists, Gneiss and Migmatites. The rocks of the Vindhyan super group are made up of sand stones, shales, limestone and breccias of widely variable composition and characters occupying most part of the reserve. The Gwalior systems

are made up of slate and shale. The soils though shallow on the hills, are, suitable for supporting forests of *Anogeissus pendula*.

### **3.4 Ecological attributes**

#### **3.4.1 Climate**

The area is characterized by Sub-tropical dry climate with distinct cold (November-February), hot (March-June) and rainy (July-September) seasons. October is a transition period. The highest temperature (above 47<sup>0</sup>C) is recorded in May-June and the lowest (up to 2<sup>0</sup>C) in December-January. The diurnal variation of temperature is high. Frost is common in winter. Drought is of common occurrence. Relative humidity on an average is 30-34%. Hot dry winds locally called 'loo' are frequent in summer. The early south-west monsoon blows mainly from westerly and south-westerly directions. Thunder storms in May-September and dust storms during summer are common. Cold westerly waves from North-North-west direction blow during winter.

#### **3.4.2 Temperature**

During the summer months of March to June the temperature is on a continuous rise. May and first half of June, being are hottest parts of the year. The maximum temperature in May and June rises up to 47<sup>0</sup>C. In the second half of June, normally pre-monsoon showers start, which brings down the temperature by 3<sup>0</sup> to 5<sup>0</sup>C. After withdrawal of monsoon by the end of second week of September, days become hot. The nights become progressively cooler. After mid-November both day and night temperatures drop. During the winters, January is the coldest month. The daily maximum temperature may be as high as 20<sup>0</sup>C and the minimum temperature may drop down to 4<sup>0</sup>C. During the cold wave spells the temperature drops further down. In the valley areas of the RTR like Lahpur valley the temperature touches freezing point.

### **3.4.3 Rainfall pattern and distribution**

The bulk of the precipitation is from SW monsoon and occurs during the months of July to September. The winter rains from NE monsoon are quite common. The average rainfall is 800 mm. The rainfall during the period from June-September constitutes about 92% of the annual rainfall. There is a large variation in rainfall from year to year. The distribution of rainfall is fairly erratic.

### **3.4.4 Humidity**

The relative humidity is generally low in most part of the year. It becomes as low as 10 to 15% during summer months. However, during the rainy days the relative humidity goes over 60%.

### **3.4.5 Wind**

Winds are generally light to moderate. During the pre-monsoon period the northwesterly winds are comparatively strong with occasional dust storms. The northeasterly winds during winters are mild. In the summer season hot winds blow from the direction between SW and NW, and are known as 'loo' and have a desiccating effect. Thunder storms occur during the period from May to September. Hail may also be associated with thunder storms during the months from February to May. During the hot season, dust storms are also not uncommon. During the month from January to March low pressure areas moving from the west affect the area when the situation of 'cold waves' develop.

### **3.4.6 Drought and its periodicity**

Droughts are cycle period occurred in the RTR. During the drought period there is an acute shortage of fodder inside and outside the RTR. All the water holes tend to dry up very early and water becomes a limiting factor.

### 3.4.7 Floral diversity and vegetation types

According to the Biogeographic classification (Rodgers and Panwar, 1988) vegetation falls in 4 B (Semi-arid zone and Gujrat, -Rajwara biotic province). The area forms the transition zone between the true desert and seasonally wet peninsular India. The forests type of Ranthambore Tiger Reserve is mainly an edaphic climax and belongs to the sub group 5B/C<sub>2</sub> Northern Tropical Dry Deciduous forests and subgroup 6B/DS<sub>1</sub> - *Zizyphus scrub*. The degradation stages found here are DS<sub>1</sub> - Dry deciduous scrub and 5/DS<sub>4</sub> - Dry Grass lands (Champion and Seth, 1968). The area is representative of dry deciduous *Anogeissus pendula* Forests type in association with *Acacia*, *Capparis*, *Zizyphus* and *Prosopis* species. Fairly large area is dominated by *Anogeissus pendula* with *Grewia flavescens* in under-story as a common associate. The main associates of dhok (*Anogeissus pendula*) are, kadaya (*Sterculia urens*), salai (*Boswellia serrata*), palash (*Butea monosperma*), amaltas (*Cassia fistula*), churail (*Holoptelia integrifolia*), gurjan (*Lannea coromandelica*) and khair (*Acacia catechu*) etc. These associated tree species form the middle storey in almost all the communities and in certain cases the under storey also. The common associates of khair (*Acacia catechu*) are raunj (*Acacia leucophloea*), berjhari (*Zizyphus nummularia*), guter (*Zizyphus xylopyra*) and tall grass species like buhari (*Eremopogon flaveolatus*), kali lamp (*Heteropogon contortus*), karad (*Dichanthium annulatum*), bhanjura (*Apluda mutica*). Some patches of tropical moist mixed forest mostly consists of jamun (*Syzygium cuminii*), guler (*Ficus racemosa*), tendu (*Diospyrus melanoxylon*), khajoor (*Phoenix sylvestris*), kusum (*Schleichera oleosa*), rohini (*Mallotus philippinensis*), behera (*Terminalia belerica*), mango (*Mangifera indica*). Such forests are common in the valley areas around water streams, lakes and reservoirs.

### 3.4.8 Faunal and diversity

Ranthambore National Park is bestowed with a wide diversity of fauna. This is one of the most striking features of the area. The Ranthambore ecosystem supports about 30 species of mammals, 12 species of reptiles and more than 300 species of birds. The nomenclature used here follows Corbett and Hill (1992). A total of 12 species of

carnivores are found in RTR, of which 5 are felids - tiger (*Panthera tigris*) and leopard (*Panthera pardus*), jungle cat (*Felis chaus*), caracal (*Felis caracal*) and rusty spotted cat (*Prionailurus rubiginosus*). Other carnivores include striped hyaena (*Hyaena hyaena*), jackal (*Canis aureus*), sloth bear (*Melursus ursinus*), common mongoose (*Herpestes edwardsii*), small Indian mongoose (*Herpestes auropunctatus*), ruddy mongoose (*Herpestes smithi*), ratel (*Mellivora capensis*), Indian false vampire (*Megaderma lyra*), palm civet (*Paradoxurus hermaphorditus*) and small Indian civet (*Viverricula indica*). Earlier, the Indian wild dog or dhole (*Cuon alpinus*) used to occur in RTR but there have been no sightings in recent times. Wild ungulates forming a prey base for the larger carnivores include chital (*Axis axis*), sambar (*Cervus unicolor*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella gazella*), wild boar (*Sus scrofa*) etc. Two primates, common langur (*Presbytis entellus*) and rhesus macaque (*Macaca mulata*) are found within the Reserve. Other animals found in the reserve are the rufous tailed hare (*Lepus nigricollis ruficaudata*), porcupine (*Hystrix indica*) and rodents such as the Indian gerbille (*Tatera indica*) and Indian bush rat (*Golunda ellioti*). A large number of aquatic birds also visit the reserve during winter. Due to the presence of villages inside and on the periphery, variety of domesticated animals also occurs within the reserve. These include livestock, domestic cats and dogs.

### **3.5 Anthropological attributes**

#### **3.5.1 Human settlements**

Ranthambore National Park protected area is under heavy anthropogenic influence from the 95 peripheral revenue villages within the buffer of two kilometers from park boundary estimated human and livestock populations in these villages are of approximately 1,50,000 and 95,000, respectively. In addition to that there are 4 villages within the Reserve having human population of 2,540 and cattle population of 9,811.

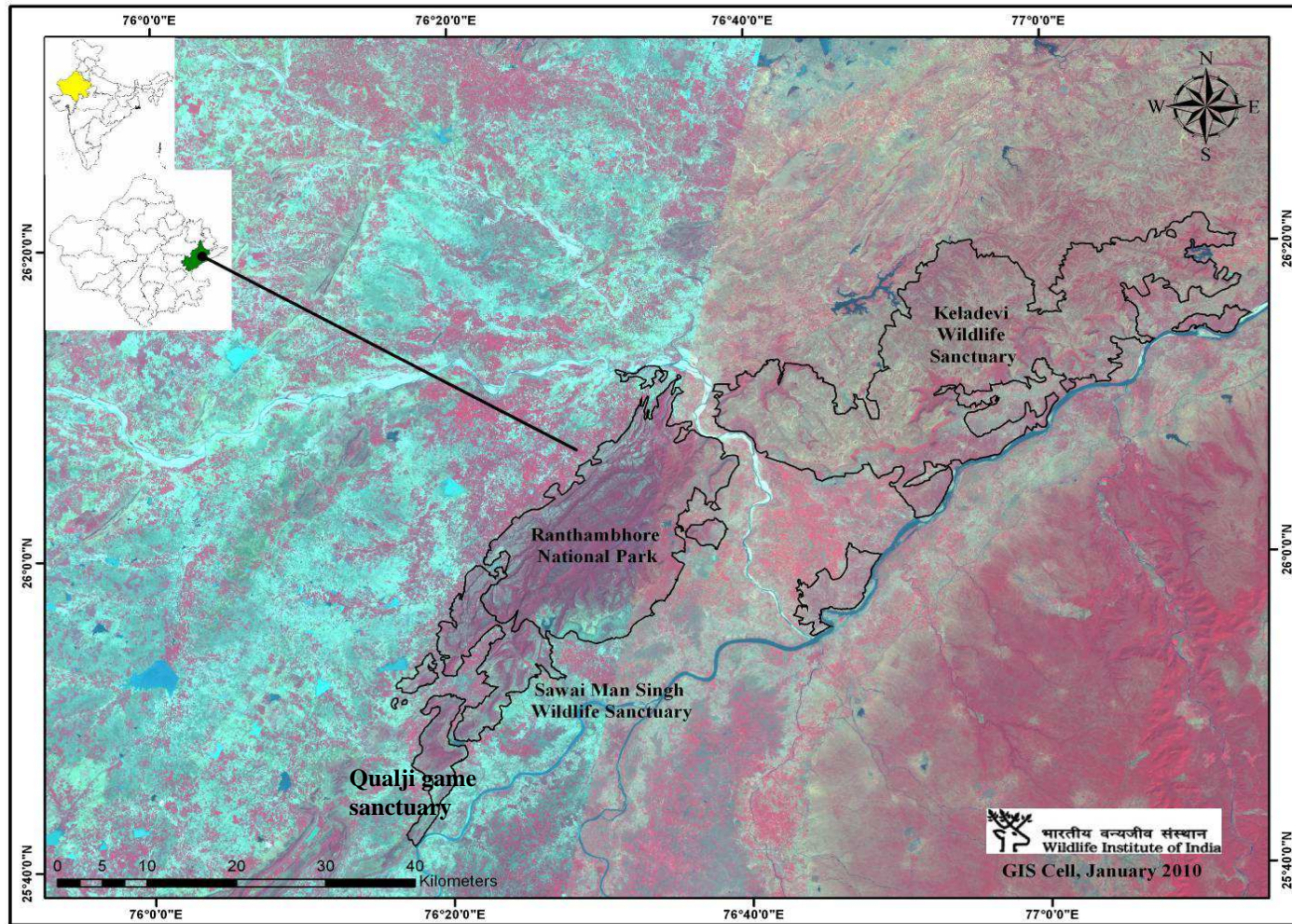
### **3.5.2 Tourism**

Owing to good network of roads tourism is well managed and regulated by the park administration. Some core zones are closed for tourism so as to keep some tiger population away from tourist pressure and rest of park area is divided in to 5 tourist zones. Tourists are taken into park in vehicles. In each zone 20 vehicles are allowed at one time. Park opens at 6 am in the morning and closes 6 pm in the evening. Park remains closed for 3 months from 1<sup>st</sup> July to 30<sup>th</sup> September due to rainy season in a year. Besides the ecotourism, a number of local religious tourists come for the “Ganesh temple” situated 5 km inside the Park area. In the month of September a fair is held at the Ganesh temple due to which there is very heavy traffic in the park.

### **3.6 Research**

A number of short and long term research projects have been conducted in relation to socio economics, prey abundance and population estimation of tiger in RNP (Berkmuller *et al.*, 1986; Kumar, 2000; Bagchi, 2003; Sharma, 2001; Karanth *et al.*, 2004 and Chauhan *et al.*, 2005). Apart from these, WII has been conducting research on tigers on population estimation by camera traps 2005 and intensive monitoring of source population of tiger by radio-telemetry with special reference to dispersal of male tiger sponsored by National Tiger Conservation Authority since 2007.

**Map 1: Conservation area of Ranthambore Tiger Reserve, Sawai Madhopur.**



## **Chapter 4**

**To study the spatial and temporal distribution of wild pigs in context of habitat attributes.**

### **4.1 Introduction**

Many population biologists have proposed different models of spatial organisation. A relative simple classification of distribution pattern over the entire range geographic range of a species consists of three categories, namely: i. Isolated populations (the range is divided into separate ‘islands’ without any exchange between them); ii. Meta-populations (the range is divided into distinct subpopulations, with exchange between them, and a certain rate of extinction and immigration; the classical example is that of a species distributed on a continent and adjacent islands); iii. Continuous populations (the range is continuously, even through heterogeneously, occupied, without local extinctions). Meta-population model may depend on initial definitions, and the border line between meta- and continuous populations is sometimes fuzzy. Exploitation of large animals by man has long been a problem of spatial interactions between predator and prey. Understanding hunter-prey relationships in the past may benefit from a good knowledge of distribution rules in present population of pig game, at the same large spatial scale.

Wild pig is a generalist species and is admirably adapted to range of habitats such as forests, secondary thickets, woodland and grasslands in which they roam in small bands (sounders) of varying number of individuals. The size of sounder seems to be a function of the carrying capacity of the habitat (Pine and Gerdes, 1973). Wild pigs live in grass or scanty bush jungle, sometimes in forest; after the rains, quite commonly in high crops. They occupy and exploit a wide variety of habitats (Eisenberg, 1981). The general habitat requirements for this species over most of its range include seasonally available forage resources and daily access to well-distributed water, shade and escape cover on a year-round basis (Pullar, 1950;

Wodzicki, 1950; Pine and Gerdes, 1973; USDA, 1981; Baber and Coblenz, 1986; Barrett, 1982 and Choquenot *et al.*, 1996). Wild pigs can thrive as readily in plains as in the mountains, in swamps as well as relatively dry steppes, in remote areas as well as in densely populated areas where they actually thrive close to civilization. Such habitats can range in elevation from sea level up to 4000 m above msl (Nasimovic, 1966 and Frädriich, 1974 and 1984).

Space use of wild boar depends on season, food availability and anthropogenic disturbances (Singer *et al.*, 1981; Boitani *et al.*, 1994; Maillard and Fournier, 1995; Baubet *et al.*, 1998; Calenge *et al.*, 2002 and Lemel *et al.*, 2003). However, few authors considered age and group structure of the observed animals as a factor affecting space use. Concerning space use, wild boar react flexible and individually on these influencing factors (Boitani *et al.*, 1994). Wild pigs are comfortable on flat to very steep terrain. Throughout its range, wild pigs showed a preference for riparian and wetland habitats as well as mesic upland hardwood forest (Kurz, 1971; Graves, 1984; Saunders and Kay, 1996; Caley, 1997; Laurance and Harrington, 1997; Mitchell and Mayer, 1997; Dexter, 1998; Friebel and Jodice, 2009 and Sparklin, 2009). Other habitats such as pine conifer forest, arid scrub brush, chaparral and grasslands were also found to be utilized, but typically only on a temporal basis. With respect to the sexes, Spitz and Janeau (1995) found that females showed a preference for denser habitats than males, which were found to spend more time in the open.

For the management of wildlife and its habitat, information on food, water and shelter and conditions suited to a particular animal species have to be known accurately. The quality of habitat is generally reflected in the status of vegetation cover and its seasonal variation. The site characteristics like fruiting trees and shrub availability and water availability are directly related to the habitat use. The necessity of assessing preference or avoidance of a given habitat or plant species in terms of its availability has long been recognized (Neu *et al.*, 1974). The inter-relationships between herbivores and their habitats are complex, and influenced by the morphology and the behavior of the animals as well as ecological responses of vegetation and other habitat parameters. Spatial behaviour of an animal have a wide meaning such as movement, habitat selection, home range, core area, territoriality, migration etcetera. Movement

and habitat selection of animals is often related to energy demand (Ford, 1983 and Tufto *et al.*, 1996). Animals balance their choice of habitat and need of movement for energy intake, as per the optimal foraging theory (MacArthur and Pianka, 1966). Generally less movement is required in more productive areas and during more productive seasons (Ford, 1983; Kie *et al.*, 2002 and Borger *et al.*, 2006). The study of habitat utilization and distribution pattern of species gives valuable information on the preference and avoidance of habitats by species over time and space (Neu *et al.*, 1974, Marcum and Loftsgaarden, 1980 and Ben-Shahar and Skinner, 1988). Usually habitat features such as vegetation, its phenophases, terrain and water are also analyzed in such studies and knowledge gained is crucial for the management of the species concerned as well as its habitat.

Studies on habitat utilization by wild ungulates in India include Green (1985), Johnsingh (1983), Karanth (1988), Rice (1984) and Schaller (1967). But wild pig (*Sus scrofa cristatus*), a widely distributed and important prey species for large carnivores in India, has not been the subject for an intensive study so far. Only two studies had been done on wild pigs. As far as the habitat use of wild pig is concerned, very few or no studies have been done in India e.g. in Sariska National park by Bhajungarao (1991). Few observations on wild boar were also made by Johansingh (1978) and Binod *et al.* (2007) in Bandipur National Park and Sariska National Park respectively. Nair and Jayson (1988) studied the habitat utilization by large mammals in teak plantation and natural forest, and focused their study on abundance of animals, fodder consumption by animals and damage to plantations by animals.

Feral pigs occupy a wide range of habitats in Australia, including the subalpine grasslands and forests of Kosciusko National Park, the semi-arid floodplains, often dominated by lignum, in western New South Wales, the *Typha* and *Phragmites* reed beds of the Macquarie Marshes in central New South Wales, the rainforests in the wet tropics of northern Queensland, and the paperbark (*Melaleuca* spp.) swamps, open flood plains, monsoon forest patches, *Mimosa pigra* thickets and dry woodlands in the Northern Territory (Australian Meat Research Committee, 1978; Giles, 1980; Saunders, 1988; Hone, 1990b; Bowman and McDonough, 1991; McIlroy, 1993 and Dexter, 1995). They prefer moist areas that provide a reliable and adequate supply of

food, water and cover for seclusion and protection from extremes of temperature (Pullar, 1950 and Australian Meat Research Committee, 1978). Feral pigs need to live in moist areas that can provide adequate food and water and enough shelter to protect against extremes of temperature (Pavlov, 1995). In Australia, feral pigs are found in a variety of habitats that can provide these requirements, including rainforest areas, monsoon forest patches, paperbark swamps, open flood plains, marsh areas, semi-arid flood plains, dry woodlands and subalpine grasslands and forests.

Feral pigs have been described as a significant threat to the ecological values of the World Heritage Listed tropical rainforests of northern Queensland (Mcilroy, 1993; Mitchell, 1993 and Mitchell and Mayer, 1997). Most community perceptions of the environmental impacts of pigs focus on their disturbance (diggings) of the soil or soil litter/vegetation material. Feral pig diggings are thought to be responsible for causing erosion, lowering water quality, changing litter composition and distribution, affecting nutrient and water cycles, affecting soil invertebrate populations and soil seed banks, and changing species succession patterns (Mcilroy, 1993; Laurance and Harrington, 1997; Mitchell and Mayer, 1997 and Tierney and Cushman, 2006).

A basic knowledge of the spatial and temporal patterns of feral pig diggings is necessary to provide an insight into the degree of ecological impacts occurring. Diggings have been used as an index of ecological impact of pigs in Australia (Hone, 1995 and Mitchell and Mayer, 1997) and elsewhere (Howe *et al.*, 1981 and Engeman *et al.*, 2003). Mitchell and Mayer (1997) described spatial digging patterns within the Wet Tropical rainforests and identified variations in digging activity between micro- and macro-habitats. Temporal patterns of feral pig diggings have been indicated in other studies within rainforests (Mcilroy, 1993 and Laurance and Harrington, 1997) but quantitative information on the impacts of feral pigs is sparse, however, particularly in Queensland's tropical rainforests. Mitchell and Mayer (1997) described broad-scale spatial digging patterns (lowland areas had higher digging activity than highland areas) and an association of diggings with tracks and drainage lines, but their study was restricted to the tropical dry season and was broad in scope. Dardaillon (1987) mapped spatial patterns in diggings and rooting by wild boar in the Camargue in France. Spatial patterns were investigated to assess whether feral pigs preferred to

dig in specific microhabitats and temporal patterns were investigated to assess the effect of the seasons on feral pig digging patterns.

The protected areas have been especially created to conserve flora and fauna of utmost importance. Some species are endangered locally or nationally, and others are ecologically important or dominant in the area, such as tiger, elephant, bear and wild pig. Wild species living outside the protected areas are equally important especially when species is threatened and problematic, which would need attention to conserve the species and mitigate the conflicts as well. The knowledge of population status of such wild species inside and outside protected areas, their spatio-temporal distribution pattern and habitat use are very important, which would enable formulation of strategies for the management of the concerned species. Peripheral areas of Ranthambore national Park are highly disturbed and fragmented, but they harbour large number of wild pigs. Estimation of wild pig population and distribution becomes more important in an area due to continuous habitat degradation and loss of habitat with the increasing human population. When human dominant landscapes are used by these animals, the study would help in developing strategies for mitigation of human-wild pig conflicts. If the man-wild pig conflicts are not resolved now, the circumstances may pose serious threats to the future conservation efforts. Therefore knowledge about the spatial and temporal distribution of wild pigs in relation to habitat attributes is very important for the field managers.

In this chapter, the spatio-temporal distribution of wild pig in context of habitat attributes in and around Ranthambore National park has been studied. This would help in management of habitats by wild pigs, developing conservation plan for the species and evolving mitigation strategies for human-wild pig conflicts on the long term basis.

## **4.2 Methods**

Ecological studies of a free ranging species involve two important components, one related to the habitat and other use of habitat by species. The present objective spatial

temporal distribution with reference to habitat attributes deals with both the above components and following methods were used to get relevant data.

To study spatio-temporal distribution of wild pigs in relation to habitat attributes in Ranthambore National Park, direct sighting of wild pigs was made, and location of indirect evidences such as diggings and faecal matter during surveys and along line transects were recorded.

If the purpose of a population census or population distribution is comparison than the data ought to be precise enough to detect differences (Rodgers *et al.*, 1991). In many cases a simple index of density using dung counts may be the most efficient way to show changes. For example counting pellets or scats in a series of quadrates in two areas can be a way to show the differences in animal use of those two areas. Similarly faecal dropping/scat is reliable indicator of animal presence and has frequently been used for estimating animal abundance and distribution (Rodgers *et al.*, 1991). Two types of sample units are considered for sample counts of animals using actual sightings; counting within blocks, and counting along transect lines to know the presence of animal(s) or/and location of the diggings and droppings. Line transect is the robust method to estimate population distribution and abundance of a species, in which animals are counted along the straight line and their number, distance and angular or perpendicular distance from the observer is recorded (Anderson *et al.*, 1979; Buckland *et al.*, 1993 and Burnham *et al.*, 1980).

Ranthambore National Park which is situated in the Sawai Madhopur district has an area of 392.2 km<sup>2</sup>. And its buffer encompasses revenue land, reserve forest, village land, degraded wasteland and private land. Of the total area, 26% of forests are in the Aravali and Vindhyan formation ranges. Forest cover maps (1:25,000) of Forest Survey of India (FSI), Survey of India toposheets (1:50,000), forest compartment maps and satellite imageries were used to study the extent of forest types using topography, drainage patterns, distribution of water, vegetation and degree of human disturbance of this park. The study area was stratified into different habitat types on the basis of topography and vegetation using Landsat data.

For the quantification of landuse pattern and vegetation, 45 linear transects in different land use and vegetation types encompassing pig habitats were used. There were 21 transects in Sawai Madhopur range, 14 transects in Khandar range and 10 in Kundera range. Line transects were laid in different habitat types in proportion to their availability (Anderson *et al.*, 1979). Along transects, quadrates and circular plots of appropriate sizes were used for sampling of tree, shrub and ground vegetation. All the transects were walked three times in a year, once during monsoon season (July and August), second time during winter (November and December) and third time during summer March and April. Sampling for trees was done within 10 m radius circular plots taken at every 250 m point along the transect of 1 km (**Figure 1**). From the same sampling points, data was also collected for shrubs and herbs within 5 and 1 m circular plots respectively. Number of each shrub and herb species was recorded. The data was subjected to stratified random sampling to analyse community characters. Decorana (Hill, 1979), Twinspan (Hill, 1979) and Canaco (Brak, 1986) were used for analysing the vegetation data.

The first few days were devoted for general reconnaissance of the areas to get an idea of the cover types, terrain and landuse pattern etc. and to develop interpretation key, which was subsequently used for translation of the spectral signature of imageries into actual cover types. Forty five linear transects were laid covering the representative landuse cover and vegetation. Pre-designed formats were used to record information on terrain, soil, canopy cover, shrub cover, shrub height, stand height, ground cover, number of each tree, shrub and herb species; GBH, water availability, number of trees cut, number of trees lopped, slope characteristics, proximity of water source and wild pig evidences such as digging and feeding signs, hoof marks etc during the field work (**Annexure I, II, III, IV**). Woody species exceeding 30 cm GBH were considered as trees, whereas less than 30 cm in GBH were counted as shrubs. Canopy cover was measured with the help of GRS densiometer.

Besides, several points were randomly taken at various locations in the study area for ground truthing and for interpretation of tones and textures of satellite image of the study area. Delineation of the vegetation types based on tonal and textural variations in the satellite data into broad physiognomic units was done. Each category gave a

unique combination of tone, texture and pattern that helped in identification of various vegetation classes. Vegetation and landuse maps showing, drainage, contour, water bodies, road network and habitations and compartment maps, maps were generated. The details of interpretation criteria of vegetation and landuse categories used for ground verification are in the **Table 1**. These plots were identical to the circular plots of transects. Post-field interpreted details were transferred on to the base map and final mapping was done on 1:50,000 scale. Hence this data was also incorporated in the transect data for increasing adequacy of the sampling.

Estimation of animals along the line transects has been used successfully for many ungulates and bird species (Burnham *et al.*, 1980). This is the first study in India to assess the wild pig spatial temporal distribution. Through intensive surveys and transect study in Ranthambore National Park, direct sightings of wild pigs in different habitats, and group structure were recorded. For each sightings, the number of pigs in each group, sighting angle and angular sighting distance from the transect path were also recorded (**Annexure V**). While covering transects, information on sex and age of wild pigs was also collected.

Presence of digging and feeding signs during surveys and along transects was also recorded. On every 100 m on each transect, wild pigs droppings were counted on a belt transect of 60 x 2 m. Besides, faecal matter wherever found was collected and its position was recorded. Location of wild pigs, individual or groups, digging and feeding signs and faecal matter were recorded using GPS (**Annexure VI**). All these locations also were marked on the toposheets and then transferred into GIS domain to map the distribution of wild pigs across the study area. Distribution map of wild pigs was prepared based on direct sightings, digging and feeding signs and faecal dropping in different habitats.

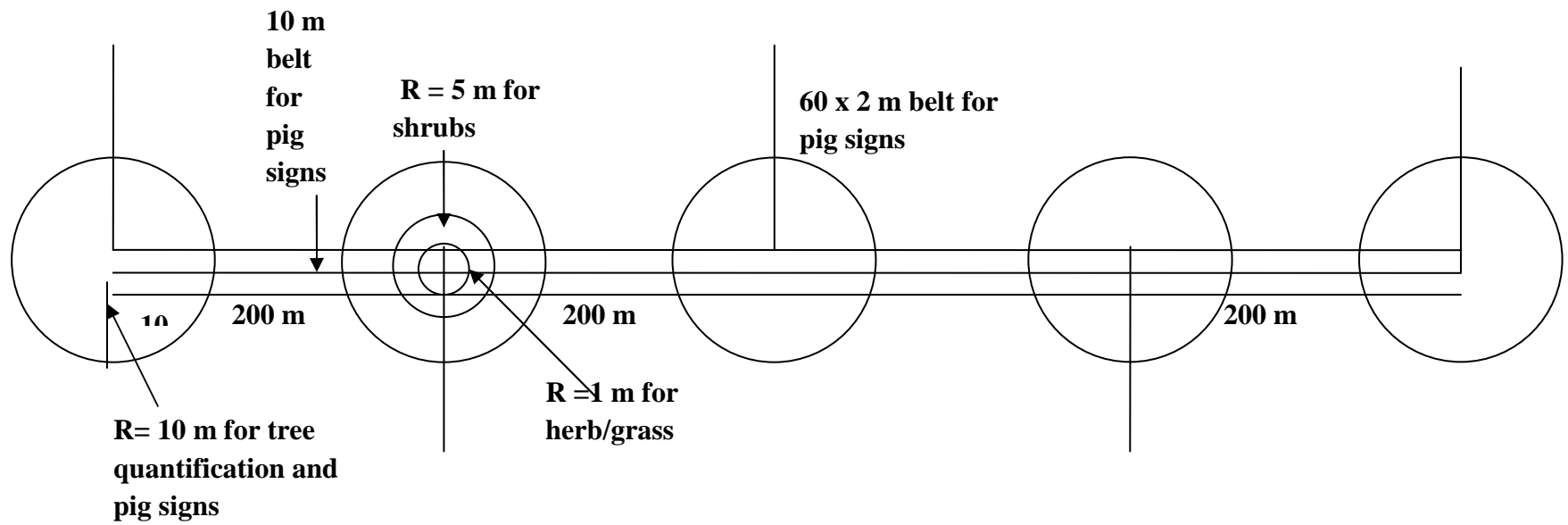
Data collected was statistically analyzed in a MS Windows based computer using spreadsheet package MS Excel 2007 and Past software. Analysis of the data was carried out using various softwares as per the objectives of analysis. Details of these software packages are given below. For preparing graphs and tables of the outputs, various softwares were done using the MS Excel 2007 data. A Kruskal-Wallis test

was used to determine whether there was any difference ( $P < 0.05$ ) between the used and available habitats (Zar, 1984). Sightings of wild pigs (location of animals) were overlaid on a vegetation map. Proportion of habitat use to habitat availability was tested by using Ivlev's (1961) index of selectivity. Habitat selectivity was defined by comparing availability ( $A$ ) and utilization ( $U$ ), using Ivlev's (1961) index of selectivity =  $(U-A)/(U+A)$ .

#### **4.2.1 Utilization vs. available**

In order to see the usage and avoidance of the different habitats in different seasons, this technique was adopted with a few modifications to suit the requirements. The main reasoning behind this method is the fact that utilization of the habitat (occupancy or avoidance) by an animal cannot be quantified unless a relative measure of the total areas of different habitats and their distribution is taken into consideration. In the present study, the availability of different habitat categories was collected along the transects at an interval of every 250 m. The utilization data was also collected in the form of animal sightings in different habitat categories. Further data on habitat utilization was collected by making observations at waterholes and by quantifying digging signs. Wild pigs unlike other ungulates have special device to dig out and reach lower most strata of vegetation (roots, tubers, rhizomes and bulb). The de-rooting habit makes wild pigs a distinct user of habitat and quantification of these diggings can give an idea of the relative use of different habitats. Digging signs along transects and during surveys were quantified within a width of two meters on either side of and those on the line of transects. Depending on the intensity of the site dug out, these digging signs were classified subjectively as low intensity over a small area, medium intensity diggings and heavy intensity diggings.

**Figure 1: Sampling layout for vegetation quantification and collection of wild pig evidences.**



### 4.3 Results

The data on spatial-temporal distribution of wild pigs in relation to habitat attributes in Ranthambore National Park showed some interesting results. Based on direct and indirect sightings, information on the spatial and temporal distribution of wild pigs was collected from Ranthambore National Park. Direct sightings of wild pigs were made, and locations of indirect evidences such as diggings and faecal matter were recorded during the surveys and along line and vehicle transects from August 2005 to January 2010. As wild pigs were active from early morning till evening time, most of the data was collected during this period.

Information on distribution of individuals or groups of wild pigs in different habitats and seasons was compiled to know the spatial and temporal use of different habitats. Habitat use by wild pigs of varying group size, composition, age and sexes was also recorded. To relate the spatio-temporal distribution of wild pigs with habitat attributes, data on landuse, vegetation terrain type, aspect, elevation, distance of water body from roads, distance of villages from roads etc. was compiled and analysed.

#### 4.3.1 Landuse and vegetation categories

The landuse categories of the Ranthambore National Park identified on the basis of tone, texture and pattern in the satellite imageries showed that each landuse category was distinct with the specific characteristics (**Table 1**). Initially there were more landuse categories identified, but to make it more meaningful and convenient, these were finally reduced to 13 categories. The landcover and landuse patterns were studied through generation of maps with vegetation, habitation and agriculture, water distribution, road network, compartment, elevation, aspect and biotic pressure layers. The 13 main vegetation and landuse categories were *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest (*Prosopis juliflora*), Water bodies and Agriculture (**Table 2**). The map of vegetation and landuse showed Fort as the fourteenth category, but it was excluded because of continuous pilgrim pressure in

this area (**Map 1**). *Anogeissus pendula* forest encompassed the maximum area i.e. 31.84%, followed by scrub forest (16.28%), Tropical dry mixed (12.70%), *Anogeissus pendula* with shrub (12.69%), Grassland (6.34%), *Prosopis juliflora* (4.56%), *Anogeissus pendula* mixed (4.35%), Rocky outcrop (2.19%), Degraded grassland (1.66%), Water bodies (1.41%), Tropical moist mixed (0.72%), *Acacia catechu* with grasses (0.39%) respectively. The agriculture constituted 4.87% of the total area and interspersed with various other landuse categories. Though water bodies covered 1.41% area, they were more or less evenly distributed in the whole area.

#### 4.3.2 Groups of wild pigs

During the study period, the group size of wild pigs varied from solitary animal to 52 individuals, and it also showed variation from season to season. We classified wild pigs into three age-classes, adults ( $\geq 2$  years old), sub-adults and piglets with stripes. Social group size of wild pigs was categorized in to 8 types viz. one, two, three to ten, eleven to eighteen, nineteen to twenty six, twenty seven to thirty four, thirty five to forty two and forty three to fifty two individuals (**Table 3**). Single and groups of wild pigs were sighted 790 times, which were comprised of 6069 individuals. Out of the total groups observed, males, females, sub adults, piglets and unknown were 853, 2386, 654, 1274 and 902 respectively, and constituted 14.06%, 39.31%, 10.78%, 20.99% and 14.86% respectively.

Wild pigs were found distributed all over the national park as well as in peripheral areas, and sighted throughout the year. Lone pigs were sighted 169 times and constituted 21.39% of the total observations. The solitary males were 119 and constituted 70.4% of the total sightings of solitary individuals. Adult males sometimes consorted with oestrous females in order to mate with them, but such relationships lasted only for few days and were temporary. The group size of 3-10 individuals was sighted maximum times (n=375), followed by solitary animal (n=169), group of two animals (n=87), 11-18 (n=72), 19-26 (n=52), 35-42 (n=18) individuals and so on. Small size groups comprised of two individuals and three to ten individuals accounted for 11.01% and 47.47% respectively of the total observations. Group size of 11-18 and 19-26 individuals

accounted for 9.11% and 6.58% respectively. Large group of 27-34 individuals were rarely seen and accounted for 0.63%. Group size of 35-42 and 43-52 individuals were seen occasionally during the study period, they constituted 2.28% and 1.52% of the total observations i.e. during or after giving birth to young ones, these groups mainly consisting of lactating females.

#### **4.3.3 Seasonal group size and distribution**

Temporally, the group size of wild pigs was also found to vary in different seasons. In winter, generally small groups of wild pigs were encountered (**Table 4**). Solitary pigs and group of two and 3-10 individuals were sighted 17.75%, 10.38% and 48.36% respectively. Large groups of 11-18 and 19-26 individuals constituted 11.74% and 10.38% and were seen less. Even larger groups of 27-34 and 35-42 individuals constituted 1.09% and 0.27% respectively of total sightings were not very frequently seen in winter. There was mortality and predation of some piglets which were born during monsoon when they were growing, during this time farrowing females started separating with their living piglets or stripers. Thus, wild pigs found to occur mostly in small and medium sized groups, and larger groups were sighted less and less. Out of all the groups, males, females, sub adults, piglets and unknown were 449, 965, 337, 458 and 551 respectively, and constituted 16.27%, 34.96%, 12.21%, 16.59 and 19.96% respectively.

In monsoon, large groups of wild pigs were also encountered along with sighting of small groups (**Table 5**). Solitary and group of two and 3-10 individuals were sighted 22.12%, 6.19% and 43.36% respectively of the total sightings. Large groups of 11-18 and 27-34 individuals constituted 2.65% and 0.88% respectively of total sightings were not very frequently seen in monsoon. Even large groups of 35-42 and 43-52 wild pigs constituted 14.16% and 10.62% respectively of the total observations. Very large groups in monsoon were sighted because of the recruitment of the new piglets in the group and because of lactating females in a large group. Out of all the groups, males, females, sub adults, piglets and unknown were 104, 607, 74, 753 and 32 respectively, and constituted 6.62%, 38.66%, 4.71%, 47.96 and 2.04% respectively.

In summer, generally small groups of wild pigs were encountered most. Solitary, group of two and 3-10 individuals group were seen 25.40%, 13.50% and 47.91% respectively of the total sightings (**Table 6**). Large groups of 11-18 and 19-26 individuals constituted 8.36% and 4.50% and were seen less. Even larger groups of 35-42 individuals constituted 0.32% and were rarely seen. Out of all the groups, males, females, sub adults, piglets and unknown were 300, 814, 243, 63 and 319 respectively, and constituted 17.25%, 46.81%, 13.97%, 3.62% and 18.34% respectively. This may be because in the summer there is mating time and male and female pair up during this time and in the summer there is scarcity of food and water that's why they used to prefer in small groups in different habitats.

#### **4.3.4 Distribution of wild pigs**

Based on direct sightings, their diggings and presence of faecal matter, wild pigs were found distributed all over the national park as well as in peripheral areas (**Map 2**).

#### **4.3.5 Direct sighting of wild pigs**

Wild pigs were found distributed in different landuse and vegetation types, namely, *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest (*Prosopis juliflora*), Water bodies and Agriculture (**Table 7**). All these habitats were differentially used by wild pigs throughout the year (**Map 3**). They were found maximum times in *Anogeissus pendula* forest (49.37%), followed by Water bodies (14.56%), Tropical dry mixed (10%), *Anogeissus pendula* mixed (9.87%), Tropical moist mixed (7.34%), *Anogeissus pendula* with shrub (3.92%), scrub forest (*Prosopis juliflora*) (2.66%), Agriculture (1.39%) and Grassland (0.89%) respectively. **Plate 1** shows wild pigs feeding on *Zizyphus* fruits in Tropical moist mixed forest. **Plate 2, 3 and 5** show wild pigs moving and feeding in *Anogeissus pendula* mixed forest in Kundal. **Plate 4** shows wild pigs moving in grassland near Malik talab. **Plate 6 and 7**

show group of wild pigs feeding on aquatic plants in water body in Rajbagh. **Plate 14 and 15** show wild pigs resting in Tropical moist mixed forest and Tropical dry mixed forest respectively.

For interpretation, *Prosopis juliflora* forest was combined with the scrub forest and grassland and degraded grassland were combined because of some similarities in habitat characteristics. **Plate 13** shows wild pigs moving and feeding in Scrub forest near Mordungari. Sighting of wild pigs could not be made in Rocky outcrop and *Acacia catechu* with grasses during the study period.

Distribution or sightings of wild pigs in different habitats were found to vary in winter, monsoon and summer seasons (**Table 8**). Out of total 790 sightings, 366 locations were in winter, 113 in monsoon and 311 in summer season. In winter, they were found maximum times in *Anogeissus pendula* forest (48.63%), followed by Water bodies (18.03%), Tropical moist mixed (13.93%), *Anogeissus pendula* mixed (10.66%), scrub forest (*Prosopis juliflora*) (3.55%), *Anogeissus pendula* with shrub (3.01%), Agriculture (1.09%) and Grassland (1.09%) respectively. Tropical dry mixed was not found to be used in winter season. Presence of wild pigs in Tropical moist mixed forest was much more in winter season than monsoon and summer seasons. This might be due to availability of *Zizyphus* (ber) fruits in Tropical moist mixed forest during this period; wild pigs were greatly attracted and preferred to feed on these fruits.

In monsoon, they were found maximum times in *Anogeissus pendula* forest (48.67%), followed by Tropical dry mixed (26.55%), *Anogeissus pendula* mixed (11.50%), Agriculture (5.31%), *Anogeissus pendula* with shrub (4.42%), Grassland (1.77%), Tropical moist mixed (0.88%) and scrub forest (*Prosopis juliflora*) (0.88%) respectively (**Table 8**). Generally Water bodies were not found to be used during monsoon season as water was available everywhere in the park. All nalahs, anicuts, ditches etc. were charged with water. **Plate 8** shows a group of wild pigs crossing a nallah. **Plate 9** shows wild pigs sounder near water body in the midst of grassland in Kundal. Water bodies in Rajbag, Padam talab, Malik talab and Malik anicut were flooded with water, and it was very difficult for them to feed on aquatic vegetations

and some other grasses on the bank of these water bodies. **Plate 10 and 11** show wild pigs with piglets in *Anogeissus pendula* forest near Malik talab and near water body in Rajbagh respectively. During monsoon, wild pigs were found to use agriculture fields more than winter and summer seasons as the ‘kharif’ crops were cultivated in this season and wild pigs preferred to feed on these crops. Further it was easy for wild pigs to dig out soft soil after rains.

Whereas in summer season, they were found maximum times in *Anogeissus pendula* forest (50.48%), followed by Tropical dry mixed (15.76%), Water bodies (15.7%), *Anogeissus pendula* mixed (8.36%), *Anogeissus pendula* with shrub (4.82%), Tropical moist mixed (2.25%) and Scrub forest (*Prosopis juliflora*) (2.25%), Agriculture (0.32%) and Grassland (0.32%) respectively (**Table 8**). During this period, agriculture was least used as there were no crops in the fields and hardly any food available. Only people having tube well could grow some crops, so there was rare movement of wild pigs towards fields.

#### **4.3.6 Indirect evidences of wild pigs**

Based on diggings and presence of faecal matter, wild pigs were found distributed all over the national park and in peripheral areas.

#### **4.3.7 Pig distribution based on diggings**

Based on diggings, wild pigs were also found distributed all over the national park as well as in peripheral areas (**Map 4**). Wild pig diggings were found distributed in different landuse and vegetation types viz. *Acacia catechu* with grasses, *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest (*Prosopis juliflora*), at the bank of Water bodies and Agriculture (**Table 9**). But all these habitats were differentially used by wild pigs throughout the year. The diggings were found maximum times in *Anogeissus pendula* forest (51.15%), *Anogeissus pendula*

with shrub (17.14%), followed by Tropical dry mixed (15.09%), Water bodies (6.65%), Agriculture (2.56%), *Anogeissus pendula* mixed (2.56%), Scrub forest (*Prosopis juliflora*) (2.05%), Tropical moist mixed (1.53%), Grassland (0.77%) and *Acacia catechu* with grasses (0.51%). **Plate 16** shows digging of wild pigs in Scrub forest. **Plate 17** shows wild pigs digging and feeding on tubers in Rajbagh. Sighting of wild pigs was not there in Rocky outcrop and during the study period.

#### **4.3.8 Pig distribution based on faecal matter**

Based on presence of faecal matter, wild pigs were found distributed all over the national park as well as in peripheral areas (**Map 5**). **Plate 18** shows faecal matter of wild pigs. Presence of faecal matter indicated that distribution of wild pigs in different landuse and vegetation types, namely, *Acacia catechu* with grasses, *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest (*Prosopis juliflora*), Water bodies and Agriculture (**Table 9**). All these habitats were differentially used by wild pigs throughout the year. Presence of faecal matter was found maximum in *Anogeissus pendula* forest (49.78%), followed by Tropical dry mixed (16.67%), *Anogeissus pendula* with shrub (14.47%), Agriculture (4.39%), Tropical moist mixed (3.51%), Water bodies (3.29%), Scrub forest (*Prosopis juliflora*) (3.07%), *Anogeissus pendula* mixed (2.19%), Grassland (1.54%) and *Acacia catechu* with grasses (1.1%). Presence of wild pigs could not be seen in Rocky outcrop.

#### **4.3.9 Availability vs. preference of habitats**

The percent availability of various habitats in Ranthambore National Park is shown in **Map 1 and Table 2**. *Anogeissus pendula* forest encompassed 31.84%, followed by scrub forest (16.28%), Tropical dry mixed (12.70%), *Anogeissus pendula* with shrub (12.69%), Grassland (6.34%), *Prosopis juliflora* (4.56%), *Anogeissus pendula* mixed (4.35%), Rocky outcrop (2.19%), Degraded grassland (1.66%), Water bodies

(1.41%), Tropical moist mixed (0.72%), *Acacia catechu* with grasses (0.39%) and Agriculture constituted (4.87%). The use of these habitats based on direct sightings and indirect evidences is shown in **Table 7 and 9**. **Plate 19** shows *Anogeissus pendula* forest frequently used by wild pigs.

According to Ivlev's index of selectivity, Tropical moist mixed forest and Water bodies were the most preferred habitats by wild pigs, followed by *Anogeissus pendula* forest, *Acacia catechu* with grass, *Anogeissus pendula* mixed forest and Tropical dry mixed forest (**Figure 2**). These habitats were utilized more than their proportional availability. Whereas the proportion of Grassland, *Anogeissus pendula* with shrub forest and Agriculture were less utilized than available. *Anogeissus pendula* with shrub forest and Agriculture were utilized less. Scrub forest and Grassland were utilized very less than their proportional availability. The Rocky outcrop was completely avoided by wild pigs.

According to Ivlev's index of selectivity, distribution of wild pigs was found to be more in Tropical moist mixed forest, Water bodies, *Anogeissus pendula* forest, *Acacia catechu* with grass, *Anogeissus pendula* mixed forest and Tropical dry mixed forest. As compared to these habitats, distribution of wild pigs was less in *Anogeissus pendula* with shrub forest, Agriculture, Scrub forest and Grassland.

#### **4.3.10 Use of habitat variables**

Wild pigs were found to use different habitat variable like terrain, canopy cover, aspects, distance from road, distance from water bodies, distance from village and use of elevations.

#### **4.3.11 Use of terrain**

Various terrain types such as flat, medium slope and gentle slope were found to be differentially used by wild pigs based on their direct sightings (**Map 6**). For the flat,

medium slope and gentle slope categories, the degree ranged from 0-1, 2-5 and above 5 degrees respectively. The slope categories more than 5 degrees (5-15, 15-25 and >25 degrees) were used by wild pigs to very less extent. Distribution based on sighting of wild pigs was highest in areas with gentle slope throughout the year (**Figure 3**). They preferred gentle slope maximum than medium slope and flat terrain. Similarly, sighting of wild pigs in areas with gentle slope was highest in different seasons. In winter, sighting of pigs in areas with gentle slope was 75.14%; with medium slope was 17.49% and flat area was 7.38%. In monsoon, sighting of pigs in areas with gentle slope was 67.26%; with medium slope was 25.66% and flat area was 7.08%. Whereas in summer, sighting of pigs in areas with gentle slope was 72.67%; with medium slope was 18.33% and flat area was 9%.

The use of slope by wild pig was found to be significantly different among the seasons and the gentle slopes were used significantly high by the wild pigs in comparison in all seasons. ( $\chi^2= 11.96$ , DF=4, P-value=0.018). In order to remove the effect of occupation area of each environmental factor on habitat distribution, appearance frequencies (area where wild pig appeared/total area\*100) were calculated (**Figure 4**). Gentle slopes under 10 degree showed the highest appearance frequency in all seasons. Most of the wild pigs were observed in areas with gentle slopes. So there was strong preference by wild pigs for the gentle terrain. Perhaps use of these terrain types by wild pigs might be governed by availability of food resources and high visibility factor.

#### **4.3.12 Use of canopy**

Distribution based on sighting of wild pigs showed much variation in their use of medium dense, open and sparse canopy types (**Figure 5, Map 7**). They preferred medium dense and open canopy much more than sparse canopy. So distribution of wild pigs in medium dense and open canopy areas was much more.

In winter, sighting of pigs in medium dense canopy area was 45.36%, in open areas was 48.36% and in sparse area was 6.28%. In monsoon, sighting of pigs in medium

dense canopy area was 39.82%, in open areas was 48.67% and in sparse area was 11.5%. Whereas in summer, sighting of pigs in medium dense canopy area was 57.88%, in open areas was 34.73% and in sparse area was 7.4%. So the use of canopy cover by wild pigs was found to be significantly different among the seasons ( $\chi^2=19.20$ , DF=4, P-value=0.001). In winter and monsoon seasons, sighting of wild pigs was highest in open canopy, while in summer season, sighting of wild pigs was highest in medium dense forest.

Appearance frequencies (area where wild pig appeared/total area\*100) were also calculated in order to remove the effect of occupation area of each environmental factor on habitat distribution (**Figure 6**). Wild pigs appeared maximum times in open canopy during winter and monsoon, whereas they appeared maximum times in medium dense canopy during summer.

#### **4.3.13 Use of aspects**

Wild pigs were found to use different aspects based on their sightings (**Map 8**). They used different aspects viz. East, North, Northeast, Northwest, South, Southeast, Southwest and West to varying extent and this enabled to know their distribution in the park (**Figure 7**). In winter, sighting of pigs was highest in North (17.49%), followed by Northwest (14.21%), Southeast (13.66%), South (13.11%), West (13.11%), East (12.02%), Southwest (8.47%) and in Northeast (7.92%). In monsoon, sighting of pigs was highest in Southwest (23.01%), Southeast (22.12%), Northeast (14.16%), East (12.39%), South (11.50%), North (7.08%), Northwest (5.31%) and West was (4.42%). Whereas in summer, sighting of pigs was highest in West (19.94%), Northwest (18.01%), South (13.50%), Southeast (12.22%), Southwest (11.58%), North (10.29%), Northeast (8.68%) and in East aspect area was (5.79%). The use of aspects by wild pig was found to be significantly not different among the seasons by Kruskal Wallis test (H=0.215, P=0.89) They preferred North in winter, Southwest in monsoon and West in summer maximum, while they were seen only a few times in Northeast in winter, West in monsoon and East in summer.

Appearance frequencies (area where wild pig appeared/total area\*100) were also calculated in order to remove the effect of occupation area of each environmental factor on habitat distribution (**Figure 8**). As for the aspect, wild pigs showed highest appearance frequency in North in winter, Southwest in monsoon and West in summer. Whereas they showed minimum appearance frequency in Northeast in winter, West in monsoon and East in summer.

#### **4.3.14 Sighting distance from the roads**

Distribution based on sighting of wild pigs showed use of areas at variable distance from the road (**Figure 9, Map 9**). They were generally found to use areas within 1 km from the road more than areas used at 2 km distance from the road. So the distribution of wild pigs within 1 km from the road side was much more. In winter, sighting of pigs within 1 km range was 84.7% and within 1-2 km range was 15.30%. In monsoon, sighting of pigs within 1 km was 96.46% and within 1-2 km area was 3.54%. Whereas, sighting of pigs within 1 km range was 93.57% and within 1-2 km area was 6.43% in summer.

We compared the use of areas by wild pigs in relation to their distance from road within the distance of 1 and 1-2 km. These two use categories of pigs were compared using the Kruskal-Wallis ( $H=3.85$ ,  $P=0.04$ ). The results showed that there was in significant difference in the use of locations in relation to distance from road. Perhaps wild pigs were found to use the areas near from roads in all the seasons.

#### **4.3.15 Distance from water bodies**

Distribution based on sighting of wild pigs showed almost no variation in distance from the water bodies in different seasons (**Figure 10, Map 10**). They were found to use areas within 2 km from the water bodies much more than 2-4 km distance from the water bodies. So distribution of wild pigs within 2 km from the water bodies was much more. In winter, sighting of wild pigs within 2 km range was 98.63% and within

2-4 km range was 1.37%. In monsoon, sighting of pigs within 2 km range was 98.23% and within 2-4 km area was 1.77%. While in summer, sighting of pigs within 2 km range was 98.71% and within 2-4 km area was 1.29%.

We compared the use of area by wild pigs in relation to their distance within 2 km and 2-4 km from water bodies. These two categories were compared using Kruskal-Wallis test ( $H=3.85$ ,  $P=0.04$ ) for variation in their distances. The results showed that there was significant difference in the use locations of pigs in relation to distance from water bodies. Wild pigs were found to use different areas in close vicinity of water bodies in all the seasons.

#### **4.3.16 Distance from the village**

Distribution of wild pigs based on their sighting showed much variation in relation to distance from villages (**Figure 11, Map 11**). They were sighted at variable distance i.e. up to 2 km, 4 km, 6 km, 8 km and 10 km from villages. They used areas within 2-4 km and 4-6 km from the village much more than 6-8 km and 8-10 km distance in all seasons. In winter, sighting of wild pigs was maximum within 4-6 km 59.56% followed by within 2-4 km area was 33.06%, within 2 km was 5.46%, within 8-10 km was 1.09% and within 6-8 km 0.82%. In monsoon, sighting of wild pigs was maximum within 4-6 km 38.94% followed by within 2-4 km area was 39.82%, within 2 km was 17.70% and within 6-8 km 3.54%. Whereas in summer, sighting of wild pigs was maximum within 4-6 km 60.77% followed by within 2-4 km area was 24.76%, within 2 km was 9.32%, within 6-8 km was 2.57% and within 8-10 km was 2.57%.

We compared the use of area by wild pigs in relation to their distance within 2 km, 4 km, 6 km, 8 km and 10 km from villages. These categories were compared using the difference Kruskal Wallis test ( $H=12.69$ ,  $P=0.01$ ) for the use of area by pigs and variation in their distances from villages. The results showed that there was significant difference in the use locations of wild pigs in relation to distance from

villages. Wild pigs were found to use different areas at variable distances from villages in all seasons.

Appearance frequencies (area where wild pig appeared/total area\*100) were also calculated in order to remove the effect of occupation area of each environmental factor on habitat distribution (**Figure 12**). They appeared maximum at 6 km distance from the village during winter and summer, whereas their appearance frequency was maximum at 4 km distance from the village in monsoon.

#### **4.3.17 Use of elevations**

Wild pigs were found to use different elevations in the study area (**Map12**). Distribution based on sighting of wild pigs showed much variation in the use of elevations viz. 200-250, 251-300, 301-350, 351-400 and 400-500m (**Figure 13**). Out of total 790 sightings, 366 locations were in winter, 113 in monsoon and 311 in summer season. In winter, sighting of wild pigs was highest (53.83%) at an elevation 351-400m, followed by 251-300m (27.60%), 200-250m (12.84%), 301-350m (3.55%) and 400-500m (2.19%). In monsoon, sighting of wild pigs was highest (30.97%) at an elevation of 200-250m and 351-400m, followed by 251-300m (30.09%), 400-500m (5.31%) and 301-350m (2.65%). Whereas in summer, sighting of wild pigs was highest (51.13%) at an elevation of 351-400m, followed by 200-250m (20.90%), 251-300m (19.61%), 301-350m (7.40%) and 400-500m (0.96%). Distribution of wild pigs was highest at an elevation from 351 to 400m in winter, monsoon and summer seasons, and they greatly avoided 400-500m elevation. These categories were compared using the difference Kruskal Wallis test ( $H=12.14$ ,  $P=0.01$  for the use of elevations by pigs). The results showed that there was significant difference in the use elevations of pigs. Wild pigs were found to use different elevations.

In order to remove the effect of occupation area of each environmental factor on habitat distribution, appearance frequencies (area where wild pig appeared/total area\*100) were calculated (**Figure 14**). Wild pigs showed highest appearance

frequency at elevation of 351-400m in all the seasons. Whereas the appearance frequency was lowest at elevation of 301-350m in all the seasons.

#### **4.4 Discussion**

In changing environment, population distribution of animal species is essentially required not only to know the trend but also to effectively manage declining or increasing problematic species populations. Since human-wild pig conflicts are on the rise and has now reached to alarming level in the most of areas, hence it requires estimation of population distribution so that future course of action to deal with the conflicts can be developed.

The landuse categories of the Ranthambore National Park showed that each landuse category was distinct with the specific characteristics. There were 13 main vegetation and landuse categories on the basis of tone, texture and pattern in the satellite imageries. They were *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest (*Prosopis juliflora*), Water bodies and Agriculture. The vegetation and landuse also included Fort as the fourteenth category, but it was excluded because of continuous pilgrim pressure. Wild pigs varying from solitary animal to group of up to 52 individuals were found to differentially use these habitat categories in different seasons.

##### **4.4.1 Group size and variation**

Wild pigs were found distributed all over the national park as well as in peripheral areas, and sighted throughout the year. Lone pigs were sighted 169 times, and most of them were solitary males. Adult males sometimes consorted with oestrous females in order to mate with them, but such relationships lasted only for few days and were temporary. The group size of 3-10 individuals was sighted maximum times. Large group of 27-34 individuals were rarely seen. Group size of 35-42 and 43-52 individuals were seen occasionally during or after giving birth to young ones, these groups mainly consisting of lactating females.

Group size of wild pigs was also found to vary in different seasons. In winter, generally small groups of wild pigs were encountered. Large groups were seen less, and even larger groups were not very frequently seen in winter. During this period, mortality and predation of some piglets which were born during monsoon when they were growing, during this time, farrowing females started separating with their living piglets or stripers.

In monsoon, large groups of wild pigs were also encountered alongwith sighting of small groups. Large groups were sighted in this season because of the recruitment of the new piglets in the group and because of more lactating females in a large group. Piglets were born during July and August. Group size was more in monsoon because after the recruitments of new piglets, generally 3-4 females got together and move together with their piglets. During onset of winter and summer, some of the piglets may die naturally, some may be predated upon by some predators and when piglets grow up female also got separated with their litters. Males could have contributed to the large groups as higher portion of males in an average group during monsoon and winter suggest the formation of bachelor herds by males after mating season. In summer, generally small groups of wild pigs were encountered most. This might be due to the reason that in the summer, male and female pair up for mating, and there is also scarcity of food and water. So they prefer to live in small groups in different habitats.

#### **4.4.2 Spatio-temporal distribution**

Wild boar is very important species for wildlife management, because of its high multiplication ability and adaptability to the environment (Kim, 1994). As natural wildlife habitat continue to disappear at an alarming rate, many species of fauna and flora in Korea were threatened with extinction (Won and Smith, 1999).

Spatio-temporal patterns of living organisms have been the object of numerous developments in the recent years. Analysis of these patterns in large mammals is required to study the distribution over very large areas. For proper habitat management, it is mandatory to have some understanding of species requirements for different habitats. Natural selection favours those individuals who prefer habitats in

which reproductive success is higher and where they survive better. 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 handful ecological studies on wild pigs in the subcontinent. Interpretation of distribution map of wild boar should take account of the spatial organisation of individuals. Numerous studies (Spitz, 1992 and Macchi *et al.*, 1995) showed that wild pigs are distributed in nuclei based on one or several adult females, living there with their young of last generation.

Since census and spatio-temporal distribution of wild pig is very important for management point of view, hence an alternative method i.e. Identification of all sites and density indices based on wild pigs evidences such as scats and diggings was used to estimate population abundance and distribution. On the basis of location of direct sighting of wild pigs and indirect evidences, distribution pattern of wild pig can be studied. Some of the sites and available habitats of wild pigs were interspersed with human settlement and agricultural areas. Locations of all sightings of wild pigs were used for estimating habitat use and preferences.

#### **4.4.3 Distribution based on direct sighting**

Based on direct sightings, wild pigs were found distributed in different landuse and vegetation types, namely, *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest (*Prosopis juliflora*), Water bodies and Agriculture. All these habitats were differentially used by wild pigs throughout the year. They were found maximum times in *Anogeissus pendula* forest, and very less in Degraded grassland. Wild pigs were not seen in Grassland, Rocky outcrop and *Acacia catechu* with grasses during the study period. These habitats might not be ideal for wild pigs, and there could be very limited food availability. Because of hard substratum, these animals were not seen distributed in Rocky outcrops.

Distribution or sightings of wild pigs in different habitats were found to vary in winter, monsoon and summer seasons. In winter, they were found maximum times in *Anogeissus pendula* forest, and few times in Degraded grassland. Tropical dry mixed was not found to be used in winter season. Presence of wild pigs in Tropical moist mixed forest was much more in winter season than monsoon and summer seasons. This might be due to availability of *Zizyphus* (Ber) fruits in Tropical moist mixed forest during this period; wild pigs were greatly attracted and preferred to feed on these fruits. In monsoon, they were found maximum times in *Anogeissus pendula* forest, and Scrub forest. Water bodies were not found to be used during monsoon season as water was available everywhere in the park. All nalahs, anicuts, ditches etc. were charged with water. Water bodies in Rajbag, Padam talab, Malik talab and Malik anicut were flooded with water, and it was very difficult for them to feed on aquatic vegetations and some other grasses on the bank of these water bodies. During monsoon, wild pigs were found to use agriculture fields more than winter and summer seasons as the 'kharif' crops were cultivated in this season and wild pigs preferred to feed on these crops. Further it was easy for wild pigs to dig out soft soil after rains. Whereas in summer season, they were found maximum times in *Anogeissus pendula* forest. During this period, agriculture was least used as there were no crops in the fields and hardly any food available. Only people having tube well could grow some crops, so there was rare movement of wild pigs towards fields.

#### **4.4.4 Distribution based on indirect evidences**

Visual impact of wild pigs on the tropical dry deciduous environment is their feeding activity or diggings associated with soil or surface vegetation disturbance. Our study revealed that wild pigs were found distributed all over the Ranthambore National Park as well as in peripheral areas based on diggings and presence of faecal matter. Diggings and faecal matter were found in different landuse and vegetation types. But all these habitats were differentially used by wild pigs throughout the year. The diggings were found maximum times in *Anogeissus pendula* forest, followed by *Anogeissus pendula* with shrub, Tropical dry mixed, Water bodies and so on.

Similarly the presence of faecal matter was found maximum in *Anogeissus pendula* forest, followed by Tropical dry mixed, *Anogeissus pendula* with shrub, Agriculture, Tropical moist mixed, Water bodies, Scrub forest (*Prosopis juliflora*), *Anogeissus pendula* mixed, Grassland and so on. Presence of wild pigs could not be seen in Rocky outcrop.

Mitchell *et al.* (2007) studied the spatial and temporal patterns of feral pig diggings in rainforests of north Queensland. Feral pigs preferred to dig in moist microhabitats where soil moisture persisted into the dry season (swamps and creeks) and most diggings occur during the early dry season. The amount of diggings has been positively associated with pig population densities in studies in Hawaii (Katahira *et al.*, 1993) and on mainland USA (Ralph and Maxwell, 1984). Hone (1988a) found that the amount of recent or fresh diggings was positively related to pig population levels. Dunning *et al.* (1992) considered a landscape as a mosaic or habitat patches (termed microhabitats in this study) with the relative amount of each microhabitat within the landscape. Rainforest complexity made calculating the relative amount of each study stratum within the landscape difficult. However, differences in the utilization of these microhabitat strata by feral pigs could be indicated by the differences in the amount of diggings between the strata. Significant differences in the utilization of these strata by feral pigs were found in the highland and transitional areas of this study. Most diggings occurred in strata that were small in size or uncommon compared with the rainforest landscape. In comparison, the strata that represent the largest portion of the total rainforest area, the ridge in the highlands and forests in the lowlands, had significantly fewer diggings.

Choquenot and Ruscoe (2003) suggested that the quality of a location or microhabitat stratum where a large herbivore such as a feral pig may prefer to spend time will be determined by the availability and quality of food resources. The preference of feral pigs to spend more time in some micro habitats was also described by Mitchell and Mayer (1997), who found that most pig diggings also occurred in small microhabitats, such as drainage lines and roads, compared with the larger area of the general forest floor. Hone (1988) described this spatial digging pattern of many sites with few diggings and few sites with many diggings as fitting a negative exponential frequency

distribution.

Engeman *et al.* (2003) also described seasonal patterns of feral pig diggings in their study in Florida. Seasonal patterns of diggings were also observed; the peak diggings were generally in the dry-season months of May or June in the highlands and in the transitional and lowland areas in July or August. Factors such as the seasonality of available above-ground food resources (e.g. fruits), in comparison with the availability of below-ground food resources (e.g. earthworms), might influence the distribution, scale and timing of diggings. Pig distribution could be driven by variations in locally or seasonally abundant food sources (Choquenot *et al.*, 1996). Other factors that could influence pig diggings were found in the studies in the Northern Territory, where seasonal variations in the distribution of pig populations were caused by seasonal flooding (Hone, 1990) and by the availability of seasonal cereal crops (Caley, 1993). Overseas studies had reported seasonal population distribution patterns being attributed to rainfall and temperature patterns in Malaysia (Diong, 1973), to food availability (Graves, 1984) and to the density of available cover (Barrett, 1978) in the USA.

#### **4.4.5 Availability vs. use of habitats**

For proper habitat management, it is mandatory to have some understanding of species requirements for different habitats. Natural selection favours those individuals who prefer habitats in which reproductive success is higher and where they survive better. 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 handful ecological studies on wild pigs in the subcontinent.

Wild pigs regularly modify their habitat use within their home range based on climatic conditions and the availability of food and water (Kurz and Marchinton,

1972; Wood and Brenneman, 1980; Baber and Coblenz, 1986; Choquenot *et al.*, 1996 and Dexter, 1998). Abrupt or seasonal changes in habitat use by wild pigs in an area are often related to food availability and dietary shifts (Sweeney, 1970; Kurz and Marchinton, 1972; Graves and Graves, 1977 and Barrett, 1978).

Analysis of habitat use and selection assumes that species choose those habitat components which will increase fitness, survival and reproductive success. Here we focused on habitat use of wild pig. Use of all the available habitat types by wild pigs indicates their ability to inhabit a variety of habitat types. However, the locations in various habitats indicated that wild pigs differed in the use of habitats available within the study area.

Based on diggings and presence of faecal matter, wild pigs were also found distributed all over the national park as well as in peripheral areas. Wild pig signs were found distributed in different landuse and vegetation types viz. *Acacia catechu* with grasses, *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest (*Prosopis juliflora*), at the bank of Water bodies and Agriculture. But all these habitats were differentially used by wild pigs throughout the year. The diggings were found maximum times in *Anogeissus pendula* forest. Presence of wild pigs could not be seen in Rocky outcrop. The availability of various habitats and their use varied in different seasons in Ranthambore National Park. Based on the Kruskal-Wallis test, the habitats used by wild pigs were significantly different from the unused habitat as indicated by presence or absence or frequency of occurrence of wild pig signs. The number of diggings and faecal matter in different habitat types was proportional to the abundance of wild pigs in study area.

The percent availability of various habitats was to varying extent in Ranthambore National Park. *Anogeissus pendula* forest covered maximum area, followed by scrub forest, Tropical dry mixed, *Anogeissus pendula* with shrub, Grassland, *Prosopis juliflora*, *Anogeissus pendula* mixed, Rocky outcrop, Degraded grassland, Water bodies, Tropical moist mixed, *Acacia catechu* with grasses and Agricultural areas.

According to Ivlev's index of selectivity, Tropical moist mixed forest and Water bodies were the most preferred habitats, followed by *Anogeissus pendula* forest, Acacia catechu with grass, *Anogeissus pendula* mixed forest and Tropical dry mixed forest. These habitats were utilized more than their proportional availability. Whereas the proportion of Grassland, *Anogeissus pendula* with scrub forest and Agriculture were less utilized than available. The Rocky outcrop was completely avoided by wild pigs. Distribution of wild pigs was found to be more in Tropical moist mixed forest, Water bodies, *Anogeissus pendula* forest, Acacia catechu with grass, *Anogeissus pendula* mixed forest and Tropical dry mixed forest.

Previous studies of habitat use in feral hogs have demonstrated that individuals tend to be habitat generalists and often, but not always, use habitat in proportion to its abundance (Ilse and Hellgern, 1995; Gabor *et al.* 2001 and Adkins and Harveson, 2007). Feral swine in the south-eastern United States have adapted to a wide range of habitat conditions, including both swamps and mountains (Hanson and Karstad, 1959). Location map on forest-types showed that wild pigs were present 85.1% in the bottomlands during October-May, and 82.5% in the pine plantations in June. Data for July indicated decreased activity in pine plantations, but these data were limited and perhaps were not representative of actual habitat use.

The two most important habitats for feral hogs in study area were forested and agricultural areas. Crops can provide needed nutrients at certain times of the year. Because reproduction is strongly linked to nutrition, agricultural areas may be important to the reproductive success of feral hogs. They provided sufficient agricultural resources for feral hogs. Forest provided both cover and food for hogs. Hard mast and herbaceous under story plants were important parts of the diets of feral hogs in many parts of the country (Henry and Conley, 1972 and Howe *et al.*, 1981).

Monthly differences in habitat utilization appeared to be related to food availability. Abundance of acorn mast during the fall influenced the time spent by feral hogs in bottomlands, and the ripening of plums in June corresponded with a sharp increase in the activity in the pine plantations. In general, habitat selected by hogs was consistent with that of hogs reported in other studies in the south-eastern United States,

indicating that hog use increased in hardwoods but decreased in pine and shrubby areas (Sweeney, 1970 and Gaines *et al.*, 2005). Mast crops, such as oaks (*Quercus*), were found to be important food sources for hogs (Wood and Roark, 1980, Singer *et al.*, 1981 and Boitani *et al.*, 1994). For both genders, the most commonly used habitats also included some species of oak, and it was likely that mast from the 3 oaks in these classes increased the importance of these vegetation types for hogs.

The wild boar is a game species that often faces extreme hunting pressures (e.g., a 40% of chance of being harvested annually, and up to 70% for adult males) (Toigo *et al.*, 2008). Consequently, its use of space was found to change markedly when the risk of being predated or hunting starts (Boitani *et al.*, 1994; Sodeikat and Pohlmeier, 2003 and Keuling *et al.*, 2008).

#### **4.4.6 Use of habitat variables**

Wild pigs were found to use different habitat variable like terrain, canopy cover, aspects, distance from road, distance from water bodies, distance from village and use of elevations. They used various terrain types such as flat, medium slope and gentle slope to varying extent. Distribution based on sighting of wild pigs was highest in areas with gentle slope throughout the year. They preferred gentle slope maximum than medium slope and flat terrain. The use of slope by wild pig was found to be significantly different among the seasons and the gentle slopes were used significantly high by the wild pigs in comparison in all seasons. Most of the wild pigs were observed in areas with gentle slopes. So there was strong preference by wild pigs for the gentle terrain. Perhaps use of these terrain types by wild pigs might be governed by availability of food resources and high visibility factor.

Distribution based on sighting of wild pigs showed much variation in their use of medium dense, open and sparse canopy types. They preferred medium dense and open canopy much more than sparse canopy. So distribution of wild pigs in medium dense and open canopy areas was much more. Wild pigs appeared maximum times in open canopy during winter and monsoon, whereas they appeared maximum times in

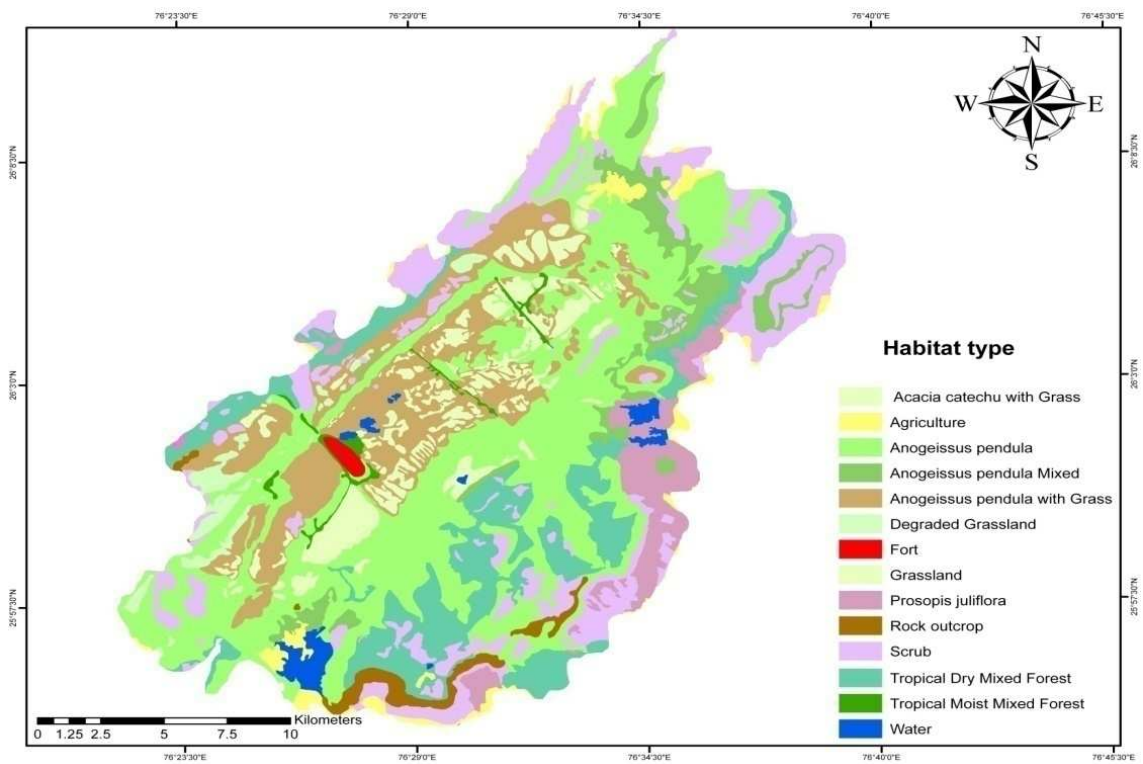
medium dense canopy during summer. Similarly wild pigs were found to use different aspects based on their sightings. They preferred North in winter, Southwest in monsoon and West in summer maximum, while they were seen only a few times in Northeast in winter, West in monsoon and East in summer.

Wild pigs were generally found to use areas within 1 km from the road more than areas used at 2 km distance from the road. There was insignificant difference in the use of locations in relation to distance from road. They were found to use the areas near from roads in all the seasons. But there was significant difference in the use locations of pigs in relation to distance from water bodies. Wild pigs were found to use different areas in close vicinity of water bodies in all the seasons. Distribution of wild pigs based on their sighting showed much variation in relation to distance from villages. There was significant difference in the use locations of wild pigs in relation to distance from villages. Wild pigs were found to use different areas at variable distances from villages in all seasons. They were found to use different elevations in the study area. Distribution based on sighting of wild pigs showed much variation in the use of elevations. Distribution of wild pigs was highest at an elevation from 351 to 400m in winter, monsoon and summer seasons, and they greatly avoided 400-500m elevation. There was significant difference in the use elevations of pigs.

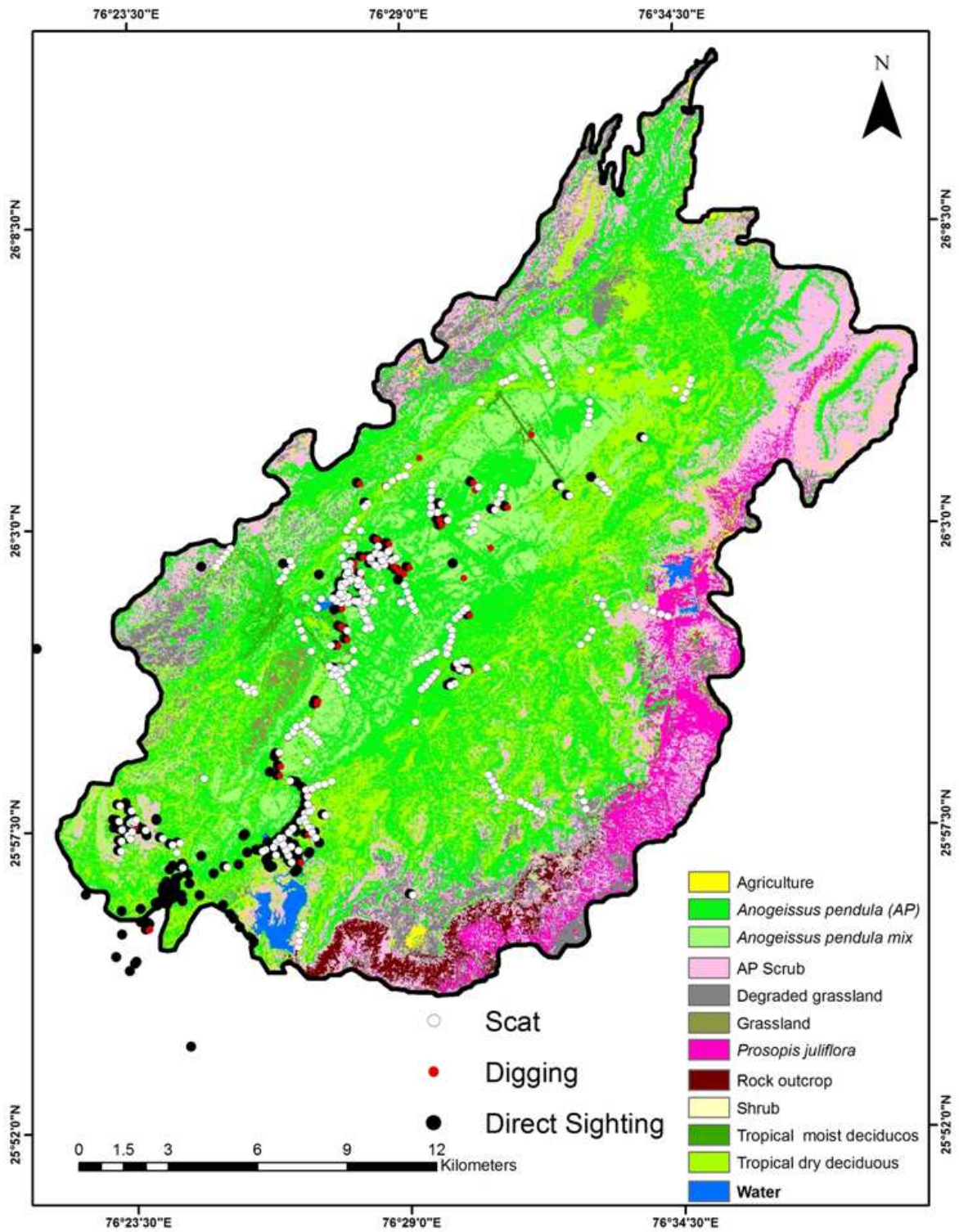
Kim *et al.* (2007) studied the habitat utilization characteristics of wild boar in Yangyang, Korea and analyzed the home range and habitat utilization pattern. The spatial distributional patterns about wild boar habitat were examined, and reported that the forest types, forest ages, aspect, and altitude were found to effect largely on environmental characteristics of wild boar habitat.

Management strategies for wild pigs in and around Ranthambore National Park should be prioritized to reducing the ecological impacts of pigs on the relatively limited available habitats that are preferred by wild pigs for foraging activities, rather than to the forest landscape as a whole. Management needs to be specific in targeting those habitats or species that have high conservation values and that have been identified as at risk from wild pig activities.

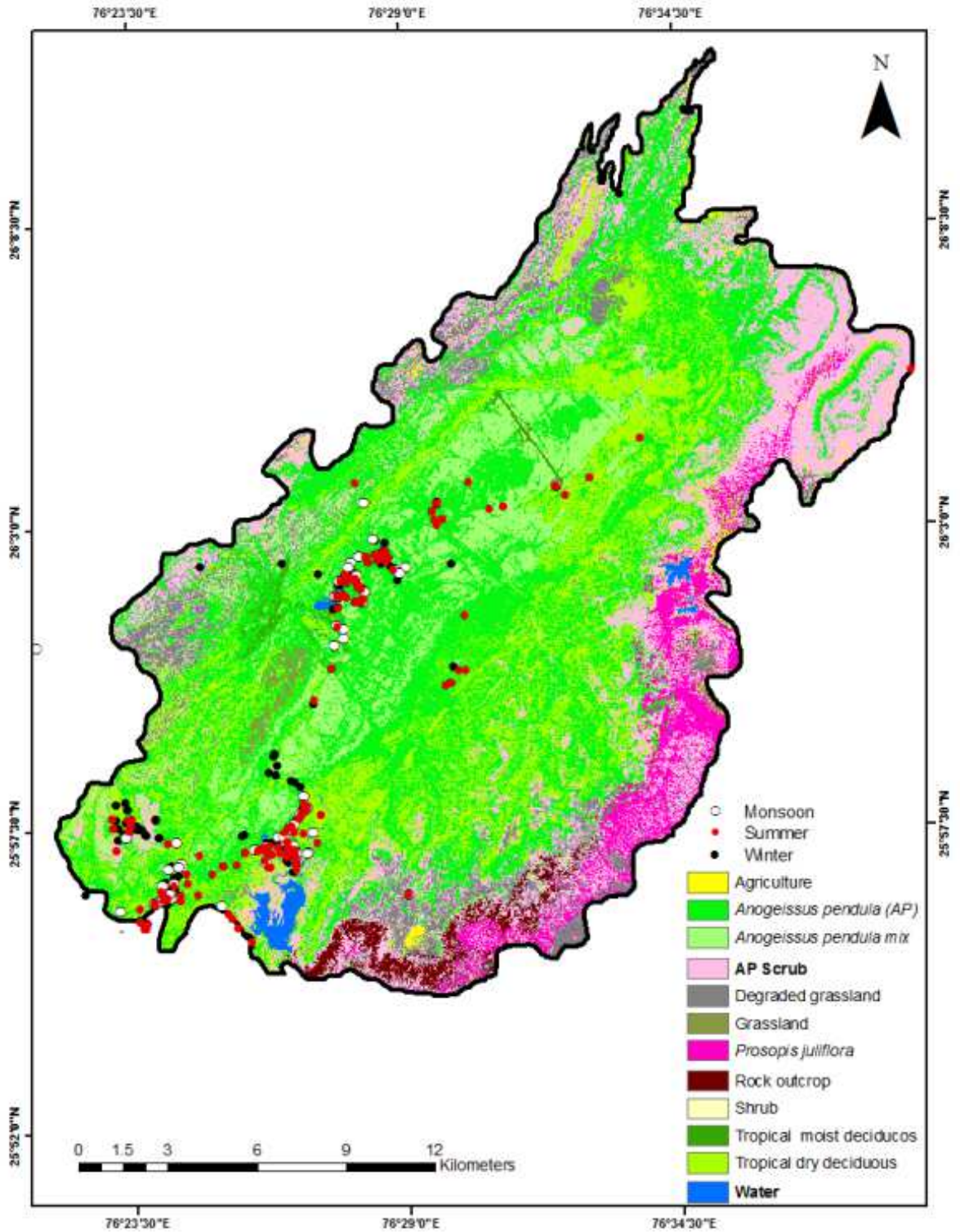
**Map 1: Vegetation and landuse categories of Ranthambhore National Park.**



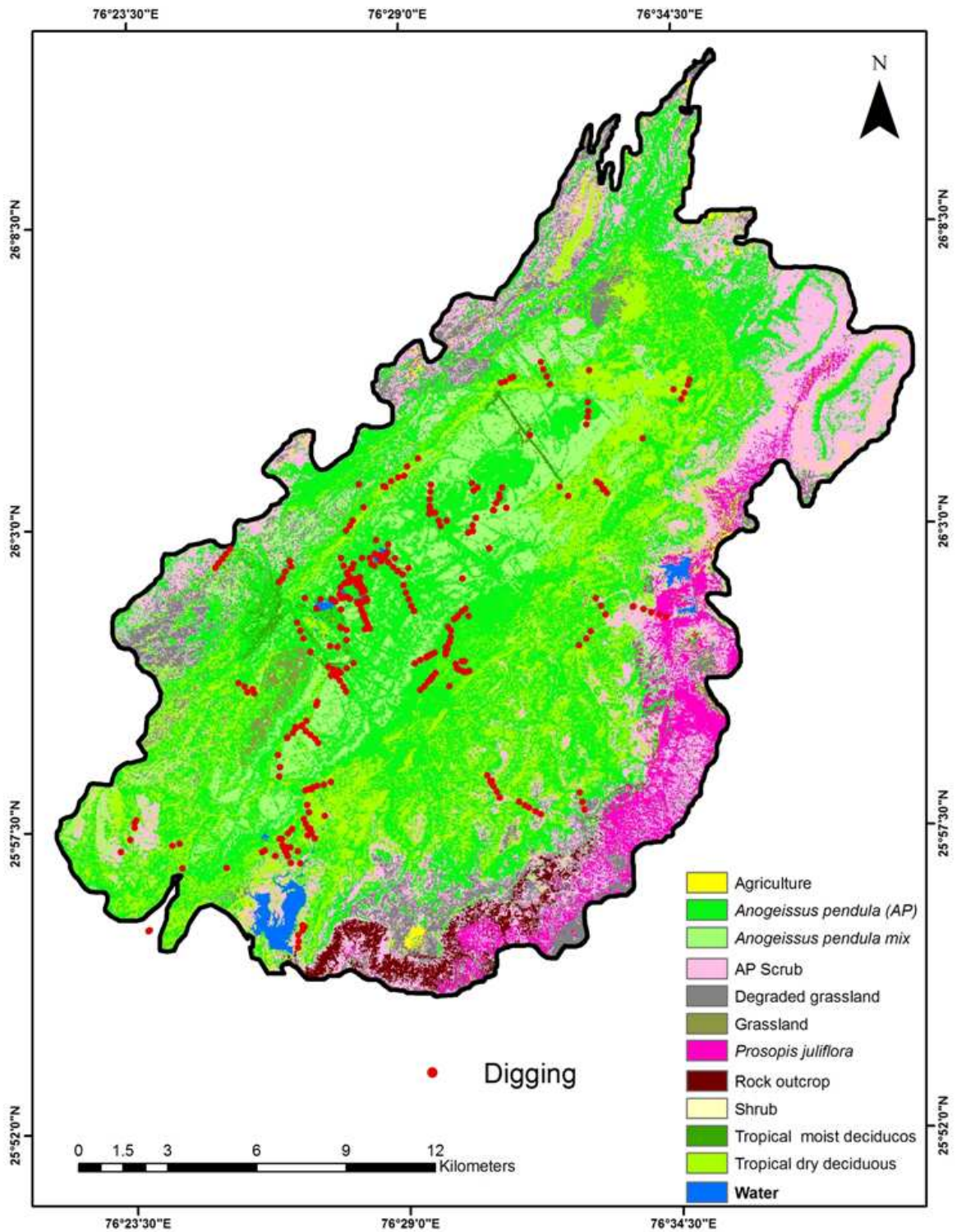
**Map 2: Distribution of wild pigs based on their sightings, diggings and faecal matter in different habitats in Ranthambore National Park.**



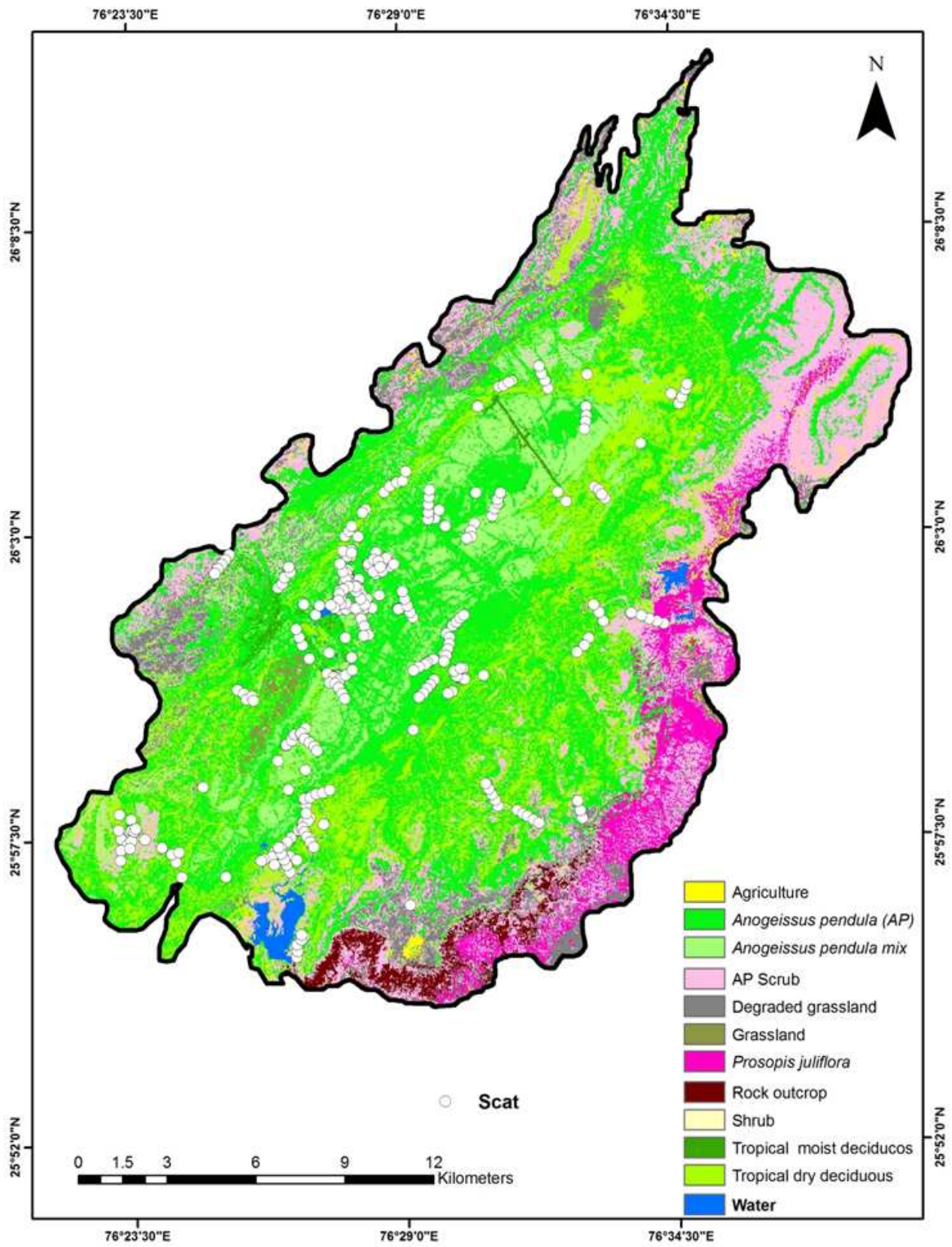
**Map 3: Sightings of wild pigs in different habitats and seasons in Ranthambore National Park.**



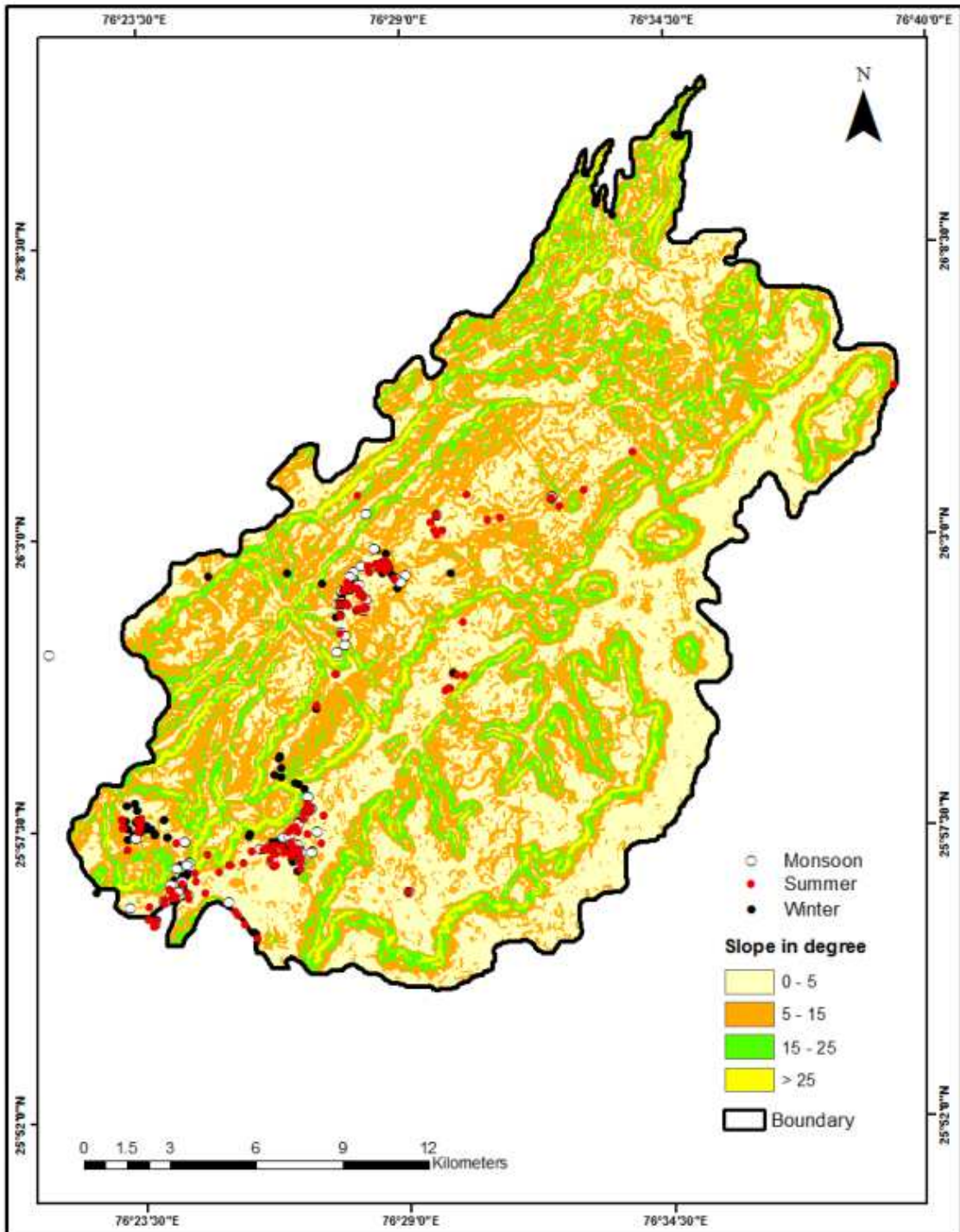
**Map 4: Distribution of wild pigs based on digging signs in different habitats in Ranthambore National Park.**



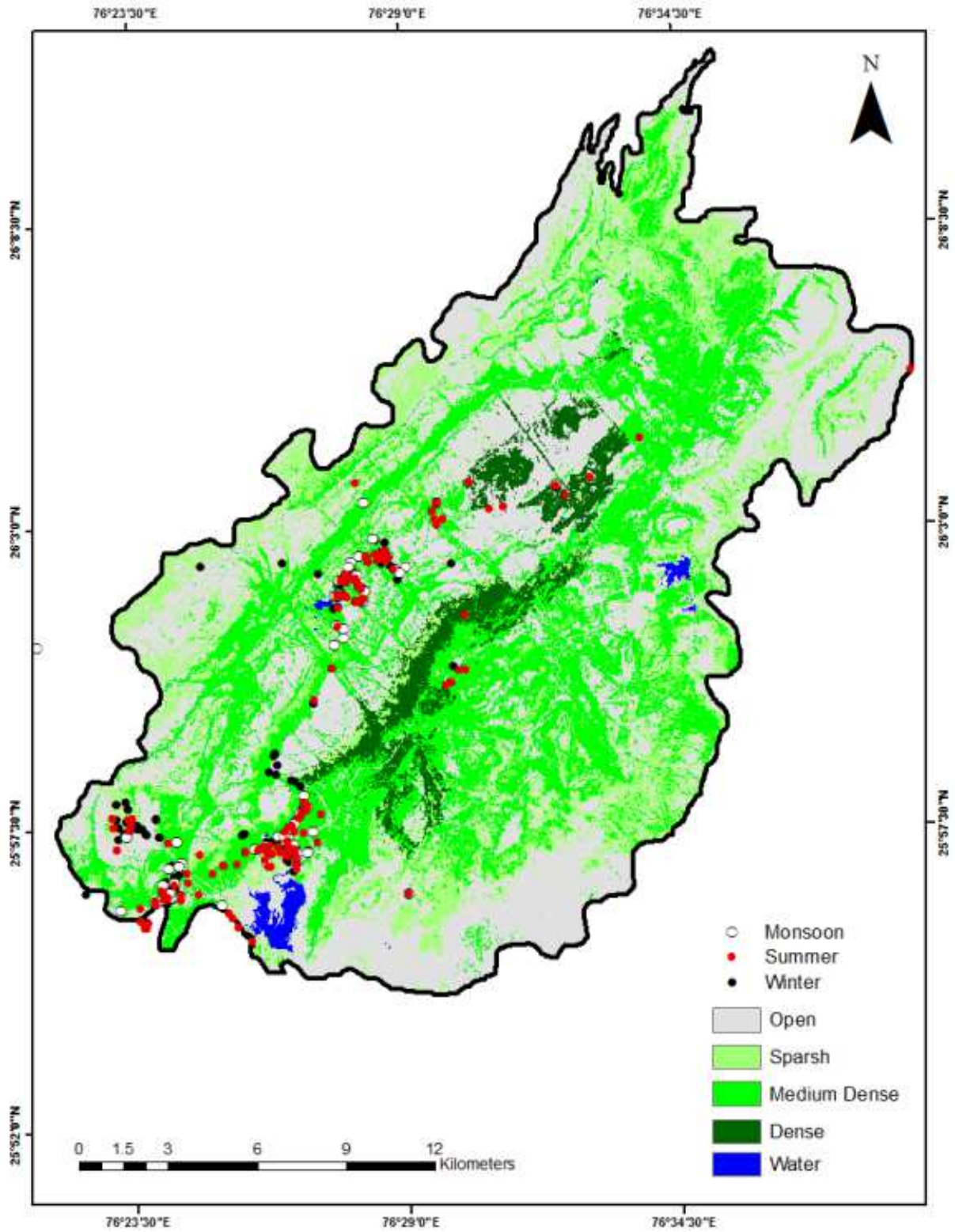
**Map 5: Distribution of wild pigs based on faecal matter in different habitats in Ranthambore National Park.**



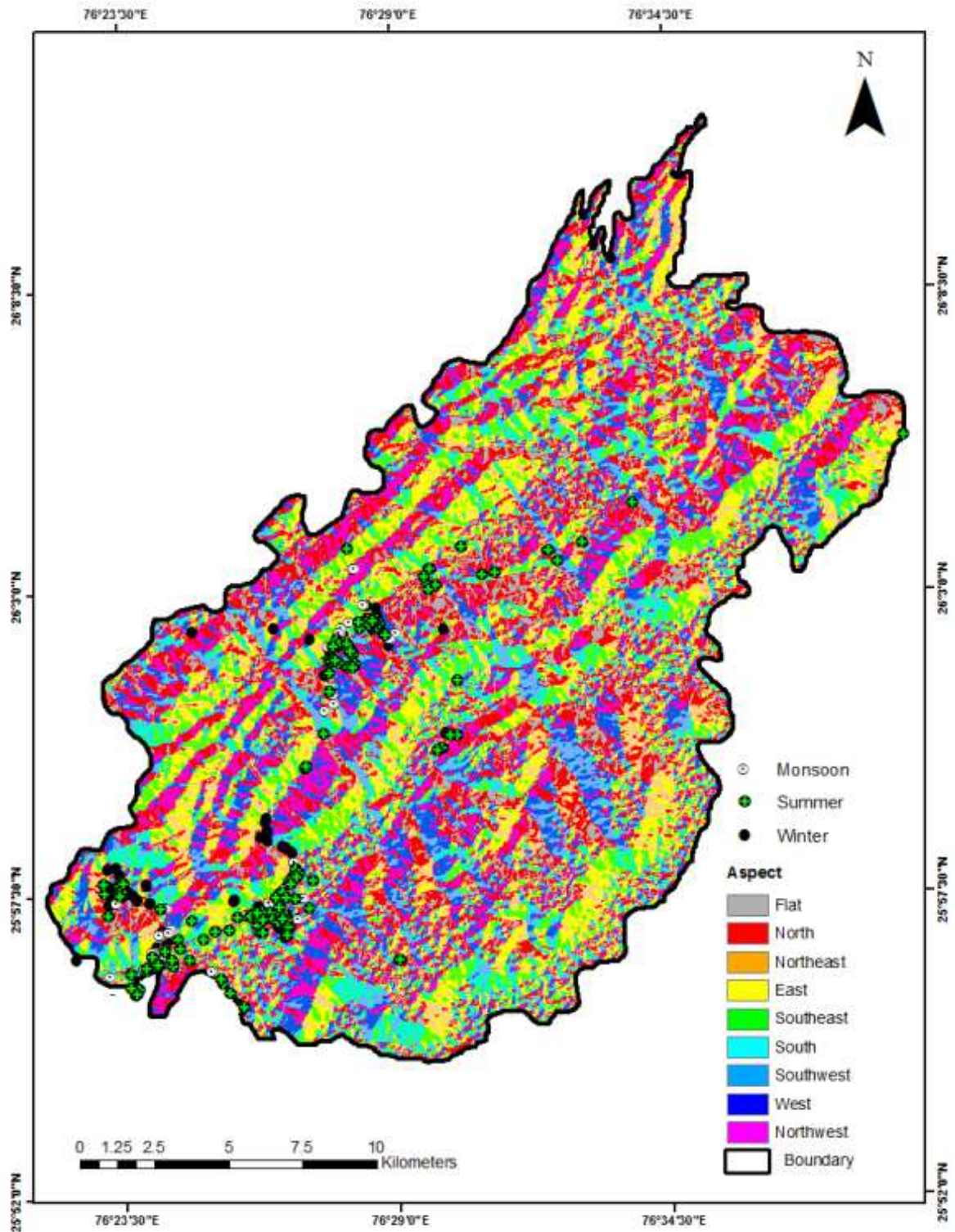
**Map 6: Use of slopes by wild pigs in different seasons in Ranthambore National Park.**



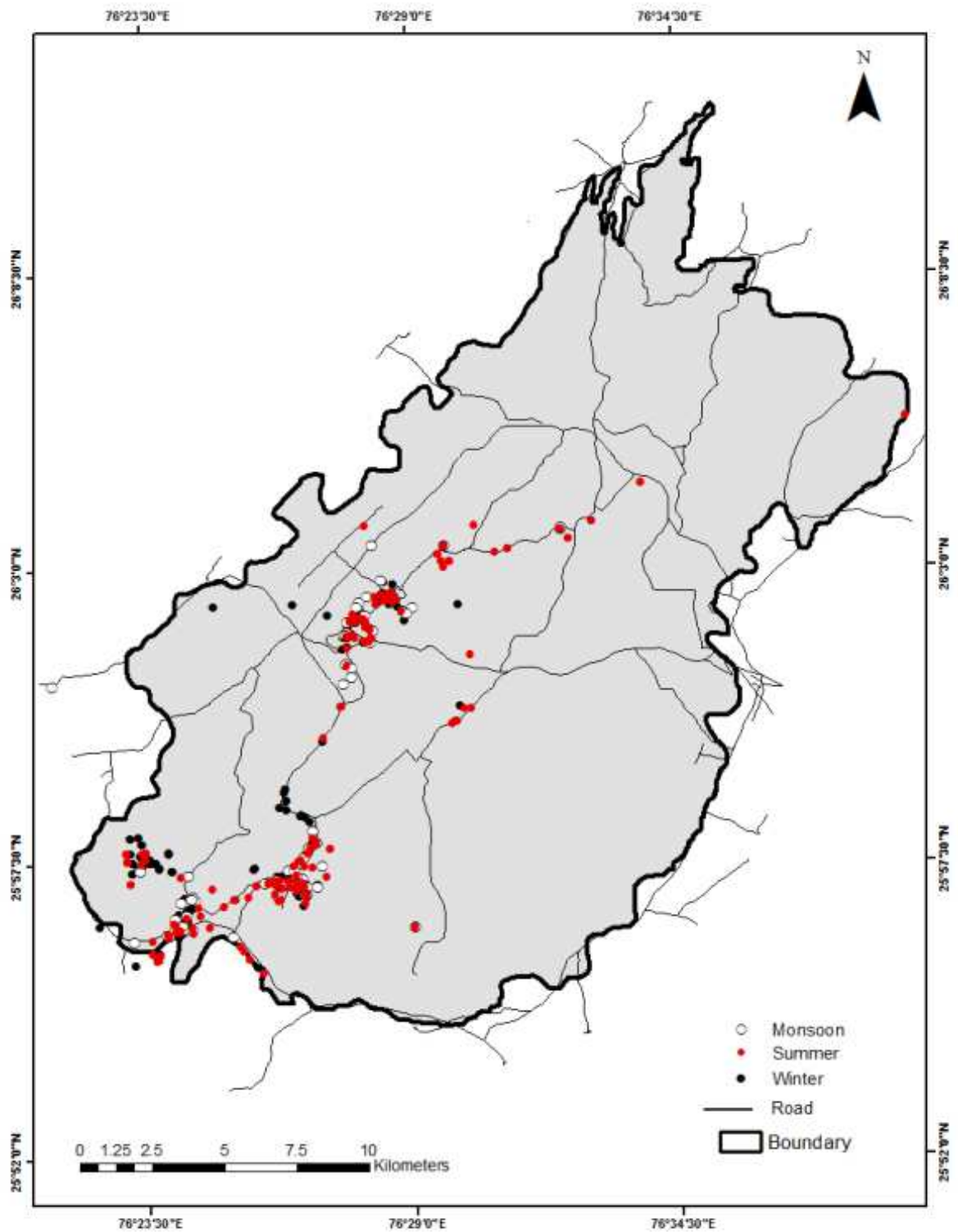
**Map 7: Use of canopies by wild pigs in different seasons in Ranthambore National Park.**



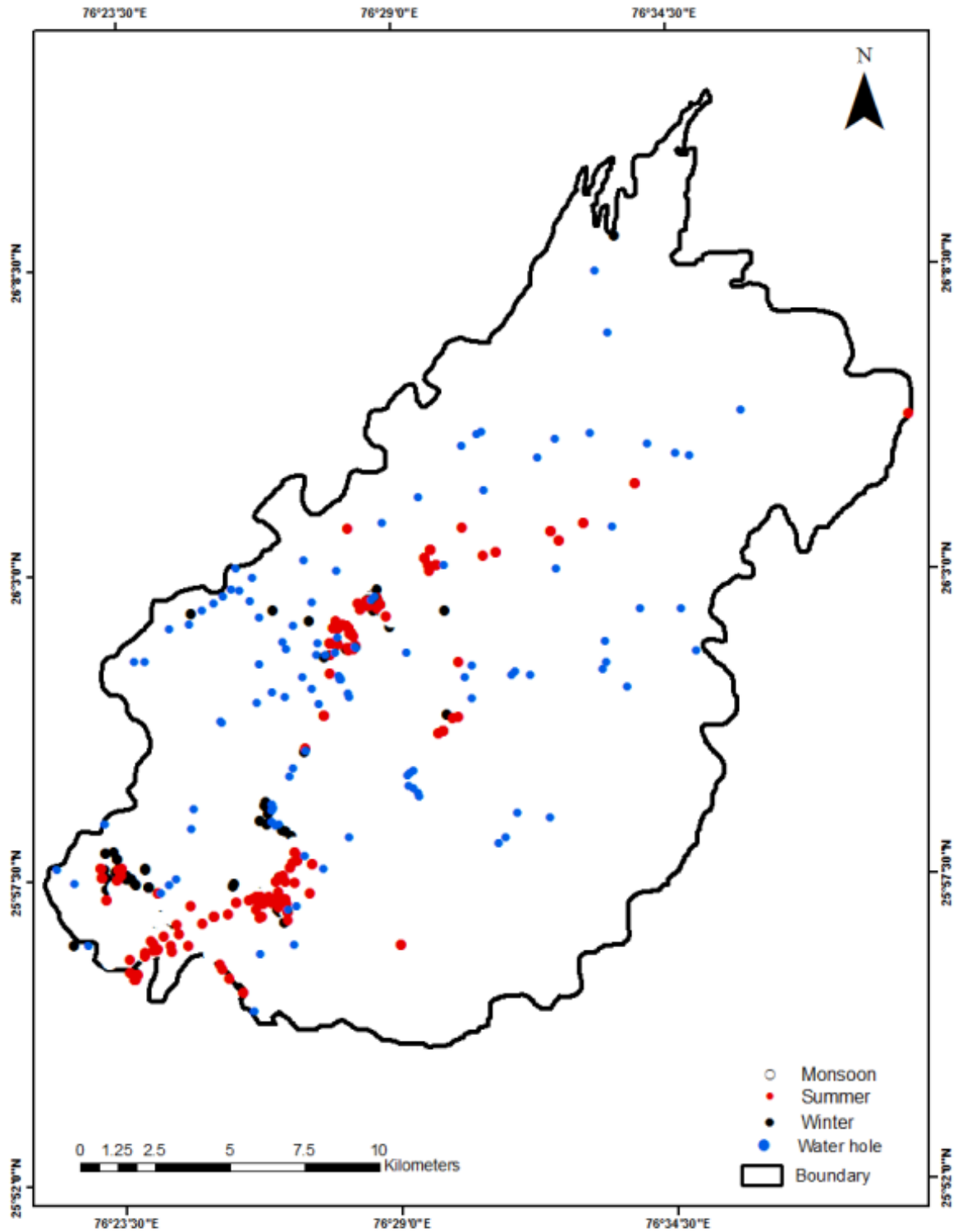
**Map 8: Use of aspects by wild pigs in different seasons in Ranthambore National Park.**



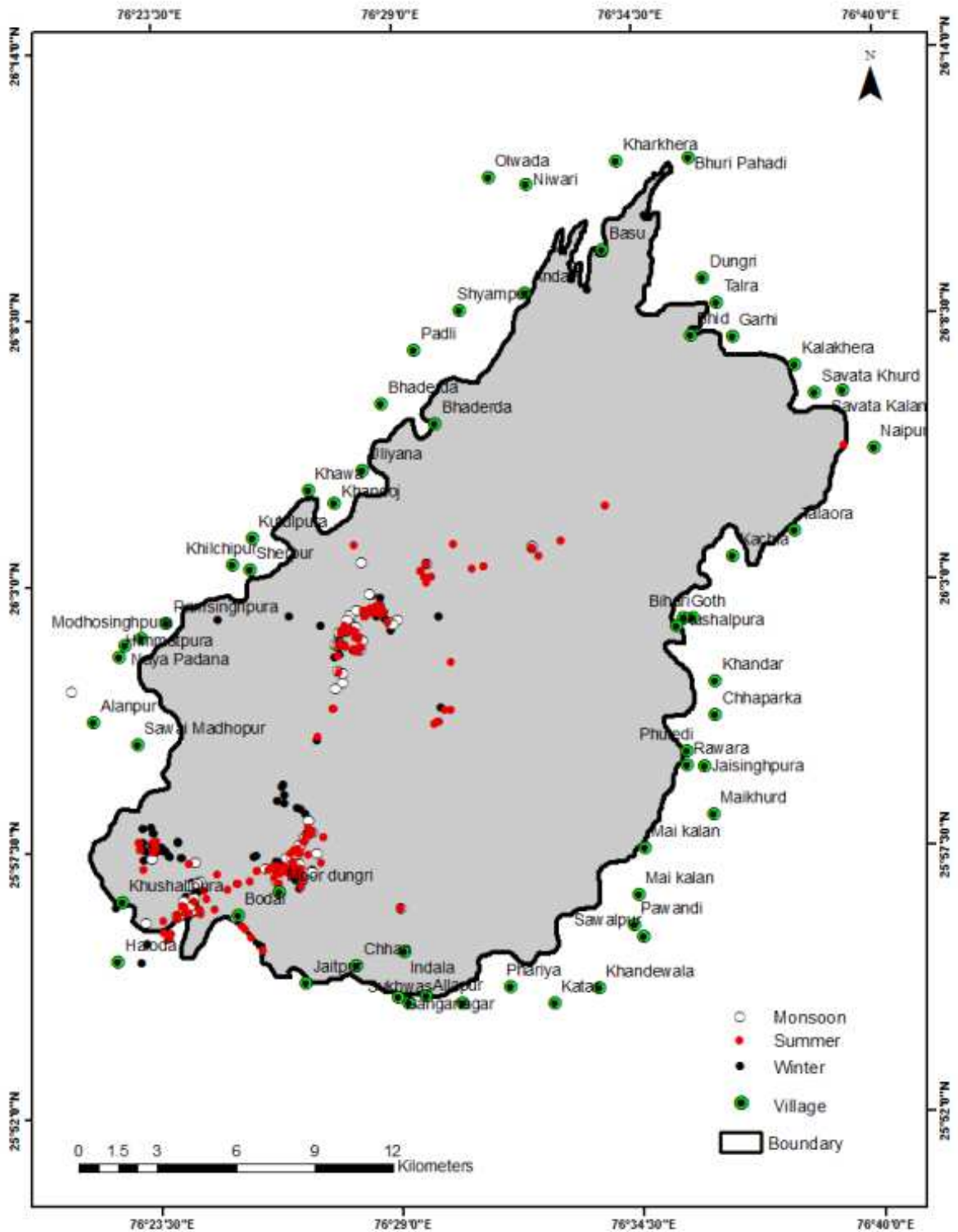
**Map 9: Sighting distance of wild pigs from roads in different seasons in Ranthambore National Park.**



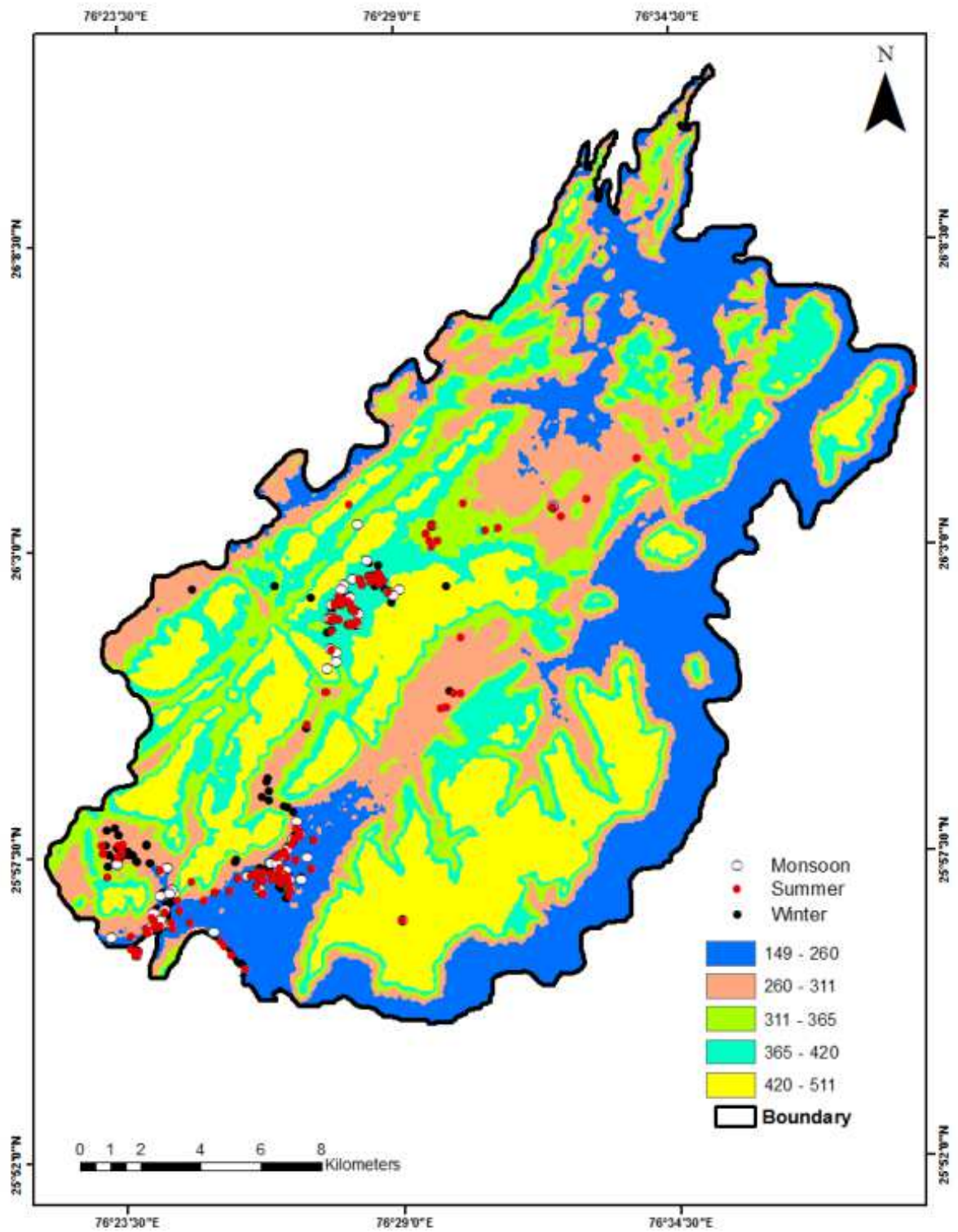
**Map 10: Sighting distance of wild pigs from water bodies in different seasons in Ranthambore National Park.**



**Map 11: Sighting distance of wild pigs from villages in different seasons in Ranthambore National Park.**



Map 12: Use of elevations by wild pigs in different seasons in Ranthambore National Park.



**Table 1: Interpretation criteria of vegetation and landuse categories of Ranthambhore National Park.**

<b>Vegetation type</b>	<b>Tone</b>	<b>Texture</b>	<b>Pattern and distribution</b>
<i>Anogeissus pendula</i> forest	Pinkish red	Smooth	Undulating and Northwardly slop
Tropical thorn forest	Dull blue	Smooth to patchy	Southwardly slops to flat plateaus
<i>Butea</i> forest	Deep red	Coarse to rough	-
Mixed forest	Deep red to dull pink	Coarse to patchy	Near ravines and water bodies
Water bodies	Black	Smooth	Lakes and reservoirs
Wetlands	Pinkish red to deep red	Patchy	Edges of lakes and reservoirs
Rocky out crop	Light sky blue	Smooth patchy	Hills and cliffs, slabs and boulders.
River bed	White to light blue	Smooth	Sandy banks of river

**Table 2: Proportion of different habitat categories in Ranthambore National Park.**

<b>Habitat type</b>	<b>Area (km<sup>2</sup>)</b>	<b>Area (%)</b>
Agriculture	23.88	4.87
<i>Anogeissus pendula</i> mixed forest	20.88	4.35
<i>Anogeissus pendula</i> forest	152.84	31.84
<i>Anogeissus pendula</i> shrub	60.89	12.69
<i>Acacia catechu</i> with grasses	1.88	0.39
Degraded grassland	7.96	1.66
Grassland	30.43	6.34
Tropical dry mix forest	60.94	12.70
Tropical moist mix forest	3.43	0.72
Scrub forest	78.16	16.28
<i>Prosopis juliflora</i> forest	21.90	4.56
Rock outcrop	10.52	2.19
Water bodies	6.78	1.41

**Table 3: Group structure of wild pigs derived from total sightings in Ranthambore National Park.**

<b>Group size</b>	<b>No. of sightings</b>	<b>No. of individuals</b>	<b>% group sightings</b>
1	169	169	21.39
2	87	174	11.01
3-10	375	2126	47.47
11 - 18	72	999	9.11
19 - 26	52	1179	6.58
27 -34	5	147	0.63
35-42	18	701	2.28
43-52	12	574	1.52
<b>Total</b>	<b>790</b>	<b>6069</b>	<b>100</b>

**Table 4: Group structure of wild pigs during winter season in Ranthambore National Park.**

<b>Group size</b>	<b>No. of sightings</b>	<b>No. of individuals</b>	<b>% group sightings</b>
1	65	65	17.76
2	38	76	10.38
3-10	177	1000	48.36
11-18	43	605	11.75
19-26	38	862	10.38
27-34	4	115	1.09
35-42	1	37	0.27
43-52	-	-	-
<b>Total</b>	<b>366</b>	<b>2760</b>	<b>100</b>

**Table 5: Group structure of wild pigs during monsoon season in Ranthambore National Park.**

<b>Group size</b>	<b>No. of sightings</b>	<b>No. of individuals</b>	<b>% group sightings</b>
1	25	25	22.12
2	7	14	6.19
3-10	49	264	43.36
11-18	3	37	2.65
19-26	-	-	-
27-34	1	32	0.88
35-42	16	624	14.16
43-52	12	574	10.62
<b>Total</b>	<b>113</b>	<b>1570</b>	<b>100</b>

**Table 6: Group structure of wild pigs during summer season in Ranthambore National Park.**

<b>Group size</b>	<b>No. of sightings</b>	<b>No. of individuals</b>	<b>% group sightings</b>
1	79	79	25.40
2	42	84	13.50
3-10	149	862	47.91
11-18	26	357	8.36
19-26	14	317	4.50
27-34	-	-	-
35-42	1	40	0.32
43-52	-	-	-
<b>Total</b>	<b>311</b>	<b>1739</b>	<b>100</b>

**Table 7: Percent sightings of wild pig in different habitat types in Ranthambore National Park.**

Habitat type	Sightings (%)
Agriculture	1.39
<i>Anogeissus pendula</i> mixed	9.87
<i>Anogeissus pendula</i> forest	49.37
<i>Anogeissus pendula</i> with shrub	3.92
Grassland	0.89
Scrub forest ( <i>Prosopis juliflora</i> )	2.66
Tropical dry deciduous ( <i>Acacia catechu</i> )	10
Tropical moist mixed	7.34
Water bodies	14.56

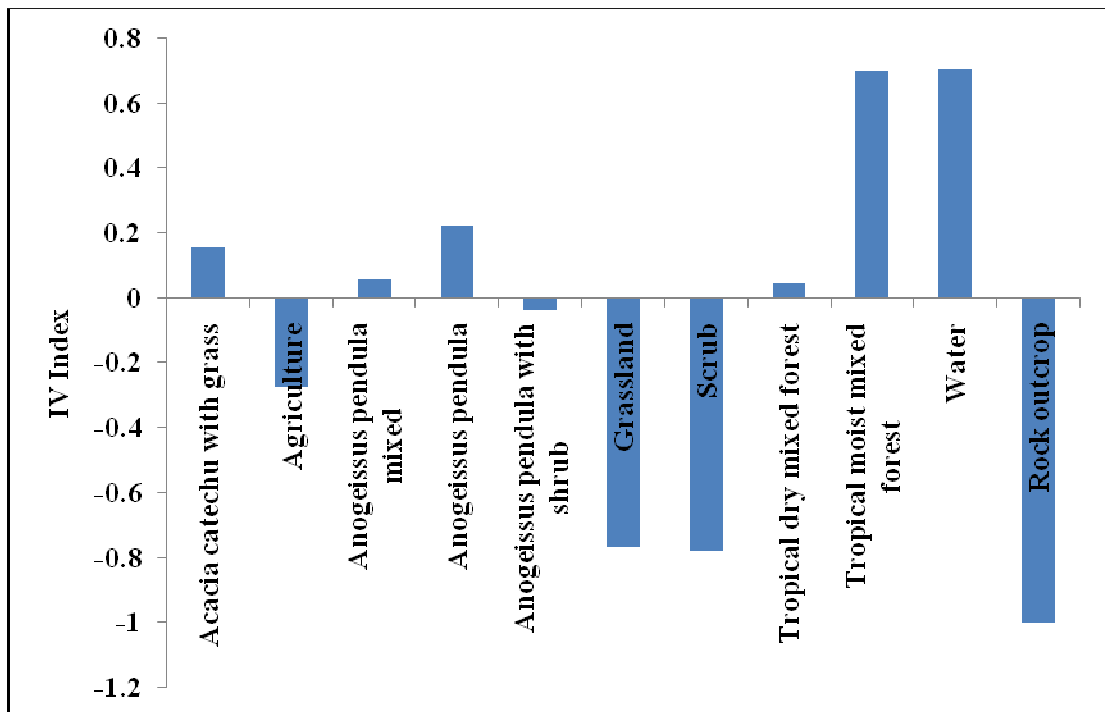
**Table 8: Percent sightings of wild pig in different habitat types and seasons in Ranthambore National Park.**

Habitat type	Winter (%)	Monsoon (%)	Summer (%)
Agriculture	1.09	5.31	0.32
<i>Anogeissus pendula</i> mixed	10.66	11.50	8.36
<i>Anogeissus pendula</i> forest	48.63	48.67	50.48
<i>Anogeissus pendula</i> with shrub	3.01	4.42	4.82
Grassland	1.09	1.77	0.32
Tropical dry mixed	0	26.55	15.76
Tropical moist mixed	13.93	0.88	2.25
Scrub forest ( <i>Prosopis juliflora</i> )	3.55	0.88	2.25
Water bodies	18.03	0	15.7

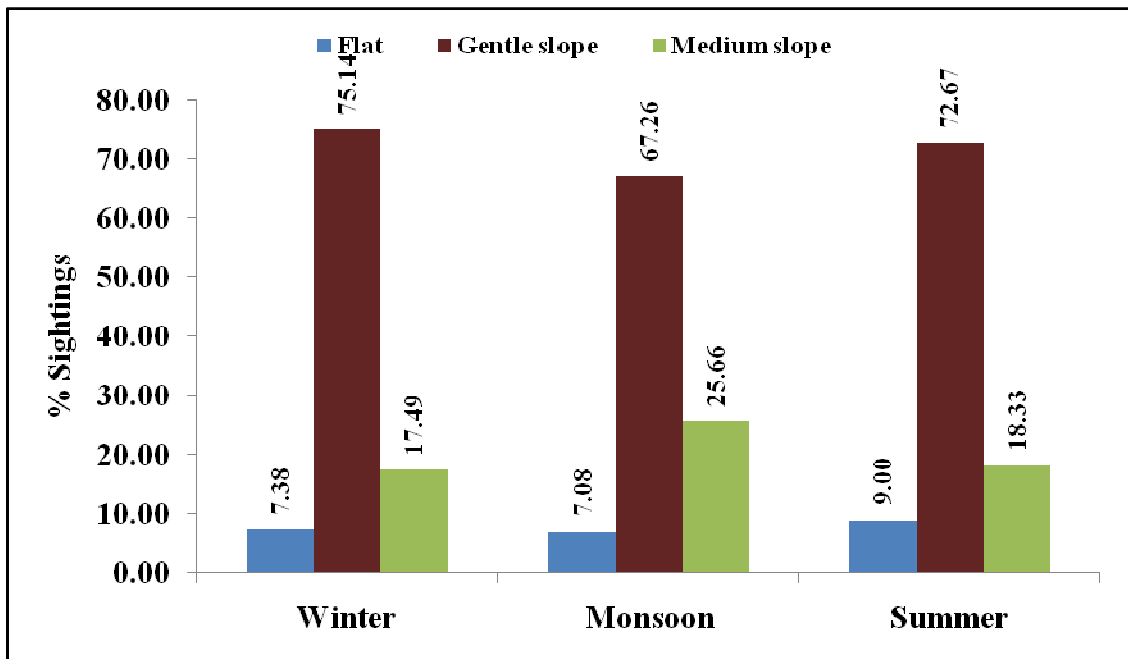
**Table 9: Percent diggings and faecal droppings of wild pigs in different habitats in Ranthambore National Park.**

<b>Habitat type</b>	<b>Diggings (%)</b>	<b>Faecal matter (%)</b>
<i>Acacia catechu</i> with grasses	0.51	1.10
Agriculture	2.56	4.39
<i>Anogeissus pendula</i> mixed	2.56	2.19
<i>Anogeissus pendula</i> forest	51.15	49.78
<i>Anogeissus pendula</i> with shrub	17.14	14.47
Grassland	0.77	1.54
Scrub forest	2.05	3.07
Tropical dry mixed	15.09	16.67
Tropical moist mixed	1.53	3.51
Water bodies	6.65	3.29

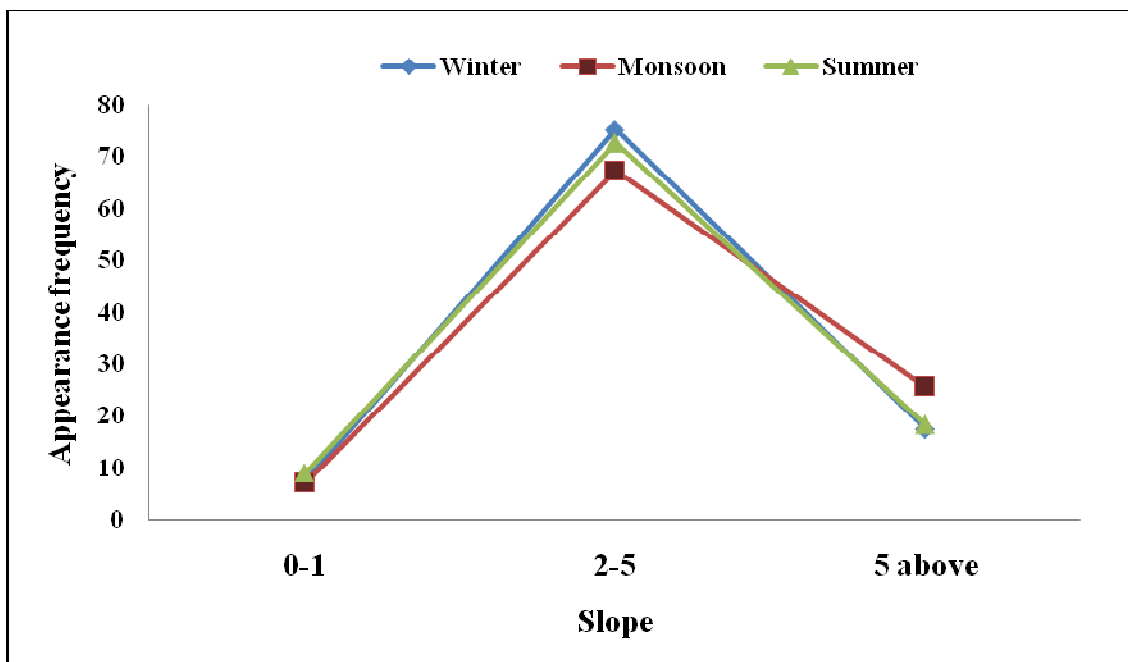
**Figure 2: Ivlev's index of habitat preference by wild pigs in Ranthambore National Park on the basis of direct and indirect evidences.**



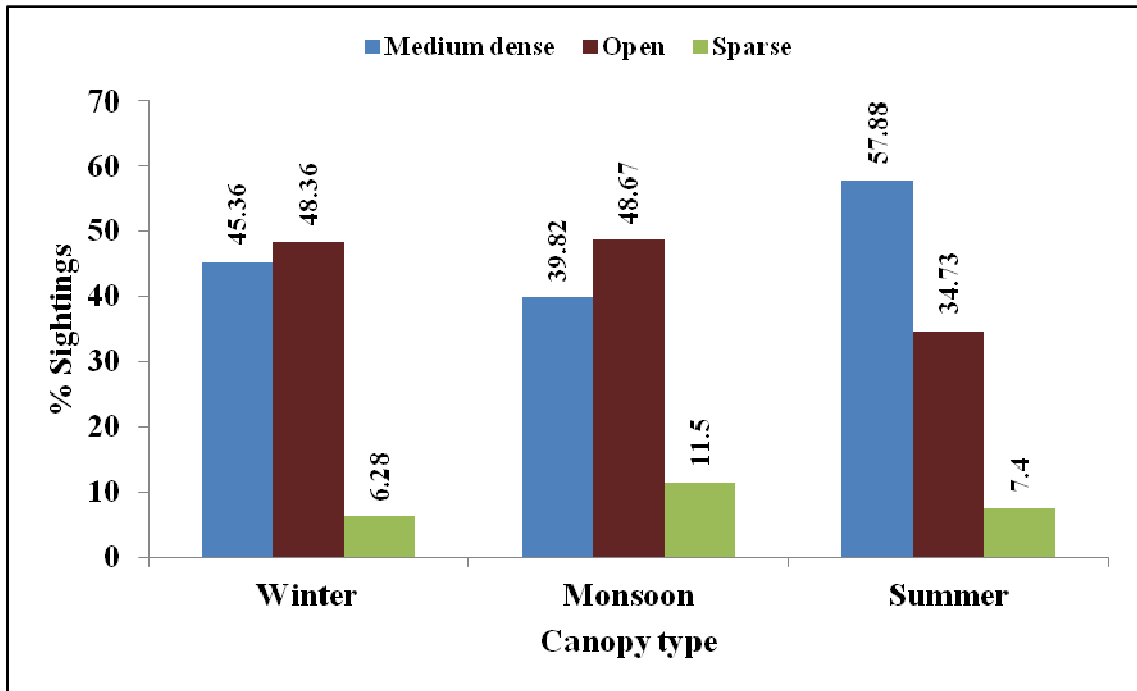
**Figure 3: Percent sightings of wild pigs in different terrain types and seasons in Ranthambore National Park.**



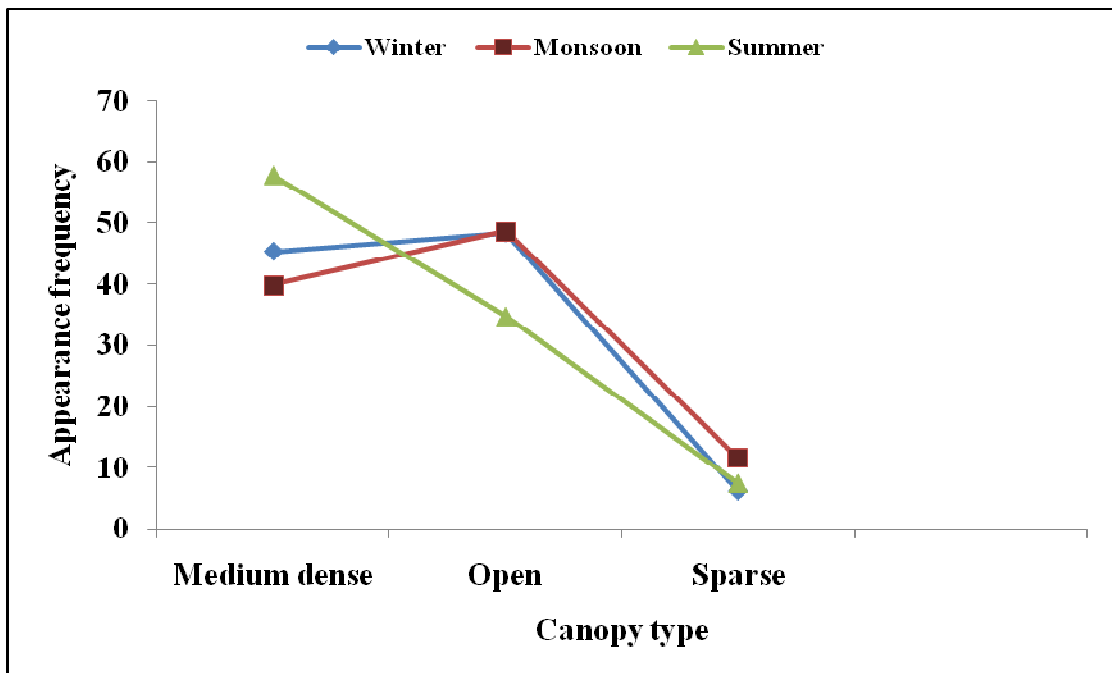
**Figure 4: Seasonal habitat distribution of wild pigs in relation to terrain in Ranthambore National Park.**



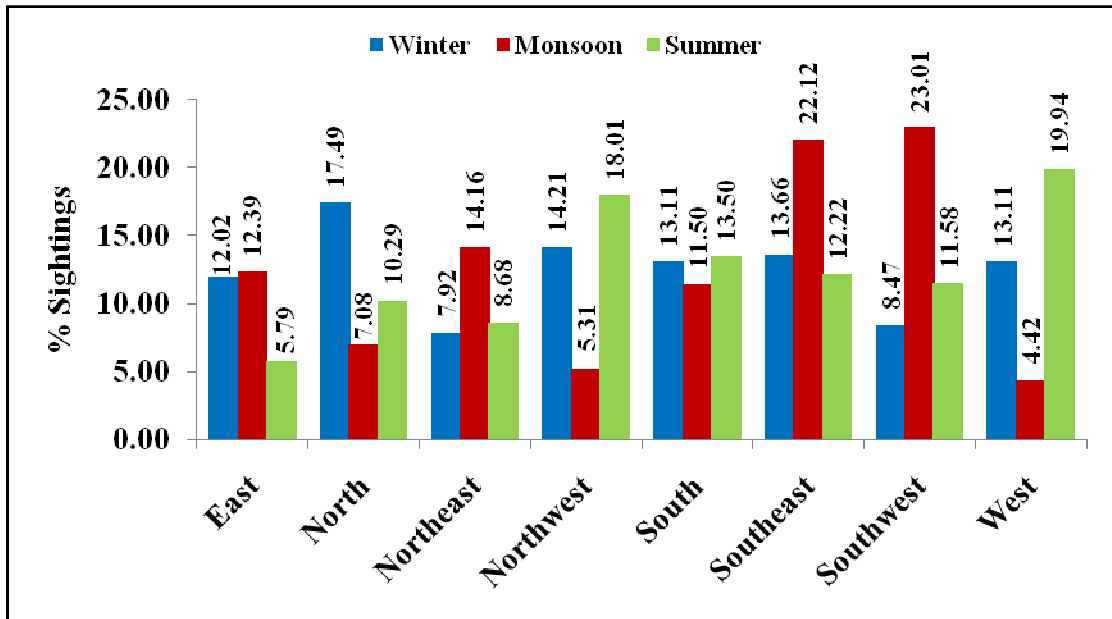
**Figure 5: Percent sightings of wild pigs in different canopy types and seasons in Ranthambore National Park.**



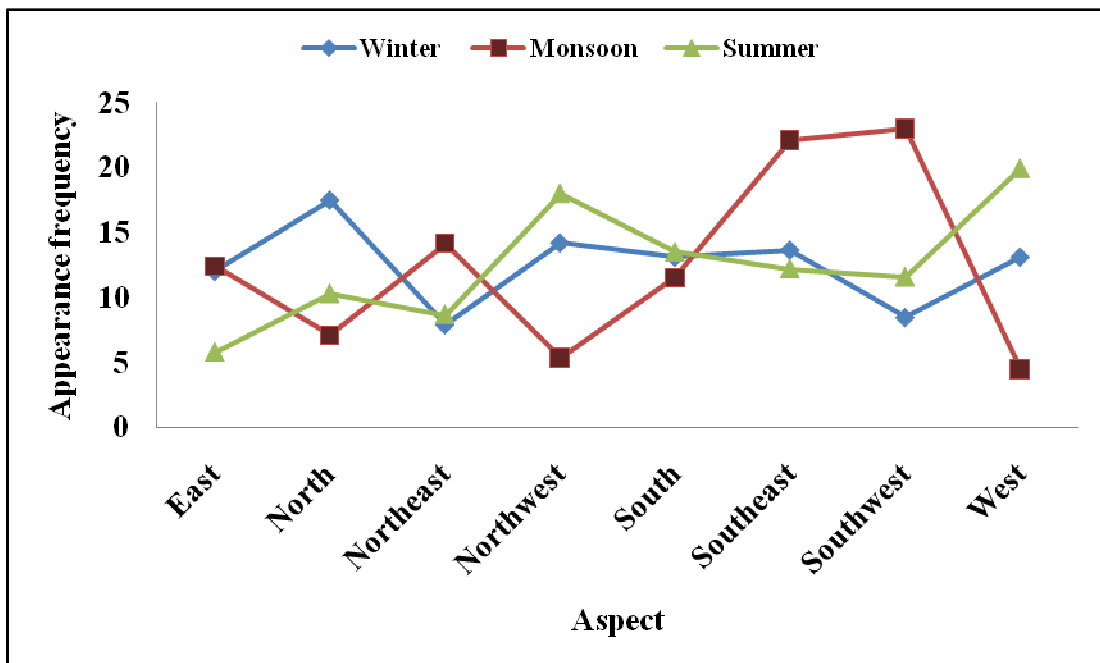
**Figure 6: Seasonal habitat distribution of wild pigs in relation to canopy cover in Ranthambore National Park.**



**Figure 7: Percent sightings of wild pigs in different habitat aspects in different seasons in Ranthambore National Park.**



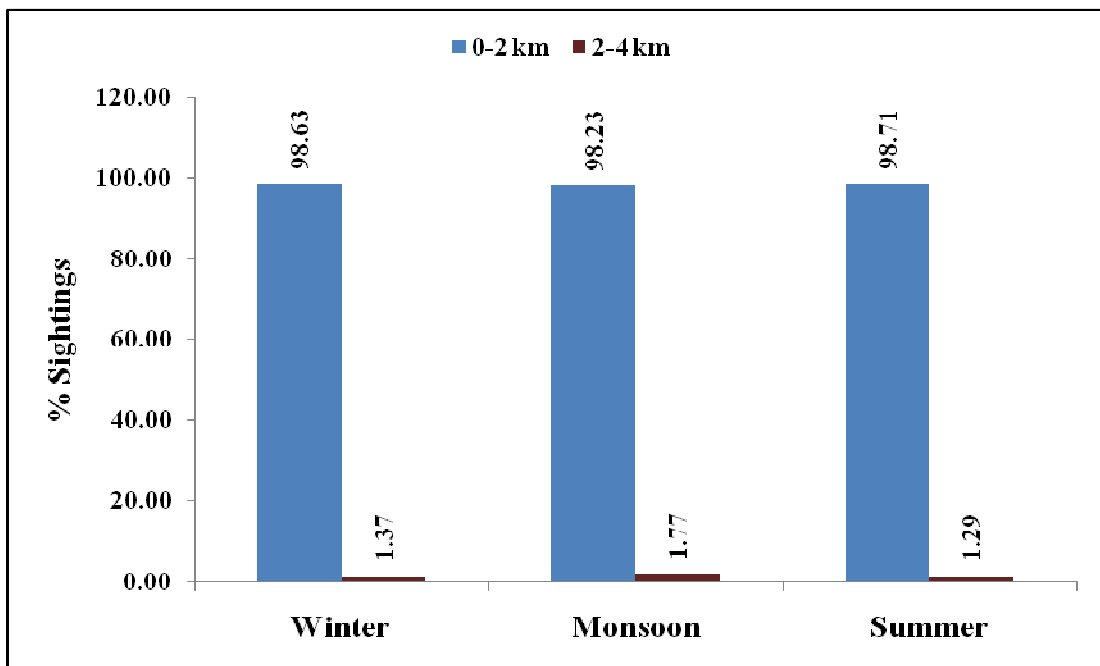
**Figure 8: Seasonal habitat distribution of wild pigs in relation to aspects in Ranthambore National Park.**



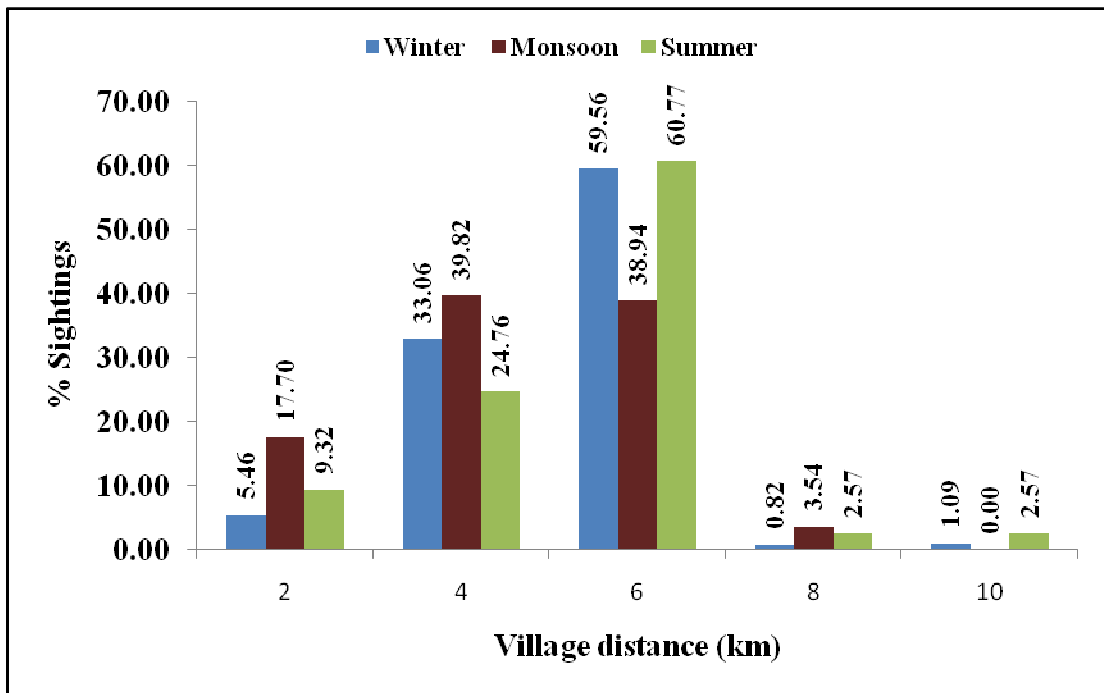
**Figure 9: Percent sightings of wild pigs at variable road distance in different seasons in Ranthambore National Park.**



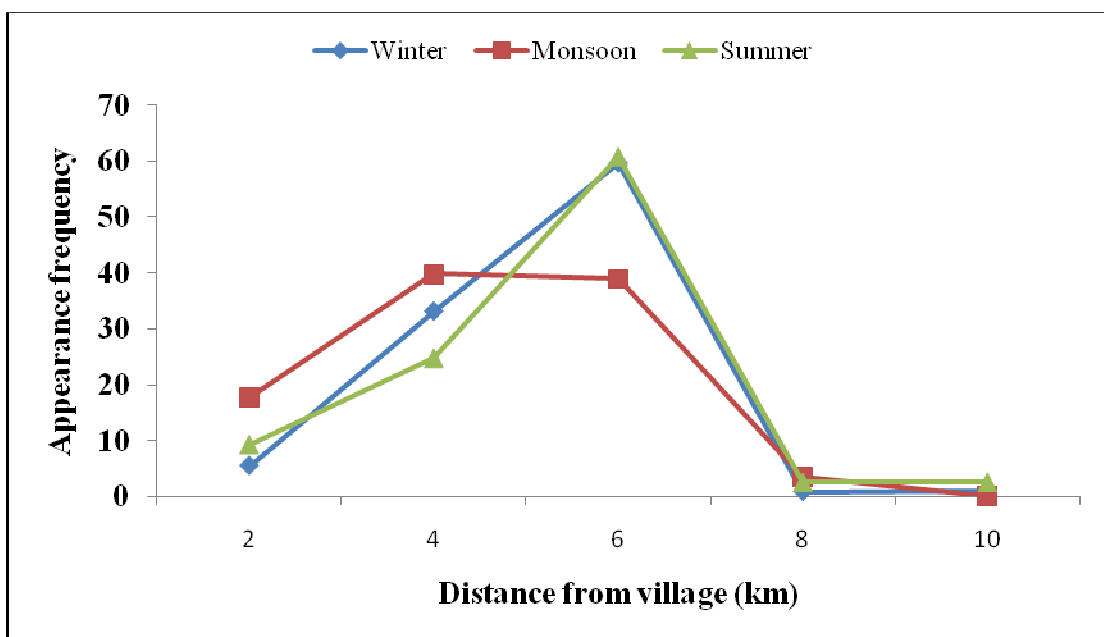
**Figure 10: Percent sightings of wild pigs at variable distance from water body in different seasons in Ranthambore National Park.**



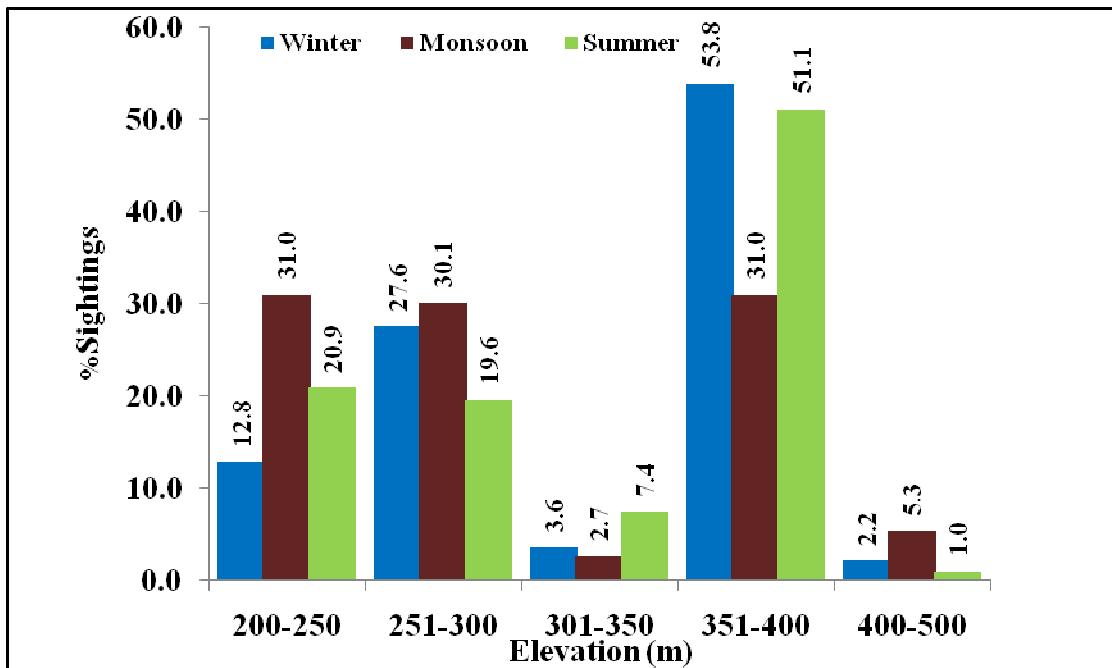
**Figure 11: Percent sightings of wild pigs at variable distance from village in different seasons in Ranthambore National Park.**



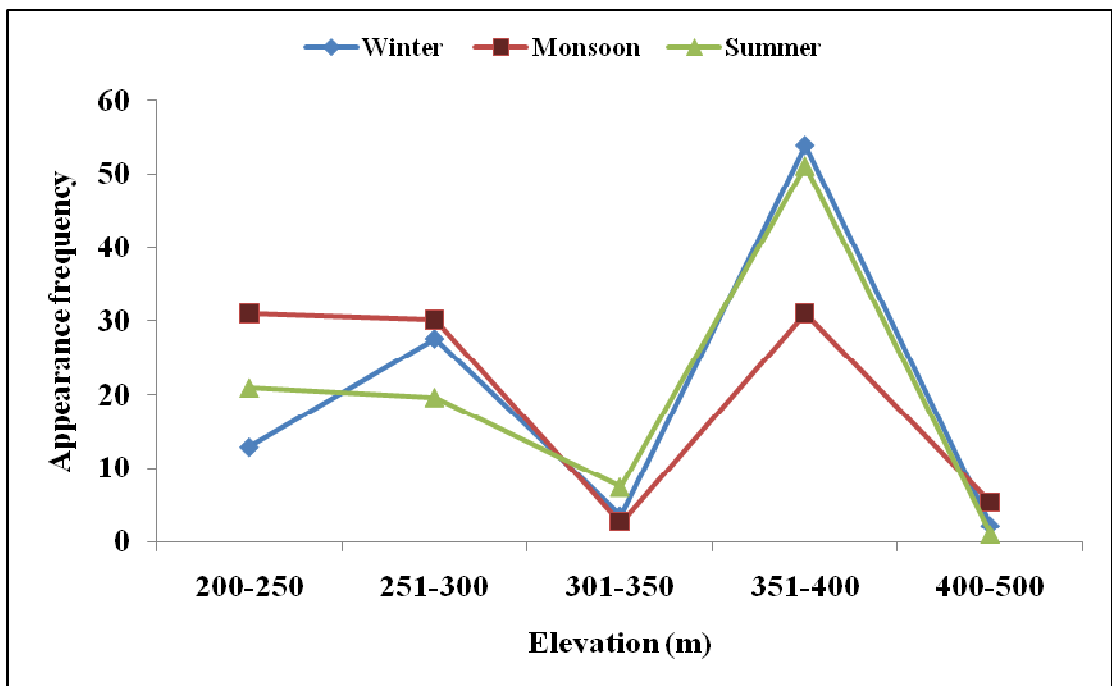
**Figure 12: Seasonal habitat distribution of wild pigs in relation to distance from village in Ranthambore National Park.**



**Figure 13: Percent sightings of wild pigs at different elevations in different seasons in Ranthambore National Park.**



**Figure 14: Seasonal habitat distribution of wild pigs in relation to different elevations in Ranthambore National Park.**



**Annexure I**

**Vegetation Composition: Trees**

**Date:** .....  
**Range/Locality :** .....  
**Transect No.:** .....  
**Circular Plot : r = 10 m**

**Compartment No.**.....  
**Bearing** .....  
**GPS Location** .....

**Altitude:** .....  
**Fire Incid.:** .....  
**Start** ..... h      **End:** ..... h

Sample Point	Tree species	Phenology	GBH	No. of trees felled	No. of trees lopped	Stand height (m)	Canopy cover (%)	Habitat
1								
2								
3								
4								
5								

**Topography: Hill/Hillock - H; Undulating - UT; Plateau - P; Valley - V; Ravine - Ra.**

**Soil: Rocky - R (            ); Sandy-Sn (            ); Gravel - G (            ); Loamy - L (            ); Clay - C (            ).**

**Annexure II**

**Vegetation Composition: Shrub**

**Date:** .....

**Transect No.:** .....

**Circular Plot: r = 5 m**

<b>Sample Point</b>	<b>Shrub species</b>	<b>Shrub height (m)</b>	<b>Dominant shrubs</b>	<b>Shrub cover (%)</b>
<b>1</b>				
<b>2</b>				
<b>3</b>				
<b>4</b>				
<b>5</b>				

**Annexure III**

**Vegetation Composition: Herb**

**Date:** .....

**Transect No:** .....

**Circular Plot: r = 1 m**

<b>Sample Point</b>	<b>Herb/grass species</b>	<b>Herb/grass height (cm)</b>	<b>Herb/grass cover (%)</b>
<b>1</b>			
<b>2</b>			
<b>3</b>			
<b>4</b>			
<b>5</b>			

**Annexure IV**

**Disturbance, Wildlife Evidence & Regeneration**

Date: .....

Transect No.: .....

**Circular Plot: r = 10 m**

Sample Point No		1	2	3	4	5
Disturbance	Distance from nearest habitation (m)					
	Disturbance from nearest road					
Cattle grazing	Dung					
	Hoof marks					
Wildlife evidences	Faecal matter					
	Pugmarks/Hoof marks					
	Digging					
	Others					
Nearest water source (m)						
Regeneration						

Disturbance from nearest road: Nil = A; Medium = B; High = C  
 Hoof marks: High = H; Medium = M; Low = L  
 Dung: Present = + Absent = -  
 Regeneration (Dominant tree): Nil = 0 Good = + Very Good = ++

**Annexure V**

**Distribution and Density by Direct Sighting**

**Date:** .....

**Transect No. :** .....

**Location on Map**

**Time: Start..... End .....**

Compt./ Locality/ GPS location	Time (h)	Activity	Group size	Habitat	Tree/Shrub/Grass				Biotic pressure	Sighting angle ( )	Angular singhting distance (m)	Perpend. Sighting distance (m)
					Species	Cover (%)	Terrain	Soil				

**Activity:** Feeding - F; Sleeping - S; Moving - M; Suckling - SK; Resting - R; Rooting - RO; Wallowing - W; Any Other - Specify.

**Habitat:** Dry Mixed Deciduous - MD; Anogeissus pendula forest - AF; Dry Deciduous Scrub - DS; A. pendula Scrub - AS; Dry Grassland - DGL; Butea forest - BF; Zizyphus Scrub - ZS.

**Terrain:** Flat - F; Gentle Slope - GS; Steep Slope - SS; Undulating - UD

**Soil Type:** Loam-L; Sandy-Sn; Gravel-G; Rockey-R

**Biotic Press.:** Fire-F; Lopping-L; Grazing-G.



**Plate 1: Wild pigs feeding on *Zizyphus* fruits in Tropical moist mixed forest.**



**Plate 2: Wild pigs moving in *Anogeissus pendula* forest during summer.**



**Plate 3: Wild pigs feeding in *Anogeissus pendula* mixed forest in Kundal.**



**Plate 4: Wild pigs moving in grassland near Malik talab.**



**Plate 5: Wild pigs feeding in *Anogeissus pendula* mixed forest in Kundal.**



**Plate 6: Group of wild pigs feeding on aquatic plants in water body in Rajbagh.**



**Plate 7: Wild pigs feeding on aquatic plants in water body in Rajbagh.**



**Plate 8: Group of wild pigs crossing a nallah or water body.**



**Plate 9: Wild pigs sounder near water body in midst of grassland in Kundal.**



**Plate 10: Wild pigs with piglets in *Anogeissus pendula* forest near Malik talab.**



**Plate 11: Wild pigs with piglets near water body in Rajbagh.**



**Plate 12: Wild pigs in *Anogeissus pendula* forest in gentle slope.**



**Plate 13: Wild pigs moving and feeding in Scrub forest near Mordungari.**



**Plate 14: Wild pigs resting in Tropical moist mixed forest in Guda.**



**Plate 15: Wild pigs resting in Tropical dry mixed forest during day time near Kala taal in Guda.**



**Plate 16: Digging of wild pigs in Scrub forest.**



**Plate 17: Wild pigs digging and feeding on tubers in Rajbagh.**



**Plate 18: Faecal matter of wild pigs.**



**Plate 19: *Anogeissus pendula* forest frequently used by wild pigs.**



## Chapter 5

### **To develop and evaluate capture and handling methods for wild pigs.**

#### **5.1 Introduction**

Physical and chemical restraint techniques for wild animals are essentially required for research and management purpose. Safe and effective traps and restraint techniques are important because of the need to capture and handle animals with a minimum of stress and injury (Peck and Simmonds, 1995 and Thompson, 1995). Although it may never be possible to eliminate capture and handling stress in wildlife studies, efforts should be made to minimize such factors when the goal is to understand the natural dynamics of wildlife populations (Laurenson and Caro, 1994). Species-specific capture methods and drugs for immobilization of animals have been developed, but they need to be tested and standardized on different species in different situations. Live-capture of free-ranging animals by mechanical methods necessitates the use of suitable devices which will efficiently catch and hold the animal unharmed. Unlike kill-trapping, live trapping provides live animals for direct examination; tagging in mark-recapture studies for determination of abundance, movement, and distribution; sampling, such as the collection of parasites or blood; and studies on growth of individuals (Diong, 1982). Capture equipments are used in the form of boxes, cages, nets, jaws, snares, pipes or guns, with different names and design modifications.

The feral pig (*Sus scrofa*) is a pest of agricultural production and the environment in many parts of world, including Australia, New Zealand and the United States (Tisdell, 1982). Trapping is widely used means of capturing pigs to reduce damage, with a variety of trap designs having been developed and used (Waithman, 1982 and Allen, 1984). The trapping of feral pig also has significance in the event of contagious disease outbreaks where the sampling of a population becomes necessary for monitoring disease. Factors that influence trap success were examined by (Fox and Pelton, 1977) in the Great Smoky Mountains of Tennessee. They found that trap

success depend on location, season, age and trap design. Coblenz and Baber (1987) in Galapagos found traps to be more expensive method of feral pig control than snares, shooting and baiting. Trapping involves the initial offer of bait, usually grain, vegetables or animal carcasses, at likely trapping sites. Where bait is taken by pigs, traps are constructed and left open. Factors that influence bait uptake by feral pigs will determine the efficacy of poisoning and trapping programs for the control of pigs (Choquenot and Lukins, 1996).

Wild pigs are often trapped for ecological studies and eradication efforts (Baber and Coblenz, 1986; Schauss *et al.*, 1990; Sterner, 1990; Katahira *et al.*, 1993 and Hone, 1995). Trapping of feral pigs in Australia has long been used as a control measure and has been useful to capture animals for research and for the game meat export industry (Saunders *et al.*, 1993 and Caley, 1994). There are two main live trap designs that are useful for capturing feral pigs: panel and silo traps. Both types of trap are made of steel mesh and incorporate a one-way entrance. The selection of trap design will depend, in part, on the resources available for the project. Silo traps are cheaper to construct, but panel traps are often preferred, owing to their transportability (Saunders, 1988 and Caley, 1999). Successful trapping of feral pigs involves initial free-feeding at sites likely to have feral pig activity or near watering points. The most commonly accepted baits are fermented cereal grains or animal carcasses (Saunders, 1988 and Caley, 1999), but this varies with the availability of natural foods and the familiarity with the food source, for example, bananas can be used in north Queensland or wheat in grain-growing areas.

Use of animal carcasses is illegal in Queensland and should not be encouraged in other states because of the risk of disease transmission. Once bait is being consumed by feral pigs, bait trails up to 100 m long are used to lure feral pigs to a chosen trap site, with the largest proportion of the trail being placed at the trap site (Saunders, 1988 and Lukins, 1989). Traps are constructed and left open, and the bait trail is re-supplied to allow the feral pigs to become accustomed to the trap. After a fixed time period the trap is set; it must then be checked daily for the duration of the trapping period, as feral pigs are highly susceptible to heat stress (Dexter, 1995). Checking also enables non-target captures to be released, although doors can now be designed to be

reliably target-specific. Trapping usually continues until no new feral pigs have been trapped for some predetermined period, usually 5 to 7 nights. Trapping alone can be used as an index of abundance by comparing trapping events via catch per unit of trapping effort. It can also be used to mark feral pigs for capture-recapture studies or radio-telemetry studies to determine population density or areas of activity and home range.

Similarly the two primary trap designs that have been used elsewhere to capture these animals are box traps (Foreyt, 1979; Schauss, 1980 and Sterner, 1990) and panel traps (Hone, 1984 and Lukins, 1989). Box traps are constructed of either wood slats or fencing around a pipe or wood frame. Panel traps are square or rectangular traps made of prefabricated steel mesh panels wired together and held in place with steel fence posts. Wild pigs commonly travel in large groups composed of related females and their sub-adult offspring, adult males tend to be solitary (Ilse and Hellgren, 1995). A trap design that allows for the capture of multiple animal groups can help reduce costs of trapping (Waithman, 1982). Both panel and box traps are effective at capturing multiple wild pigs (Hone, 1984; Baber and Coblenz, 1986; Lukins, 1989 and Choquenot *et al.*, 1993), but panel traps tend to capture larger groups than box traps (Waithman, 1982). Although box traps may require little labor after initial assembly, they can be difficult to transport into remote areas with limited road access. Disassembled panel traps can be readily carried into remote areas, but require more labor for reassembly. Minimizing stress associated with capturing and handling animals is another consideration in trap design. Painful trapping and handling procedures can have adverse physiological consequences including weight loss, increased systemic concentrations of stress hormones, and capture myopathy (Boever, 1986; Kreeger *et al.*, 1990, 1991 and Kaufman and Kaufman, 1994). Safety and animal welfare considerations are especially important for wild pigs because they are aggressive when confined in traps and can injure themselves in attempts to escape.

Capturing, marking and transporting wild animals are sometimes difficult or even dangerous. For this reason, more and more special drugs are used to bring about a temporary immobilization of animals. These drugs can be applied from a distance in the form of intramuscular injections. It made imperative to discover an immobilizing

drug that would allow one person to safely handle a trapped wild pig and obtain the necessary biological data and, at the same time, reduce chances of injury to the pigs. Immobilization of wild pigs would facilitate the following activities: ear-tagging (Matschke, 1962) and ear-notching for identification, radio-collaring, examination for dentition patterns (Matschke, 1967) and for external parasites, measurements for growth studies and blood sampling for checks of chromosome numbers, hematologic values and blood parasitism.

Chemical restraint is a useful tool in field studies on ecology of medium to large mammals to avoid damages or injuries to both humans and animals during immobilization. Handling feral pigs (*Sus scrofa*) for research requires the intramuscular administration of an immobilizing agent that has a wide safety margin, is quick acting and restrains animals for a period sufficient for data collection. Failures in the chemical immobilization of wild boar and related species were never described, but the recourse to twofold drug injections (Sweitzer *et al.*, 1997a) or capture mortality were often reported (Zurowski and Sakowicz, 1965; Henry and Matschke, 1968; Matschke and Henry, 1969; Wood *et al.*, 1977; Gallagher *et al.*, 1985; Fournier *et al.*, 1995; Gabor *et al.*, 1997 and Sutherland-Smith *et al.*, 2004).

A variety of drugs has been tested on wild pigs in different countries. The main used drugs in wild pigs and peccaries are the dissociative anaesthetics alone, such as Ketamine (Lochmiller *et al.*, 1984; Gallagher *et al.*, 1985 and Hellgren *et al.*, 1985); the mixture of Tiletamine and Zolazepam (Fournier *et al.*, 1995), and the combination of dissociative drugs with alpha 2-adrenergic agonists, such as Xylazine (Baber and Coblenz, 1982; Allen, 1992; Gabor *et al.*, 1997; Isle and Hellgren, 1995; Sweitzer *et al.*, 1997a and Selmi *et al.*, 2003) and Medetomidine (Tast *et al.*, 2000 and Sutherland-Smith *et al.*, 2004). Generally, the application of different anaesthetic protocols results in similar benefits and problems, and the choice of protocol could be based on cost, human safety, tolerance to high dosage, presence of drug policy restriction etc. (Harthoorn, 1975 and Nielsen, 1996).

The outcome of the anaesthesia in wild animals was found to be strongly influenced by many environmental factors and capture methods applied (Nielsen, 1996 and

Sweitzer *et al.*, 1997b). Often, the interaction between animal and environmental factors results in a serious stress syndrome, as reported in wild pig (Fournier *et al.*, 1995 and Sweitzer *et al.*, 1997b), and could be an important cause of chemical restraint failure (Harthoorn, 1975; Murray, 1978 and Nielsen, 1996). Therefore, the knowledge of all the possible factors that influence wildlife anaesthesia outcome becomes an important step in the planning and managing of field work activities and for ensuring animal welfare. The use of immobilization drugs and doses varied with the species and time. Wild pigs are usually captured in early spring. Although wild pigs are sometimes chemically immobilized during summer but such captures are more difficult due to high ambient temperatures and increased dose requirements.

Wild pigs captured in both box and panel traps are usually physically restrained for processing, or temporarily restrained to administer hand injections of Ketamine hydrochloride and Xylazine hydrochloride to immobilize them for processing (Baber and Coblenz, 1982). Physically restraining pigs to hand inject this drug combination is necessary because the recommended immobilization dose of 15-20 mg/kg Ketamine HCl and 15-20 mg/kg Xylazine HCl requires a large total volume of drugs, which is difficult to administer using pole syringes or darts. Currently, the following standard dosages of Medetomidine (M) (Domitor®, Zalopine®) and Tiletamine-Zolazepam (TZ) (Zoletil®) are used for immobilization of free-ranging boars: sub-adults male (40 kg) 1.25 mg M + 62.5 mg TZ; adult females (2-3 years, 40-55 kg) 2.5 mg M + 125 mg TZ; large males (> 80 kg) 15 mg M + 750 mg TZ. A fixed M:TZ ratio is used so that doses can be split or combined.

Tiletamine-Zolazepam is the drug combination of choice for immobilization of wild pigs. Tiletamine-Zolazepam has a wide margin of safety and has no major cardiopulmonary or thermoregulatory side effects in wild pigs. The main disadvantage of this combination is extended recoveries. There is no reversal agent for Tiletamine, and the use of a Benzodiazepine antagonist like Flumazenil (Anexate®) for reversal of Zolazepam in animals immobilized with high doses of Tiletamine-Zolazepam is not recommended. However in combination with Medetomidine, the effective dose of Tiletamine-Zolazepam can be reduced, and Atipamezole can then be used to shorten the recoveries.

Wild pigs are also immobilized using a mixture of Tiletamine hydrochloride and Zolazepam hydrochloride (Zoletil 100®-Virbac) and Xylazine hydrochloride (Rompun®-Bayer) in the same amount (1:1 ratio); 1 ml of the final mixture contained 25 mg of Tiletamine, 25 mg of Zolazepam, and 50 mg of Xylazine. The reference dosage of 5 mg/kg (2.5 mg of Xylazine, 1.25 mg of Tiletamine, and 1.25 mg of Zolazepam) was set on the basis of a previous experience in the Presidential Estate of Castelporziano (Central Italy) on 84 wild boars, and it is similar to the dosage proposed by Gabor *et al.* (1997) for wild hog of 4.4 mg/kg. All the captured animals weighted greater than 35 kg, and the drugs were administered with a projectile - Dan-Inject® in the hind quarter. The dose of the anaesthetic mixture was calibrated and administered after visual estimation of the body weight; therefore, variations with respect to reference dosage were observed.

Recent emphasis on research reflecting concern for endangered populations has necessitated the development of more efficient and safer techniques for capturing wild pigs. In this chapter, details of developing and evaluating baiting procedure, capture technique by using box traps (panel traps) for wild pigs and also capturing them in free ranging situation and handling of wild pigs are presented.

## **5.2 Methods**

For capturing wild pigs, planning of capture procedures, designing and fabrication of traps, trapping protocol, selection of capture sites, setting of panel traps, bait preparation and pre-baiting to habituate wild pigs were essentially required and undertaken. To make trapping effective and causing less injury to animals, modification of traps was also done. Simultaneously, chemical restraint technique, drugs and dosages were also established.

### 5.2.1 Trap Design

Several trap designs exist, differing mainly in their gate construction. These include the silo trap, the drop-gate trap, the panel trap and the box trap. All are basically an enclosed area with a one-way gate. Choice of trap design will depend upon habitat, materials available and accessibility to site. For capturing and radio-collaring of wild pigs, trap designs used in this study were modified from the designs of Waithman, 1982 and Allen, 1984. Panel traps were preferred because of their portability and ease of construction. Each trap could be dismantled into individual panels and carried to reasonable distance from a vehicle to the trap site, a frequent requirement in inaccessible areas. It is best to use steel mesh with a small grid size e.g. 50 mm x 75 mm or 50 mm x 100 mm. A grid larger than this will damage the feral pigs' snouts if they charge the mesh. Panel traps are square traps made up of angle iron and wire mesh.

Disassembled panel traps can be easily carried to different areas after using it in one place. Panel traps were assembled in the field using different size sections of welded steel mesh panels 1.5 m high with a mesh size of 10 cm x 10 cm. Different trap designs were tried in early stages of study. By observing pigs at these traps on a number of occasions it was observed that the design did not have a marked effect on success rate providing that basic standards were met (i.e. door width, trap size and gate movement). Generally the traps rely on proper functioning of the door. This is a key element. The front or gate panel was tilted inwards slightly to ensure that the gate closed into its frame. Initially we used a simple square design (2.4 m x 2.4 m) to capture pig. However, during trapping pigs captured suffered injuries ranging from lacerations and abrasions when they charged the steel mesh panels during escape attempts.

To reduce trap-related injuries we developed and used the modified panel trap at all other study sites. The design of the modified panel trap included we put padding of mattress inside the trap in the lower half and covered these mattresses with the gunny bags and put the squeeze panel inside the trap. The traps had been placed in the strategic locations in the field areas and bait comprising of maize, groundnut, gram and

molasses was being provided on daily basis. Bait was increasingly attracting the wild pigs and consumed by them.

### **5.2.2 Fabrication of panel trap**

For capturing wild and feral pigs, standard methods used world over included the use of box traps and panel traps. Several trap designs exist, differing mainly in their gate construction for capturing wild pigs and feral hogs. These include the silo trap, drop-gate trap, panel trap and box trap. All are basically an enclosed area with a one-way gate. Choice of trap design will depend upon habitats, materials available and accessibility to site.

For capturing and radio collaring of wild pigs in Ranthambore National Park, the trap designs of Waithman (1982) and Allen (1984) were used. Panel traps were preferred because of their portability and ease of construction. Each trap could be dismantled into individual panels and carried to reasonable distance from a vehicle to the trap site, a frequent requirement in inaccessible areas. Panel traps are square traps made up of angle iron and wire mesh.

Panel traps were fabricated by using steel mesh panels of 1.5 m high and 2.5 m breadth with a mesh size of 10 cm x 10 cm. The steel mesh with a small grid size of 50 x 75 mm or 50 x 100 mm was used for fabrication. A grid of larger size was not used for pigs as that could damage their snouts by dashing against mesh. This panel trap was found very effective in capturing wild pigs. But there were several associated problems; pigs captured suffered injuries, lacerations and abrasions, as they repeatedly dashed against panels, especially when they were approached closely for darting.

### 5.2.3 Trapping protocol

In the study area, the pre-baited sites that showed evidence of pig rooting, trails, wallows, and fecal matter, we increasingly used a mixture of fermented corn, gram, groundnuts and jaggery for feeding wild pigs. When pig activity was detected and bait was consumed on 1-2 successive days, a trap was established. We initially set up traps without the gate panel to familiarize pigs consuming bait in a semi enclosed area. If activity continued, the trap was completed and baited until pigs started feeding inside the trap, after which the trap was set for capture.

### 5.2.4 Selection of capture sites

Two factors known to influence success in wild pig trapping are selection of sites with recent pig activity and pre-baiting of both the trap site and trap itself (Choquenot *et al.*, 1993 and Saunders *et al.*, 1993). So we conducted surveys of wild pig areas in Sawai Madhopur, Khandar and Kundera ranges, and selected Rajbag, Guda, Kundal, Lahpur, Lakardah, Malik anicut and Patwa Bawari and selected specific areas for capturing of these animals. Wild pigs could be seen in *Anogeissus pendula* mix forest, *Anogeissus pendula* forest, grassland opening in *Anogeissus pendula* forest, Water body and Scrub forest in above areas (**Plate 1 to 6**). At each place, population status and movement pattern of wild pigs were established. Wild pigs were regularly sighted in these areas, and also their fresh scats and digging signs were observed. Based on this information, initially we selected 8-11 baiting sites close to water points. Later depending on the visits and congregation of wild pigs at these sites and consumption of bait by them, only 4-5 sites highly used by wild pigs were finally selected and baiting continued.

### 5.2.5 Setting of panel trap

Two panel traps were set at the strategic locations in the selected sites, Rajbag and Guda. These two sites were selected for setting the traps in such a way that baiting and

capture of pigs could be done in the open areas without much vegetation. The panels were assembled in the field area by aligning the panels and joining them with nuts and bolts in Rajbag and Guda (**Plate 7 to 9 and 13, 14**). The gate was provided in the front panel, and it was slightly tilted inside to ensure that the gate could fall back into the angle-iron frame on triggering (**Plate 10**). For trapping, a rope was tied with the door and taken over the pulley to a distance place in a hide where a person was present to pull it and close the door.

### **5.2.6 Bait preparation**

Presence of bait in trapping devices explains part of the variability in trap response. While certain baits elicit higher trap response than others: failure of capture may actually be explained by the ineffectiveness of the bait. In general, bait should function to attract the animal's attention and induce it into the baited trap. Baiting was done by concentrating fairly generous amounts of bait at the trigger mechanism and outside the trap. A bait line was created by scattering the bait from the trigger point to outside the trap. The bait was scored as unattractive if no animal was caught in the trap even though activity was observed within this area from the time the trap was baited to the time it was inspected. In addition, the effectiveness of each bait material should be evaluated by observing the length of time the food item was good as bait. Baits differed in their attractiveness to pigs visiting a trap site. Bait preferences can vary from area to area, with wild pigs more attracted to bait with a strong smell.

Baits can include grain, fermented wheat, oats and barley soaked in water in addition to molasses, commercial pig or poultry pellets, vegetables, fruit, meat or carcasses. Bait quantity of 10-20 kg may be required each time when the trap is set. Some people add meat meal to the grain before fermentation; this is illegal and makes a strong smell. The meat can be placed in plastic pipes with air holes drilled in them and the pipes tied to the trap mesh. The smell should be very strong and lasts a long time, as the meat cannot be consumed. Visiting pigs showed no interest in carrion, as was frequently evidenced by trails that stopped short or went past the entrances of such traps.

In Ranthambore National Park, we used the fermented bait comprised of maize, groundnut, gram and molasses. This bait increasingly attracted the wild pigs and consumed by them. For making bait increasingly effective, it was properly fermented so that it greatly smelled from distance. For this purpose, we soaked maize and gram in water in a big container and added yeast to it and closed its mouth with lid, then kept this container for three- four days for fermentation.

### **5.2.7 Pre-baiting**

Before trapping, wild pigs were offered bait repeatedly at selected sites in the study area. Free feeding was continued for a number of days. Pre-baiting was started at each site 15-20 days prior to trapping of wild pigs. We started placing the bait, preferred food items of wild pig, at each site in the morning time every day.

### **5.2.8 Habituation of wild pigs**

The most commonly observed trap behavior was trap-habituation. We started habituating the wild pigs by baiting with fermented gram, maize, jaggery and groundnuts at the selected sites (**Plate 11 and 12**). When they got used to the sites, then after a week or so the panel traps were set in these sites. Initially we placed the bait in front of door outside the trap. When the animals got habituated to the bait and started taking it, we started placing more and more bait inside as well as outside the trap. After few days of baiting, wild pigs started coming nearer to the traps and waiting for the bait. **Plate 15** shows wild pigs in front of panel trap attracted to feed on bait. **Plate 17** shows wild pigs entering in to panel trap to feed on bait at Rajbag. **Plate 18 and 19** show group of wild pigs inside the panel trap feeding on bait at Rajbag.

As and when, we used to arrive in the trapping sites; they used to come running, making different sounds, to feed on the bait. Initially they were hesitant to go inside

the trap, but later they started entering inside more and more. **Plate 16** shows wild pig coming out of panel trap after feeding on bait.

### **5.3 Results**

To develop capture techniques for wild pigs, capture trials using panel traps and in free ranging situation were done in Rajbag, Guda, Kundal, Patwa bawari and Malik talab areas. While carrying out capture operation, observations on behavior of pigs to traps and trap shyness etc. were recorded.

#### **5.3.1 Capturing wild pigs**

The panel traps were set in different places, and then the bait comprising of fermented maize, groundnut, gram and molasses was provided inside and outside the traps to attract wild pigs. The fermented bait was increasingly attracting the wild pigs and in such a way, wild pigs were slowly habituated to visit these traps. One of the groups having two sows and five piglets at Rajbag got so much habituated that they often used to arrive and wait at the baiting site (**Plate 15**). Piglets were not scared of going inside the trap, but mothers were cautious to enter inside the trap. As and when they entered inside the trap, they were quickly coming out from inside. At the time of habituation, the door was kept open for few days. These animals got completely habituated to the bait and started increasingly feeding on it from outside and inside the trap. Two to three groups of wild pigs were regularly visiting the trap to feed on the bait. In Guda, one big group comprising of more than 30 wild pigs used to remain near around the trap to feed on the bait material. **Plate 20** shows a group of wild pigs feeding and resting inside the panel trap at Guda. Following this, wild pigs were captured successfully in the trap at both the places.

During 2007-2008, wild pigs were captured in the panel trap more efficiently. By using the panel traps, a total of 153 wild pigs of varying age classes ranging from <5 kg to 80 kg were captured without a single capture-related mortality in Rajbag and

Guda (**Table 1 and 2**). Out of 153 animals, 47 and 106 wild pigs were trapped in the panel traps at Rajbag and Guda respectively (**Plate 3**). Out of 47 wild pigs captured in panel trap at Rajbag, 19 individuals suffered injuries to some extent. Whereas only 12 individuals suffered minor injuries out of 106 wild pigs captured in the modified panel trap at Guda. Wild pigs suffered mainly snout injuries in both the places.

When wild pigs were found to enter inside the trap and started feeding on the bait, the gate was closed by releasing the rope and the animals got trapped (**Plate 21**). Many a times even after capture, the animals kept on feeding. But at the time of approaching the trap in a vehicle, the animals used to agitate a lot and repeatedly dashed against the panels of the trap and as a result, some injuries were caused to these animals. **Plate 22 and 23** show wild pigs immobilized using dart at Rajbag. While darting also, the trapped pigs started hitting each other, and even in two to three occasions, there were injuries to these animals, especially to females or younger ones. Once the captured female started chewing legs, snouts and ears of the sub-adult male and also kept on hitting him. So in order to save the male, the trapped animals were released (**Plate 24**). In another case, when a trapped male was approached for darting, it also started agitating and started hitting against the panels of the trap and injured itself. In Rajbag, one trapped male tried jumping over the panel again and again, and finally he escaped by jumping the five feet high panel and ran away. To avoid this type behaviour, the open top of the trap was partially closed by using rope mesh. By using this trapping technique, although wild pigs were successfully captured, but the animals were susceptible to injuries.

### **5.3.2 Behaviour of pigs to traps**

The behavioural responses of wild pigs to the trap type were recorded by making direct observations and indirect signs of the animals such as tracks and partially consumed bait inside and outside the trap. Track signs and remnant bait at trap sites, gave useful clues on the responses of wild pigs to baits and capture traps. Panel trap with the bait provided was found very effective in orienting behaviour of wild pigs for their capture.

### **5.3.3 Trap shyness**

Initially wild pigs showed lot of alertness and caution in approaching and entering the trap at Rajbag and Guda areas. Wary animals left clear and distinct tracks outside the trap entrance and inside the front end of the trap. Baits outside the trap were usually eaten; baits along the bait trail leading to the entrance were also consumed. But in almost every case, they were hesitant to go inside the trap, this trap wariness was found to be caused by the gate, the enclosed area and triggering device. This behaviour was frequently observed in traps with a drop or fall door mode of capture, but the wary behaviour was reduced by using trigger rope, and it was found to be effective.

### **5.3.4 Modification of trap design**

To avoid or reduce injuries to wild pigs, design of the panel trap was slightly modified. Cushioning or padding of mattress covered with the gunny bags were provided on the lower half of the panels from inside (**Plate 25**). This also enabled to obstruct the visibility from inside to outside (**Plate 26**). While capturing, wild pigs could not make out our presence outside, thus they were not scared and not much dashing against the panels. One smaller compartment was created by partitioning the trap having a transit door in between and also added a squeeze device inside the panel trap at Guda. To avoid injuries to animals, padding of mattress was provided inside the trap in the lower half and covered the mattress with the gunny bags.

### 5.3.5 Immobilization of wild pigs

A variety of drugs has been tested on wild pigs in different countries (**Table 6**). Combination of Ketamine hydrochloride and Xylazine hydrochloride, Telazol and Xylazine hydrochloride was mainly used for immobilization of wild and feral pigs. Reversine was mainly used as antidote.

### 5.3.6 Inside panel trap

In Ranthambore National Park, the wild pigs captured in panel traps were immobilized using combination of Ketamine hydrochloride and Xylazine hydrochloride initially (**Table 1 and 2**). In Rajbag, 5 males and 8 females were darted using combination of Ketamine hydrochloride and Xylazine hydrochloride. In Guda, 3 males and 8 females were darted using the above drugs. Depending on sex and size of individuals, different dosages of Ketamine hydrochloride and Xylazine hydrochloride were used as shown in the tables. **Plate 27 and 28** show preparation of dart for immobilization of wild pig at Rajbag.

The dosage of Ketamine hydrochloride and Xylazine hydrochloride used in Rajbag varied from 150 to 350 mg and 100 to 250 mg respectively. Whereas in Guda, dosage of Ketamine hydrochloride and Xylazine hydrochloride varied from 150 to 400 mg and 100 to 250 mg respectively. Except two individuals, there was incomplete sedation of 11 wild pigs captured in Rajbag. Only one animal could be collared in Rajbag but its collar fall off in next few days. Other individual could not be collared because of early arousal. Likewise except one individual, there was incomplete sedation of 10 wild pigs captured in Guda. Because of incomplete sedation in most individuals, collaring could not be done in Guda. Even the male completely sedated could not be fitted with collar due to early arousal (**Annexure I**).

### 5.3.7 Efficacy of panel trap

During 2007-2008, wild pigs were captured in the modified panel traps more efficiently. By using the modified panel traps, we captured 153 wild pigs of varying size ranging from <5 kg to 80 kg without a single capture-related mortality in Rajbag and Guda (**Table 3**). Out of 153 animals, 47 and 106 wild pigs were trapped using panel traps in Rajbag and Guda respectively.

In 13 attempts in Rajbag, the mean number of wild pigs captured was 3.6. Whereas in 11 attempts in Guda, the mean number of wild pigs captured was 9.6. So the mean number of captured pigs was less in Rajbag ( $3.6 \pm 1.7$ ) than in Guda ( $9.6 \pm 5.0$ ). In total 24 trap efforts in both the places, the efficacy of the traps was 6.6. In Rajbag, the trap efficacy was 3.6, whereas it was 9.6 in Guda. Some individuals among 153 animals were recaptured. Although we detected the difference in the efficacy of traps but in both the places, the trap efficacy was considerable high in capturing varying groups of wild pigs. This could be due to the smaller group size in Rajbag and larger group size in Guda region. The fall snap or push type of gate fixed in panel traps was easier to trigger and thus found very effective.

Though the panel trap was found effective, wild pigs occasionally escaped due to negligence. Captured pigs escaped on few occasions; three times through the door, one time jumping over the top of traps before roofing of nylon ropes was provided, and once by breaking through the wire mesh, twice while handling of wild pig when they were not fully sedated (**Table 1 and 2**).

### 5.3.8 Free ranging situation

For capturing wild pigs in free ranging condition, wild pigs were provided bait in open area; they were attracted to the bait after getting its smell (**Plate 29**). While they were feeding on the bait, the targeted animals, two males and one female, were darted one each in Jagner, Malik Talab and Kundal (**Plate 30 to 34**). Initially a mixture of Ketamine hydrochloride and Xyalzine hydrochloride was used on three wild pigs, and

the dosages varied from 300 mg Ketamine HCl+150 mg Xylazine HCl to 350 mg Ketamine HCl+150 mg Xylazine HCl (**Table 4**). Drug showed its effect within 2-3 minutes, but these animals were not fully down. As the darted animals showed little staggering movement, arousal and then they ran away. It was concluded that the drugs were not appropriate and their dosages were perhaps not sufficient to immobilize the animals. So this drug combination was not found effective in immobilizing wild pigs.

Following this, combination of drugs like Xylazine hydrochloride, Telazol and Succinyl chloride were used for capturing of wild pigs in Kundal, Rajbag, Malik Talab, Patwa Bawari and Guda. When wild pigs were provided bait and they were feeding on it, the targeted animals were darted using these drugs. The animals were calmed down within 2-5 minutes. Other members of the sounder were still busy in feeding. The capture trials and anesthesia with Telazol and Xylazine hydrochloride were conducted on free-ranging wild pigs for radio-collaring from April 2008 to January 2009. Seven free-ranging wild pigs, two males and five females, were captured successfully by using combination of Xylazine HCl and Telazole. Xylazine and Telazol combination was used in the ratio of 1:1 and the dosages varied from 300-350 mg Telazol and 300-350 mg Xylazine HCl (**Table 5**). These drugs and dosages were found very effective and caused complete sedation to all animals. The first sign of the drugs' effect was a lowering of the head, followed by loss of coordination. Animals usually collapsed into sternal recumbency and entered a cataleptoid state, the eyes remaining open and muscles relaxed (**Plate 35 and 36**). Salivation was minimal during the period immobilized.

The heart rates, respiration rates, and body temperatures of animals immobilized with combination of Ketamine hydrochloride and Xylazine hydrochloride and Telazol and Xylazine hydrochloride to determine which of the drug combination was safe and helped to reduce handling stress in wild pigs. From the point of view of practical application of immobilizing drugs for wild animals, the dosages of the drugs should be considered effective if the animals calmed down slowly. The duration of reaction was counted from the moment of falling down of animal until the moment of the first successful attempt to stand up. Effective escape to the forest was considered to be the moment of return to normal condition of the animal. After collaring, the wild pigs

were found recovering; the first indication of recovery was grunting which occurred about halfway through the immobilization period. As the drug effects lessened, slight head and leg movements intensified into attempts to roll to the sternum. Shortly after sternal recumbency was achieved, animals tried to stand until they were able to do so and flee. They first stood up and then staggered and fell several times on their sterna and stood up again and then finally escaped into the forest. Standing up was usually accompanied by trembling of the body. Slowly the trembling in pigs subsided. At this time, some of the wild pigs dragged themselves along but still they were unable to escape.

### **5.3.9 Induction time**

The induction time' is defined as the time interval between administration of drugs and satisfactory immobilization of an animal (Nielsen, 1996). Immobilization time was the period beginning at the point of no movement until the pig first stood during the recovery. In Ranthambore National Park, the induction time of drugs Telazole and Xylazine hydrochloride on wild pigs varied from 10 to 23 minutes that led to complete sedation. After injection of drugs, an improper anaesthesia was observed when signs of recovery appeared during the handling operations or when a second dose was administered. Pigs were placed in lateral recumbency for recovery.

### **5.3.10 Reversal using antidote**

For reversal of immobilization in wild pigs darted with drugs, all the seven animals were administered with 3-4 ml of Reverzine or Atipamezole (Antisedan®) (**Table 5**). Due to the long elimination time of drug, reversal was given 50-60 minutes after darting that helped successful recovery of animals. Blood samples (n=7) for haematology and serum chemistry were also collected within 10 minutes after immobilization was induced for genetic study. Immobilized pigs were left to recover undisturbed at the capture sites.

During the capture period of two years, there was no mortality of wild pigs in the free-ranging situation, and a good anaesthetic efficiency was observed. All immobilized animals recovered within 140 to 260 minutes after intravenous administration of the antagonist (**Table 5**). Seven animals showed signs of arousal or recovery shortly after reversal, but these side-effects were of brief duration. All wild pigs were continuously monitored until full recovery was evident. This almost took 4-6 hours in wild pigs immobilized with Xylazine and Telazole. All radio-collared animals were checked the next day of their capture, and monitored thereafter.

### **5.3.11 Post capture handling**

Immobilized animals are required to be properly monitored and clinically examined. In Ranthambore National Park, immobilized wild pigs were kept in lateral recumbency with the mouth and head low relative to the body to prevent aspiration of saliva or vomitus. An eye gel (Viscotears®) was also applied to the cornea to prevent drying. These pigs were protected from direct sunlight into the eyes by using a blind-fold.

Thermoregulation is monitored by frequent measurements of the rectal temperature (RT). Immobilized wild pigs in the study area showed normal RT ranging from 38.0-39.0°C except one animal in which temperature increased above normal. But it was controlled by repeated spraying of water on its body. Hyperthermic conditions in animals (RT > 40.0°C) were usually controlled by applying water to the axilla, groin, and or tongue. Oxygen supplementation was also done to hyperthermic animals since the oxygen demand increased by 10% for each degree centigrade increase in the body temperature.

Cardiorespiratory function was also monitored using a pulse oximeter (Nellcor®) with the sensor applied to the tongue. Relative arterial oxygen saturation of > 90% was considered to be the clinically acceptable in a field situation. A decreasing trend or SpO<sub>2</sub> < 90% indicated hypoxemia and supplementation with intra-nasal oxygen (2-5 litre/min) was required to improve oxygenation by using a portable oxygen cylinder.

The colour of the mucous membranes in the mouth was also monitored to assess blood oxygenation. A pink or red colour was found normal; bluish membranes indicated hypoxemia. All wild pigs immobilized and captured were handled carefully and rapidly to avoid injuries and minimize stress. The recovery phase was followed through visual observations.

## 5.4 Discussion

For capturing wild pigs, selection of the capture sites, pre-baiting, setting up of traps and radio collaring were done in extreme isolation from local people. Any disturbance from people and cattle would have adversely affected the capture operation. Traps and snares have been used with some success in controlling feral pigs and management of their populations. When used with other control methods, like direct reduction, containment, or exclusion, trapping within a multi-approach operation can be more effective. The important question for which research data must be available when considering traps for pig control is: when to use, what kinds of traps at what place. Certain months of the year would be more effective and strategic in impacting: the population by trapping. Activity and movement patterns increase in response to the fruiting season of *Zizyphus mauritiana*.

The capturing and immobilization of wild pigs was done early in the morning and after radio-collaring, they were released safely. The animals' density, their distribution, social organization, and individual differences in behaviour to trapping devices as a result of differences in physiology, age, or sex will generally affect trap ability. These factors are outside the control of researchers. The second group of variables may be termed method factors. Trap design, triggering mechanism, efficiency, placement, number, baits, and baiting techniques all affect the total number of capture.

To study the movement, activity pattern, habitat use and home range of wild pigs, capture trials on wild pigs were conducted by using panel traps and also in free ranging situation in Rajbag, Guda, Kundal, Patwa bawari and Malik talab areas of Ranthambore National Park. Among the selected capture sites, three were in the core zone and two on the periphery of park. The panel traps were set in different places, and then the bait comprising of fermented maize, groundnut, gram and molasses was provided inside and outside the traps to attract wild pigs. The fermented bait was increasingly attracting the wild pigs and in such a way, wild pigs were slowly habituated to visit these traps.

Reactions of pigs to food baits provides useful information on the favoured and alternative baits which could be used in control programs using live- or kill-trapping methods. When poisoning programs are considered, favoured baits could be inoculated with the desired poison. In parts of Australia, pig and animal carrion were found to be very effective bait for feral pigs. Meat baits inoculated with 1080 (Sodium monofluoroacetate) and air-dropped into the animals' range were highly successful in pig eradication operations (Bisset, 1977). Inoculated baits like these have been eaten by pigs in the field and demonstrated some potential for chemical control.

One group having two sows and five piglets at Rajbag got very much habituated that they often used to arrive and wait at the baiting site. These animals got completely habituated to the bait and started increasingly feeding on it from outside and inside the trap. Two to three groups of wild pigs were regularly visiting the trap to feed on the bait. In Guda, one big group comprising of more than 30 wild pigs used to remain near around the trap to feed on the bait material. By using the panel traps, a total of 153 wild pigs of varying age classes were captured without a single capture-related mortality in Rajbag and Guda. Out of 153 animals, 47 and 106 wild pigs were trapped in the panel traps at Rajbag and Guda respectively. By using this trapping technique, although wild pigs were successfully captured, but the animals were succumbed to injuries. But at the time of approaching the trap in a vehicle, the animals used to agitate a lot and repeatedly dashed against the panels of the trap and as a result, some injuries were caused to these animals. Wild pigs suffered some injuries in both the places. Out of these wild pigs captured in the panel trap, 31 individuals suffered injuries to some extent at Rajbag and Guda.

Generally the success of 2.5 pigs per trap night indicated the trap's effectiveness, and success rates were similar for traps with top-hinged or side-hinged squeeze gates. Other studies reported trap successes of 3.2 pigs per trap night in box traps (Schauss *et al.*, 1990), and 1.0 and 2.0 pigs per trap night in panel traps (Choquenot *et al.*, 1993 and Saunders *et al.*, 1993). The trapping techniques helped reduce capture stress because few injuries were noted among animals captured, and injecting pigs with darts minimized the need to manually restrain them.

As reported by Sweitzer *et al.* (1997b), large traps could be an important source of stress because the animals have more space to injure and excite themselves while attempting to escape. In particular circumstances, the complex interactions between drugs and stress and potentially other factors (i.e., drug sensitivity, pre existent pathology, etc.) could be fatal leading to cardiovascular failure. Spraker (1993) considered the stress syndrome the first cause of capture mortality in wildlife. The high influence of handling (also including trapping methods) on the safety of chemical restraint in wild pigs is confirmed by the absence of mortality described by Sweitzer *et al.* (1997a,b) when stress in captured animals was reduced applying a modified panel, burlap draped around the trap.

In 13 attempts in Rajbag, the mean number of wild pigs captured was 3.6 and in 11 attempts in Guda, the mean number of wild pigs captured was 9.6. Although we detected the difference in the efficacy of traps but in both the places, the trap efficacy was considerable high in capturing varying groups of wild pigs. This could be due to the smaller group size in Rajbag and larger group size in Guda region. The fall snap or push type of gate fixed in panel traps was easier to trigger and thus found very effective.

Wild pigs showed lot of alertness and caution in approaching and entering the trap at Rajbag and Guda. In almost every case, they were hesitant to go inside the trap, this trap wariness was found to be caused by the gate, the enclosed area and triggering device. This behaviour was frequently observed in traps with a drop or fall door mode of capture, but the wary behaviour was reduced by using trigger rope, and it was found to be effective. In general, the use of small traps and reducing catch size should be preferred for the improvement of the anaesthetic safety and efficiency. The advantages obtained in medium and large traps (i.e. the number of animals caught) is balanced by several disadvantages such as death, anticipated recovery, and double injection. The choice of a drug and its dosage are only a small part of a complex system because many factors influence the success of wild boar immobilization.

Different drugs used to immobilize wild pigs in Ranthambore National Park. Combination of Ketamine hydrochloride and Xylazine hydrochloride, Telazol and Xylazine hydrochloride was mainly used for immobilization of wild and feral pigs. Reversine was mainly used as antidote. Initially, wild pigs captured in panel traps were immobilized using combination of Ketamine hydrochloride and Xylazine hydrochloride. But there was incomplete sedation of wild pigs captured in Rajbag and Guda. Because of incomplete sedation, collaring could not be done. However the advantages of Ketamine hydrochloride and Xylazine hydrochloride included a wide safety margin, short induction time, an optimal immobilization period, muscle relaxation, minimal salivation, and little excitement during recovery.

In free ranging condition, capturing of wild pigs was tried using mixture of Ketamine hydrochloride and Xylazine hydrochloride. Although the drugs showed its effect within 2-3 minutes, but these animals were not fully down. The darted animals showed little staggering movement, arousal and then they ran away. It was concluded that the drugs were not appropriate and their dosages were perhaps not sufficient to immobilize the animals. So this drug combination was not found effective in immobilizing wild pigs. Later seven free-ranging wild pigs were captured successfully by using combination of Xylazine HCl and Telazole. Xylazine and Telazol combination was used in the ratio of 1:1 and the dosages varied from 300-350 mg Telazol and 300-350 mg Xylazine HCl. These drugs and dosages were found very effective and caused complete sedation to all animals. For reversal of immobilization in wild pigs darted with drugs, all the seven animals were administered with 3-4 ml of Reversine or Atipamezole.

Whether lower heart rates, respiration rates, and body temperatures were related to drug types remains unclear, but results suggest lower stress among animals immobilized with Telazol and Xylazine HCl using darts compared to those immobilized by hand with Ketamine HCl and Xylazine HCl. In addition to minimizing injuries, facilitating capturing, and safely processing multiple animals, other advantages of the modified panel trap are (1) up to four disassembled traps can be transported in the back of a full-sized pickup, and (2) disassembled traps can be

moved into remote areas by minimum man power. Although the trap can be rapidly disassembled, 1-2 hours of labour with 2-3 people is required for assembly.

From the point of view of practical application of immobilizing drugs for wild animals, the dosages of the drugs should be considered effective if the animals calmed down slowly. The duration of reaction was counted from the moment of falling down of animal until the moment of the first successful attempt to stand up. Effective escape to the forest was considered to be the moment of return to normal condition of the animal.

Immobilization of feral pigs using Ketamine HCl and Xylazine HCl was superior to other drugs reported for immobilizing feral and European wild pigs for example Succinylcholine chloride (Zurowski and Sakowicz, 1965; Matschke and Henry, 1969 and Wood *et al.*, 1977), Cap-Chur-Barb (Henry and Matschke, 1968), and Cap-Chur-Gem (Matschke and Henry, 1969a and Henry and Matschke, 1972). Most of these drugs had serious shortcomings, and only Succinyl choline chloride is in current use today. Induction time using Ketamine HCl and Xylazine HCl was short and variability was small. The much narrower dose range for Succinyl choline chloride suggested by Wood *et al.* (1977) reduced mortality to 2.2%, but induction time increased and response was quite variable ( $4.4 \pm 2.3$  minutes). The immobilization period induced by Ketamine HCl and Xylazine HCl was considered optimal for handling, measuring, and releasing wild pigs within a minimal time period. Immobilization time using Succinyl choline chloride was short and highly variable, example it was  $25.6 \pm 7.4$  minutes (Matschke and Henry 1969a), and  $11.6 \pm 6.1$  minutes (Wood *et al.*, 1977). The variation in immobilization time using Ketamine HCl and Xylazine HCl could be explained in part by age, with older animals remaining immobilized for longer periods. Zurowski and Sakowicz (1965) suggested some of the variation in immobilization time observed using Succinylcholine chloride in European wild boar may also be age related. Thurman *et al.* (1996) used Ketamine alone to anesthetize and immobilize domestic pigs. There was marked salivation in pigs when using Ketamine, and administered atropine sulfate prior to Ketamine to control it. With the use of Ketamine HCl and Xylazine HCl, these adverse side effects were uncommon due to the muscle-relaxing properties of Xylazine.

The high rate of partial anaesthesia was associated with dosage amount and capture management. Under dosage could be determined by the used dosage combined with imprecise body weight estimation. After the administration of 4.35 mg/kg of a 1:1 mixture of Tiletamine/Zolazepam and Xylazine in feral hogs, an effective chemical immobilization was observed by Gabor *et al.* (1997). Similar results were reported by Sweitzer *et al.* (1997a) using 4.8 mg/kg of a 1:1.9 mixture of Tiletamine/Zolazepam and Xylazine. The under dosage was taken into account to explain the main anaesthetic failure, but no data were reported by Gabor *et al.* (1997), while a significant weight underestimation in not completely anesthetized animals was described by Sweitzer *et al.* (1997a).

Whether lower heart rates, respiration rates, and body temperatures were related to drug types remains unclear, but results suggest lower stress among animals immobilized with Telazol and Xylazine HCl using darts compared to those immobilized by hand with Ketamine HCl and Xylazine HCl. For high values of catch size, the stress of each captured animal increases (fear, struggling, etc.), thus delaying the induction of anaesthesia, and a greater amount of anaesthetic is required (Harthoorn, 1975 and Thurmon *et al.*, 1996). The animal's physical conditions could influence the induction phase; every time an animal shows a prolonged excitement state during this stage, extra doses of anaesthetic have to be administered (Nielsen, 1996); chemical restraint failure or mortality are more likely (Harthoorn, 1975 and Murray, 1978).

**Table 1: Capturing wild pigs using panel traps and Ketamine and Xylazine HCl drug combination in Rajbagh.**

<b>S. No.</b>	<b>No. of pigs trapped</b>	<b>Sex</b>	<b>Ketamine HCl + Xylazine HCl (mg)</b>	<b>Drug effect</b>	<b>Reaction</b>	<b>Outcome</b>
1	4	Male	150 + 100	Incomplete sedation	Broke wire mesh of trap and ran away	Collaring could not be done
2	4	Female	250 + 150	Incomplete sedation	Injured themselves dashing against cage wall and biting each other	Collaring could not be done
3	5	Female	300 + 150	Incomplete sedation	Broke wire mesh of trap and ran away	Collaring could not be done
4	2	Male	300 + 200	Mild sedation, Jumped out	Jumped over the cage and ran away	Collaring could not be done
5	4	Female	250 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
6	6	Female	300 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done

<b>S. No.</b>	<b>No. of pigs trapped</b>	<b>Sex</b>	<b>Ketamine HCl+ Xylazine HCl (mg)</b>	<b>Drug effect</b>	<b>Reaction</b>	<b>Outcome</b>
7	1	Female	300 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
8	3	Male	300 + 200	Incomplete sedation	Ran during handling	Collaring could not be done
9	5	Female	250 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
10	1	Female	300 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring done
11	6	Female	300 + 150	Incomplete sedation	Door got opened	Collaring could not be done
12	4	Male	350 + 250	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
13	2	Male	300 + 200	Incomplete sedation	Injured themselves dashing against cage wall and biting each other	Collaring could not be done

**Table 2: Capturing wild pigs using panel traps and Ketamine and Xylazine HCl drug combination in Guda.**

<b>S. No.</b>	<b>No. of pigs trapped</b>	<b>Sex</b>	<b>Ketamine HCl+ Xylazine HCl (mg)</b>	<b>Drug effect</b>	<b>Reaction</b>	<b>Outcome</b>
1	15	Male	150 + 100	Incomplete sedation	Broke wire mesh of trap and ran away	Collaring could not be done
2	12	Female	250 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
3	14	Female	300 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
4	3	Female	300 + 200	Mild sedation, Jumped out	Jumped over the cage and ran away	Collaring could not be done
5	5	Male	400 + 200	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
6	14	Female	300 + 150	Incomplete sedation	Ran during handling	Collaring could not be done

<b>S. No.</b>	<b>No. of pigs trapped</b>	<b>Sex</b>	<b>Ketamine HCl + Xylazine HCl (mg)</b>	<b>Drug effect</b>	<b>Reaction</b>	<b>Outcome</b>
7	11	Female	300 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
8	2	Female	300 + 150	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
9	12	Female	300 + 250	Incomplete sedation	Door got opened	Collaring could not be done
10	14	Female	300 + 200	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done
11	4	Male	350 + 250	Incomplete sedation	Injured themselves dashing against cage wall and then released	Collaring could not be done

**Table 3: Efficacy of panel traps for capturing wild pigs in Rajbagh and Guda.**

<b>Location</b>	<b>No. of attempts</b>	<b>No. of pigs captured</b>	<b>Mean number of pigs captured (<math>\bar{x}\pm SD</math>)</b>	<b>No. of escapes</b>	<b>Trap efforts</b>	<b>Efficacy (pigs/trap effort)</b>
<b>Rajbagh</b>	13	47	3.6 $\pm$ 1.7	3	13	3.6
<b>Guda</b>	11	106	9.6 $\pm$ 5.0	2	11	9.6
<b>Total</b>	24	153	7.0 $\pm$ 4.7	5	24	6.6

**\*Trap effort is the total number of days/trial and nights for which the traps were set for captures including nights in which no animals were captured.**

**Table 4: Capturing wild pigs in free ranging conditions using different drug combinations.**

<b>S. No.</b>	<b>Location</b>	<b>Capture method</b>	<b>No. of pig(s) darted</b>	<b>Sex</b>	<b>Drug(s) used</b>	<b>Drug effect</b>
1	Jagner	Darting directly	1	Male	300 mg Ketamine HCL + 150 mg Xylazine HCl	Staggered & ran away
2	Malik Talab	Darting directly	1	Male	350 mg Ketamine HCL + 150 mg Xylazine HCl	Staggered & ran away
3	Kundal	Darting directly	1	Female	350 mg Ketamine HCL + 150 mg Xylazine HCl	Staggered & ran away
4	Kundal	Feeding and darting	1	Male	350 mg Telazol + 350 mg Xylazine HCl	Complete sedation
5	Rajbagh	Feeding and darting	1	Female	300 mg Telazol + 300 mg Xylazine HCl	Complete sedation
6	Kundal	Feeding and darting	1	Female	300 mg Telazol + 300 mg Xylazine HCl	Complete sedation

<b>S. No.</b>	<b>Location</b>	<b>Capture method</b>	<b>No. of pig(s) darted</b>	<b>Sex</b>	<b>Drug(s) used</b>	<b>Drug effect</b>
7	Malik Talab	Feeding and darting	1	Male	400 mg Telazol + 400 mg Xylazine HCl	Complete sedation
8	Patwa Bawari	Feeding and darting	1	Female	300 mg Telazol + 300 mg Xylazine HCl	Complete sedation
9	Rajbagh	Feeding and darting	1	Female	300 mg Telazol + 300 mg Xylazine HCl	Complete sedation
10	Guda	Feeding and darting	1	Female	350 mg Telazol + 350 mg Xylazine HCl	Complete sedation

**Table 5: Drug dosages and induction and recovery time of immobilized wild pigs in free ranging situations.**

<b>Sex ( body weight)</b>	<b>Telazol+Xylazine (mg) 1:1 ratio</b>	<b>Induction time (min.)</b>	<b>Effective handling time (min.)</b>	<b>Reverzine (ml.)</b>	<b>Recovery time (min.)</b>
Sub-adult male (40 kg)	700	10-20	50	3.5	140-230
Adult female (40 kg)	600	15-23	49	3.0	156
Adult female (50 kg)	600	15-20	50	3.0	235
Adult male (80 kg)	800	10-15	45	4.0	230
Adult female (40 kg)	600	15-20	50	3.0	260
Adult female (45 kg)	600	12-18	45	3.5	240
Adult female (50 kg)	700	10-17	45	3.5	225

**Table 6: Capturing of wild or feral pigs using various traps and drug combinations in different countries.**

<b>S. No.</b>	<b>Year</b>	<b>Place</b>	<b>No. of animals</b>	<b>Capture method</b>	<b>Drug(s) used</b>	<b>Dosage</b>	<b>Bait</b>
1	1969-70	South Carolina	-	Box trap	Pentobarbital scopolamine - (500mg pentobarbital sodium + 1 mg scopolamine HBr per cc	1cc/8.6 lb to 1cc/53.9 lb. body weight	Corn
2	1985-88	Kosciusko national park, Australia	17	Panel trap	-	-	Fermented wheat
3	1979	Santa Catalina	38	Box and corral trap	Ketamine (100mg/ml) Xylazine (100mg/ml)	Ratio 1:1	-
4	1977-79	Great Smoky mountain, Tennessee	20	Enclosure trap	Ketamine hydrochloride	-	-
5	1964	Pisz district, Poland	20	Permanent trap	Succinyl choline chloride	0.27 - 1.34 mg/kg body weight. Dose of 0.6 mg/kg	-

<b>S. No.</b>	<b>Year</b>	<b>Place</b>	<b>No. of animals</b>	<b>Capture method</b>	<b>Drug(s) used</b>	<b>Dosage</b>	<b>Bait</b>
6	-	-	151	Box trap	Succinyl choline chloride	0.46 - 1.20 mg/kg	-
7	1991-93	Maremma Natural park	18	Fixed trap	Ketamine hydrochloride, Atropine sulfate & Azaperone	-	Maize
8	1989-90	Northern territory, Australia	1740	10 - 15 traps	-	-	Grain and carcass
9	1985-87	Sunny corners, Australia	22	Traps	-	-	-
10	1989-92	New South Wales, Australia	585	Traps	-	-	-
11	1985-88	Kosciusko NP, Australia	107	Panel trap	-	-	Fermented wheat
12	1994-95	California	144	Modified panel trap	Telazol and Xylazine hydrochloride	Telazol 2.8-3.3 mg/kg & 1.4-1.6 mg/kg Xylazine	-

## Annexure I

### Immobilization Data

Date: .....

No. :.....

Frequency: .....

Drug used	Ketamine HCl/ Telazol	
	Xylazine HCl.	
Dose (mg/kg)		
Dart time		
Sternal recumbancy		
Full immobilized		
Age group (A J C)		
Sex		
Pulse rate (bt./min.)		
Respiration (breaths/min.)		
Body temperature (°C)		
Body weight (kg)		
Blood sample		
Hair		
Recovery time*		
Time of darting antagonist		
Recovery**		

\* Without antagonist

\*\* With antagonist

**Plate 1: *Anogeissus pendula* mix forest with wild pigs surveyed for the selection of capture site.**



**Plate 2: Wild pigs in grassland opening in *Anogeissus pendula* forest selected as capture site.**



**Plate 3: Water body with wild pigs surveyed for the selection of capture site.**



**Plate 4: Water body with sambar and wild pigs surveyed for the selection of capture site.**



**Plate 5: *Anogeissus pendula* forest with wild pigs surveyed for the selection of capture site.**



**Plate 6: Wild pigs sounder moving and feeding in Scrub forest near in Guda.**



**Plate 7: Setting of panel trap near a water body in Rajbagh.**



**Plate 8: Aligning and bolting side panels to set the trap in Rajbagh.**



**Plate 9: Joining side panels by tightning bolts in Rajbagh.**



**Plate 10: Panel trap is set for tying triggering rope and capturing wild pigs.**



**Plate 11: Panel trap is set for putting bait and capturing wild pigs in Rajbagh.**



**Plate 12: Putting fermented gram and maize inside panel trap in Rajbagh.**



**Plate 13: Setting panel trap of for capturing wild pigs in Guda.**



**Plate 14: Panel trap is set for capturing wild pigs in Guda.**



**Plate 15: Wild pigs in front of panel trap attracted to feed on bait.**



**Plate 16: Wild pig coming out of panel trap after feeding on bait.**



**Plate 17: Wild pigs entering in to panel trap to feed on bait in Rajbagh.**



**Plate 18: Wild pigs inside the panel trap feeding on the bait in Rajbagh..**



**Plate 19: A group of wild pigs inside the panel trap feeding on bait in Rajbagh.**



**Plate 20: A group of wild pigs feeding and resting inside the panel trap in Guda.**



**Plate 21: Approaching wild pigs for darting in Rajbagh.**



**Plate 22: Darting wild pig inside the panel trap in Rajbagh.**



**Plate 23: Wild pig immobilized using dart in Rajbagh.**



**Plate 24: Door opened to release the partially sedated wild pigs.**



**Plate 25: Fixing pad inside the panel trap to avoid injuries to wild pigs in Guda.**



**Plate 26: Modified panel trap with padding and feed inside ready for capturing wild pigs in Guda.**



**Plate 27: Preparing dart for immobilization of wild pig in Rajbagh.**



**Plate 28: Dart prepared for immobilization of wild pig in Rajbagh.**



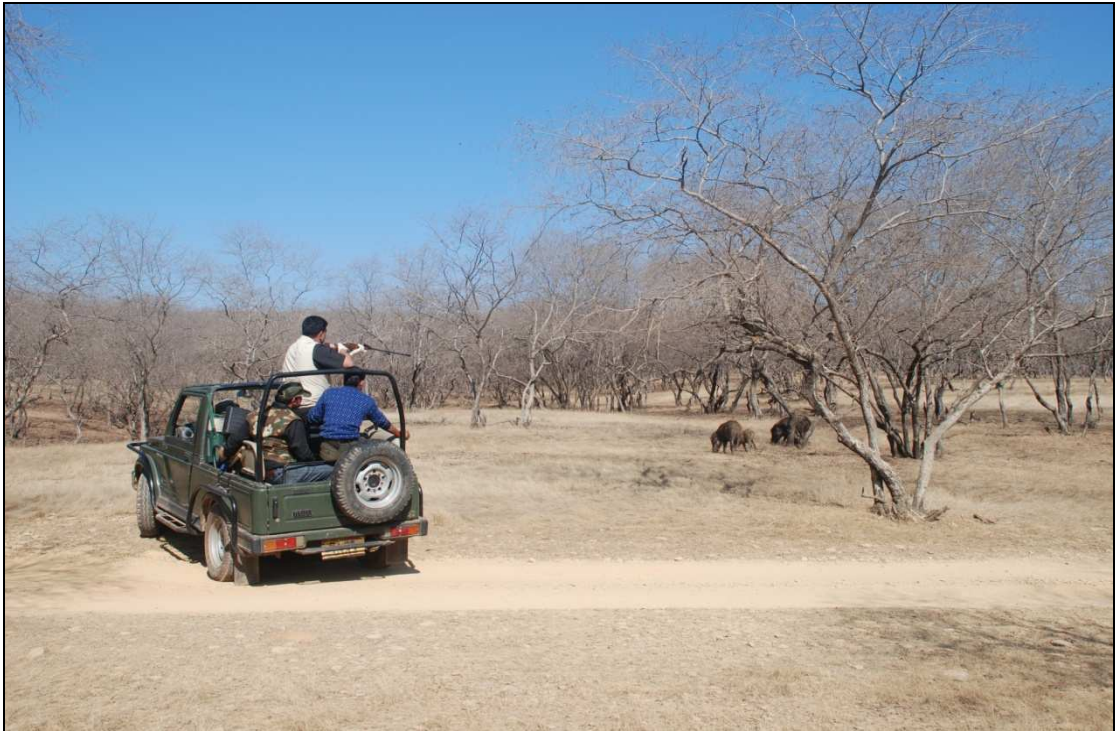
**Plate 29: Habituating wild pigs by feeding bait in free ranging situation.**



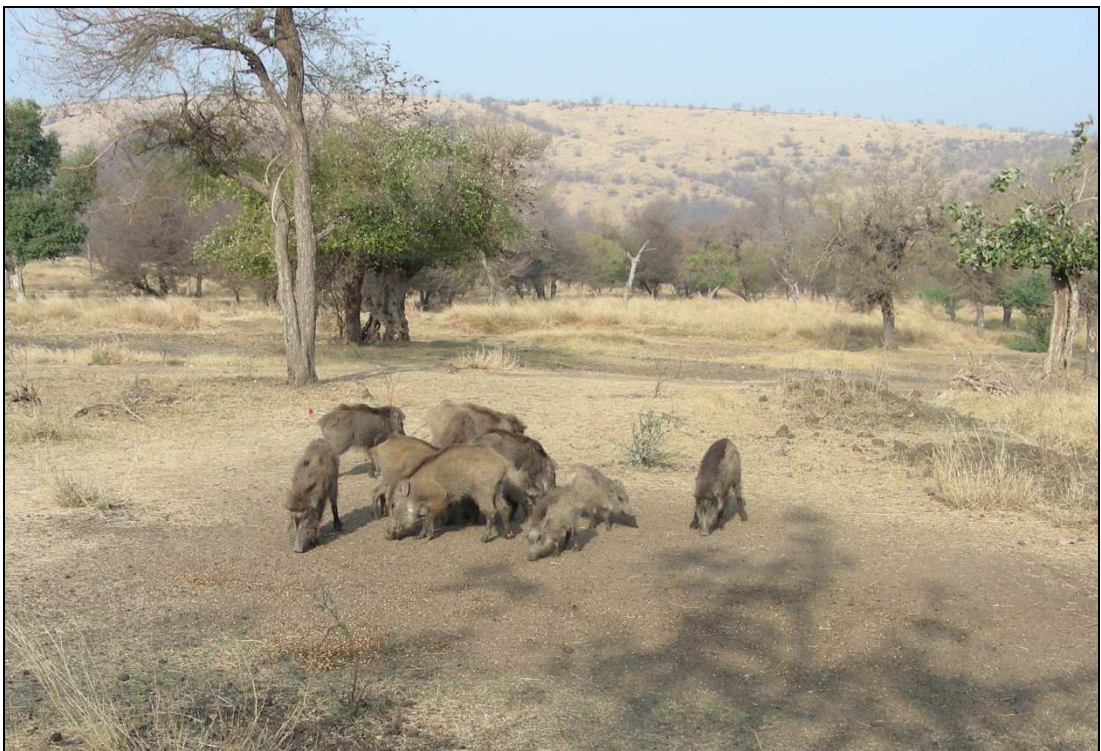
**Plate 30: Wild pig darted in a group in free ranging situation in Kundal.**



**Plate 31: Darting wild pig in free ranging condition in Rajbagh.**



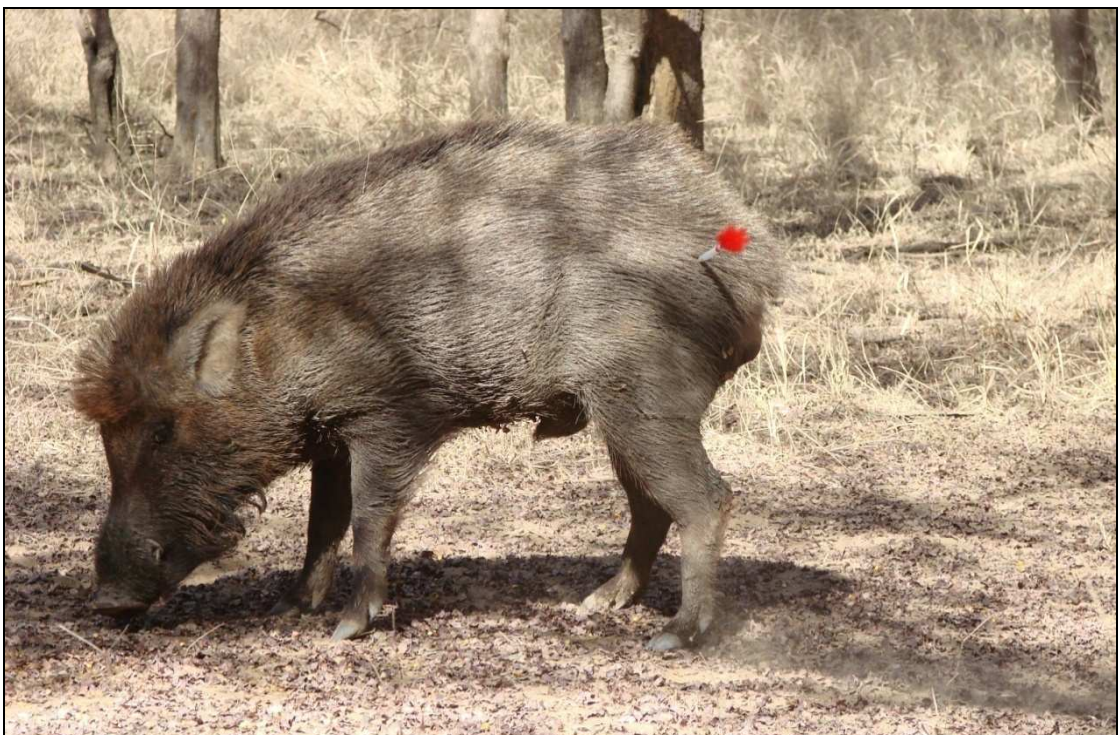
**Plate 32: Wild pig darted in another group in free ranging situation in Kundal.**



**Plate 33: A sow darted in free ranging condition in Kundal.**



**Plate 34: A wild boar darted in free ranging condition in Malik Talab.**



**Plate 35: A sow immobilized using dart in free ranging condition near Rajbagh.**



**Plate 36: Immobilized sow in sternal recumbency with a blind-fold in Guda.**



## Chapter 6

### Study of the ranging pattern of wild pigs based on radio-telemetry.

#### 6.1 Introduction

The wild pig (*Sus scrofa*) is one of the most widely distributed large mammals. To study the habitat use, movement, activity pattern, home range, interaction among the individuals and other socio-biological aspects, wild pigs need to be radio collared.

The home range and movement patterns of the feral pig are of major importance in any management program.

Review of literature revealed that classical and applied scientific investigations on the wild pigs were carried out in Europe, North America, New Zealand and Pakistan. There is no notable contribution from Indian sub-continent. American literature on feral pigs, *Sus scrofa*, mostly dealt with distribution, morphology, ecology, habitat, feeding and foraging impact on native flora and management aspects (Matschke, 1967; Barrett, 1970, 1978; Pine and Gerdes, 1973; Bratton, 1975; Wood and Roark, 1980; Baber and Coblentz, 1986, 1987 and Anderson and Stone, 1993). Occurrence, migration, ranging pattern, habitat, feeding, mortality, reproduction, hunting and management have been reported by many European authors (Fedyushin, 1964; Miroslov, 1965; Rakov, 1970; Mackin, 1970; Fadeev, 1973, 1975, 1981; Jezierski, 1977; Andrzejewski and Jezierski, 1978; Genov, 1981; Erkinaro *et.al.*, 1982; Kratochoil *et.al.*, 1986; Dradaillon, 1986, 1988 and Gerard *et. al.*, 1991).

Many studies on capture and radio-collaring of wild and feral pigs were carried out in Australia and outside India. These studies on wild and feral populations in other areas have yielded important information on habitat preferences, home range traditions and a better understanding of life history strategy in this animal (Barrett, 1971, 1978; Kurz and Marchinton, 1972; Giles, 1978 and Wood and Breneman, 1980). This information has in turn assisted biologists to predict the pig's influence on a given

ecosystem and made it possible for managers to plan control programs. Size of home range of pigs in a given habitat must be taken into consideration when planning a control program (Tester and Siniff, 1974). Home range determinations necessitate the collection of data on the consecutive locations of tagged animals. In early studies on home ranges of the pigs, a single interrupted or continuous mark-recapture program was normally used to collect location data. Capture-recapture data are found to be usually influenced by bait, trap variables and animal behaviour. Direct sighting is the simplest, sometimes preferred, method of collecting data (Jewell, 1966) and this technique has been used to describe home ranges of feral pigs in the Sierra foothills, California (Barrett, 1971). The dense forest vegetation and restricted human mobility in the valley precluded the use of follow-the-animal method or tag-resight data for recording home range. Radioactive substances were used to obtain animal locations, but rapid faecal deterioration in the rain forest and other habitat considerations made this study method undesirable. Radio-tagging with transmitters has the potential of establishing a continuous data-link between an investigator and study animals whose locations can be recorded from a distance.

Radio-telemetry was used to collect location data. This method has been used effectively in home range and movement studies for many terrestrial vertebrates (Werber, 1970 and Will and Patrick, 1972), but only to a limited extent for wild and feral pigs. Theoretically, radio-tracking has been more efficient in providing a greater number of location data per unit effort than sighting or trapping animals (Lance and Watson, 1979). Moreover, such data was found relatively free of biases inherent in other methods of studying home ranges (Mech, 1974). Habitat impact resulting from research activities would be minimal compared to the other methods of data collection mentioned above.

A home range is defined as the area an individual normally traverses during its activities of food gathering, mating, and caring for young ones (Truve, 2004). In the case of feral pigs, home ranges were usually influenced by food availability, weather, breeding, and hunting pressure (Matschke and Hardister, 1966). In free ranging feral hogs, the females were found to travel in family groups called sounders. These groups were made up of several sows along with their young ones. Upon maturing, females

could settle into their home ranges relatively quickly because of the lack of competition. On the other hand, competition and territoriality might cause boars to travel great distances to establish their home ranges (Morini *et al.*, 1995). Adult boars were often solitary and join other pigs only when breeding opportunities arise (Boitani *et al.*, 1994, Nakatani and Ono, 1995 and Kammermeyer *et al.*, 2003). Human presence was found to alter the movements of wild pigs (Singer *et al.*, 1981), and hunting and control efforts often increase the area travelled by pursued hogs. This pressure might cause dispersal into new areas and alter home ranges (Sodeikat and Pohlmeier, 2003).

In Europe, home ranges of Eurasian boars increased due to the animals migrating in search of available food during harsh weather (Maillard and Fournier, 1995). Continuous pressure was reported to cause pigs to disperse and leave their normal home range (Maillard and Fournier, 1995). This would expand the pig population into new areas, which would increase damage. Wild boars in Europe were reported to have home ranges of 40-150 km<sup>2</sup>. Pure wild boars often had larger home ranges than the feral pigs in North America (Boitani *et al.*, 1994). This was due to the Eurasian boars migrating to warmer areas that contain more food sources. Home ranges for feral pigs in North America ranged from an average of 1.1-5.32 km<sup>2</sup> (Kurz and Marchinton, 1972, Singer *et al.*, 1981, Baber and Coblenz, 1986 and Boitani *et al.*, 1994). The smaller home ranges of feral pigs in North America were due to the milder climates and plentiful food sources year round in the environments they inhabited. While knowledge of feral pig home ranges has been found useful, feral pig habitat preference would help managers and biologists develop more effective control regimens. In Congaree National Park (CNP), South Carolina, USA, which was one of the largest and most intact tracts of old-growth, bottomland hardwood forest home range estimates were relatively small compared to estimates from other studies of feral hogs (Friebel and Jodice, 2009).

Knowledge of habitat use by a species of animal is necessary for understanding land-cover preference and it helps biologists to draw inferences about the habitat use in relation to availability (Bond *et al.*, 2002). These inferences then led to wildlife management decisions regarding that species of animal. Feral pigs were found to use

a wide variety of habitat conditions (Hanson and Karstad, 1959 and Dickson *et al.*, 2001). The habitat use by wild pigs was found dependent on the type of cover and cover density (Barrett, 1978). Thick cover provided protection from humans and other predators, while providing the pigs with preferred bedding sites. In the Southeast, pigs were found to use riparian forests associated with a steady water source, but they were reported to inhabit areas from bottomland swamps to mountainous forests (Kurz and Marchinton, 1972; Wood and Brenneman, 1980 and Dickson *et al.*, 2001).

The bulk of literature that is available from Europe, America and Australia has little or no application in India due to different environmental, socio-cultural and agricultural practices. Although the research conducted so far in India includes few ecological parameters, but the studies are not management oriented. No work has been done on home range, activity pattern, feeding ecology of wild boar, and developing capture techniques for pigs in India. In this chapter, research findings on the ranging pattern of wild pigs from Ranthambore National Park are presented.

## **6.2 Materials and Methods**

Safe and effective trapping and restraint techniques were followed because of the need to capture and handle the study animals with a minimum of stress and injury (Peck and Simmonds, 1995 and Thompson, 1995).

The study on capture and radio-collaring of wild pigs was conducted from April 2008 through June 2010. We studied the ranging pattern of wild pigs based on radio-collaring technique in Ranthambore National Park. For radio-collaring of wild pigs, we surveyed wild pigs populations in Sawai Madhour (Project Tiger range), Khandar and Kundera ranges, and selected Rajbag, Guda, Kundal, Lahpur, Lakardah, Malik anicut and Patwa Bawari areas to plan and select specific areas for capturing these animals. In this process, Rajbagh, Guda, Kundal, Patwa Bawari and Malik Talab areas were selected for capturing wild pigs in free ranging situation.

### 6.2.1 Transmitters

The VHF radio-collars of 150-151MHZ frequency range were imported M/s Telonics, Arizona, USA. Each transmitter broadcast in these collar was on a different frequency so that collared animals could be identified in field area.

### 6.2.2 Collar attachment

Nylon or leather harnesses were essentially required for fitting collars on wild pigs as their neck was thicker than head and no antlers or horns were present in their body to hold back the collars. For mounting radio-collars on wild pigs, well designed harness made up of nylon polymer mix were procured and used on animals. These harnesses could be seen on collared animals body (**Plate 1 and 2**). Collars were secured in position by locking the overlapped free ends of nylon belts with steel pop rivets. Initially we used leather harness but later we got the nylon harnesses fabricated and used. Instrumented animals were then monitored for physiological parameters before regaining consciousness release.

### 6.2.3 Pig Collaring

For capturing wild pigs in free ranging condition, the animals were provided bait in open areas; they were increasingly attracted to the bait after getting its smell. Then pigs were immobilized, weighed, sexed and aged by their dentition. A combination of drugs like Ketamine hydrochloride, Xylazine hydrochloride and Telazol were used for capturing of these animals in Kundal, Rajbagh, Malik Talab, Patwa Bawari and Guda. **Plate 9** shows completely sedated wild pig fitted with radio-collar. Wild pigs were handled carefully and rapidly to avoid injuries and minimize stress. All animals were fitted with VHF radio-collars. **Plate 3, 4 and 6** show mounting of radio-collar on wild pig and monitoring of physiological parameters. **Plate 5** shows capture team taking body weight of an immobilized wild pig.

While collaring was done, it was ensured that there was enough space for two fingers between the collar and the neck. During April 2008 to June 2010, we captured seven wild pigs, two males and five females and successfully radio-collared them (**Table 1**). The transmitter was activated by removing the magnet and tested with the receiver before the animal is released (**Plate 7**). Water was sprayed on immobilized wild pig for controlling body temperature (**Plate 8**). After collaring, these animals were monitored continuously. **Plate 10** shows reviving radio-collared wild pig in Kundal area. **Plate 11** shows radio-collared wild pig with capture and collaring team.

#### **6.2.4 Monitoring**

Direct observations were also made on the habitat use and activity pattern of other non-collared wild pigs during August 2005 through June 2010. We sighted 6069 wild pigs, and recorded their point of locations, time, habitat use and activity etc. within the protected area and in peripheries of the park. But the data obtained from the radio-collared animals was only used for studying the ranging pattern of wild pigs.

The collared animals were allowed for one to two days to adjust to instrumentation and were then regularly tracked twice a week. Radio-locations of each collared animal were determined by ground tracking through VHF signal following ‘homing in’ and ‘triangulation’ technique (White and Garrot, 1990). **Plate 12** shows tracking of radio-collared wild pigs. Telonics made TR-4 receiver along with ‘Yagi’ antenna were used to track the radio-collared animals (**Plate 12**). At each location, the hand-held antenna was swept around 360 degrees for each frequency. If radio contact was established or if direction finding was possible, the sweeping was gradually reduced in the direction of the loudest signal at a set receiver gain. During the tracking period, each wild pig was radio-located and sighting records were maintained. Information on its group size, sex ratio, activity pattern and social behaviour was obtained from visual observations (**Annexure I**). The radio-collared pigs were continuously monitored using Yagi antenna from morning time till evening, and also during night on certain days for one year. Attempts were made to locate all the radio-collared wild pigs twice

a week. Co-ordinates for the all radio-location points were determined with the help of Global Positioning System (GPS).

During monitoring, wild pigs were closely followed in vehicle from the time of their appearance in the morning till they returned for resting in the evening. When the pigs were located inside dense vegetation, we first encircled the point and then slowly moved in to locate the pigs directly or sense their activities, and waited for the pigs to move out from there. All the activities viz. moving, resting, digging or feeding performed by the pigs were recorded (**Plate 13 and 14**). Presence of the collared and non-collared pigs in different habitats viz. *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest (*Prosopis juliflora*), Water bodies and Agriculture were also noted. All these habitats were differentially used by wild pigs throughout the year. During this period, movement of collared and non-collared pigs in forests, crop field and human habitation was recorded in different months. Besides habitat use and activity pattern, we also recorded the distance of pigs from human and water sources in different seasons. On the basis of rainfall and temperature, three distinct seasons, namely, winter season from November to February, summer season from March to June and monsoon from July to October were considered for making observations on the habitat use and activity pattern of wild pigs. Monitoring of the collared wild pigs continued during winter, summer and monsoon, and all radio-locations were recorded.

### **6.2.5 Vegetation map and polygons**

Vegetation map was generated on a 1:50,000 scale using Indian Remote Sensing Satellite-1B Linear Imaging Self Scanning Sensors (IRS-1B LISS II B, 1996) false colour composite (FCC) along with Survey of India toposheets, maps of Forest Survey of India and using secondary information obtained from ground truthing. ARC VIEW version 3.2 and ARC/INFO version 8.0.2 were used in the Geographic Information System (GIS) domain to digitize and generate vegetation map. Co-

ordinates of all radio-location points were transferred to get polygons of individual radio-collared wild pigs on this vegetation map.

### **6.2.6 Estimation of home range**

Radio-telemetry technique was followed to estimate the home range and habitat use by wild animals as this technique is found most updated and useful to gather information on home range, daily and seasonal movement pattern of animals (White and Garrot, 1990). The radio-location data was converted to Universal Transverse Mercator (UTM) coordinates and used for estimating the home ranges. ArcView 3.2 (ESRI, 2006) used to estimate home ranges of wild pigs. Two methods of home range analysis were used in the present study i.e. minimum convex polygon method (Mohr, 1947) and kernel method (Worton, 1989)).

## **6.3 Results**

The Ranthambore National Park having an area of 392 km<sup>2</sup> encompasses different vegetation and landuse categories, namely, *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest, Water bodies and Agriculture. The physiography of the park includes undulating terrain with rolling hills of low to moderate heights traversed with rivers and several streams. Wild pigs were found distributed almost in all these habitats.

### **6.3.1 Ranging pattern of wild pigs**

Wild pigs were captured and radio-collared in Kundal, Rajbagh, Malik Talab, Patwa Bawari and Guda areas and their movement and ranging pattern was studied by tracking and monitoring the radio-collared animals. In total two males and five female pigs were radio-collared during 2008 and 2009 (**Table 1**). The Male 1 and 2 were

radio-collared with transmitters having frequency of 151.340 and 151.510 MHz respectively. Whereas the Female 1, 2, 3, 4 and 5 were mounted with collars having frequency of 151.620, 151.800, 151.780, 151.860 and 151.600 MHz respectively.

### **6.3.2 Effect of radio-collaring on wild pigs**

All these neck collars mounted on wild pigs did not appear to produce discomfort on head or body movements, but appeared to accept the collars after 1-2 days. Total weight of the collar-transmitter was much less than 5% of body weight. Movements of tagged wild pigs during the study period were unlikely to have been influenced by the collar transmitter. However one collar was dropped after few days by Male 1.

### **6.3.3 Home range of wild pigs**

To study the movement and ranging pattern, the remaining radio-collared one male and five females were monitored in the park areas. Home range of wild pigs was estimated using minimum convex polygon method (Mohr, 1947) and Kernel method (Worton, 1989). The home ranges at 100% MCP home ranges estimated in ArcView 3.2 software extension (ArcView, 1996).

During 2008, the home range of Kundal female 1 was 14.3 km<sup>2</sup> and Rajbag female 2 was 0.5 km<sup>2</sup> by using 100% MCP (**Table 2 and Map 1**). Among the animals collared in 2009, the male in Lakarda showed a home range of 18.5 km<sup>2</sup>. The female 3 in Patwa Bawari and female 4 in Rajbag showed home ranges of 24.3 km<sup>2</sup> and 6.5 km<sup>2</sup> respectively. The Guda female 5 collared in peripheral area of the park showed home range of 21.5 km<sup>2</sup>. The female 3 in Patwa Bawari and the female 5 collared in peripheral area, Guda showed larger home range as compared to the female 4 in Rajbag which was collared in core area (**Table 2 and Map 2**).

The home range of the three females in Patwa Bawari, Rajbag and Guda using 100% MCP was 24.3 km<sup>2</sup>, 6.5 km<sup>2</sup> and 21.5 km<sup>2</sup> respectively (**Table 3**). The home range

these three females using 95% confidence level was 19.3 km<sup>2</sup>, 3.8 km<sup>2</sup> and 6.0 km<sup>2</sup> respectively. Whereas the home ranges of the three females in Patwa Bawari, Rajbag and Guda using 75% MCP were 13.4 km<sup>2</sup>, 0.6 km<sup>2</sup> and 1.6 km<sup>2</sup> respectively. Using 50% confidence level, the home range of the three females in Patwa Bawari, Rajbag and Guda was found to be 4.2 km<sup>2</sup>, 0.4 km<sup>2</sup> and 0.5 km<sup>2</sup> respectively.

The animal movement analysis extension was also used in ArcView (Hooge and Eichenlaub, 1997) to calculate the 95% Fixed Kernel (Worton, 1989) home ranges. Core areas were calculated as 50% Fixed Kernel estimators. Estimates of 95% Kernel home range size of the three females in Patwa Bawari, Rajbag and Guda was 14.0 km<sup>2</sup>, 1.9 km<sup>2</sup> and 4.4 km<sup>2</sup> respectively. Estimates of 75% Kernel home range size of the three females in Patwa Bawari, Rajbag and Guda was 3.8 km<sup>2</sup>, 0.5 km<sup>2</sup> and 1.4 km<sup>2</sup> respectively. Whereas the core area 50% Kernel home range size of the three females in Patwa Bawari, Rajbag and Guda was 1.4 km<sup>2</sup>, 0.2 km<sup>2</sup> and 0.7 km<sup>2</sup> respectively (**Tables 4 and 6, Map 3, 4 and 5**). Seasonal home ranges of the three females tracked throughout the year in Patwa Bawari, Rajbag and Guda was also estimated using Kernel method.

#### **6.3.4 Seasonal variation in home ranges**

The seasonal home ranges were also estimated for three females using 100% MCP which were tracked throughout the year following minimum convex polygon method (Mohr, 1947). The seasonal variations in home ranges of radio-collared wild pigs are shown in (**Table 5**).

The home ranges of the female in Patwa Bawari were 8.8 km<sup>2</sup>, 2.0 km<sup>2</sup> and 4.4 km<sup>2</sup> in winter, monsoon and summer seasons respectively, which were much smaller than the annual home range of 24.3 km<sup>2</sup> (**Table 5 and Map 6**). Larger area was covered by this wild pig during winter than monsoon and summer season. The female covered very small area during monsoon i.e. 2.0 km<sup>2</sup>. The home ranges of the female in Rajbag were 4.3 km<sup>2</sup>, 3.3 km<sup>2</sup> and 0.8 km<sup>2</sup> in winter, monsoon and summer seasons respectively, which were also smaller than the annual home range i.e. 6.5 km<sup>2</sup> (**Table**

**5 and Map 7).** The area covered by this wild pig was more during winter as compared to areas covered in monsoon and summer. The home range of this female wild pig fell into the core area of National park.

The home ranges of the female in Guda were 15.9 km<sup>2</sup>, 2.0 km<sup>2</sup> and 6.3 km<sup>2</sup> in winter, monsoon and summer seasons respectively (**Table 5 and Map 8**), which were also smaller than the annual home range of 21.5 km<sup>2</sup>. This wild pig covered larger area during winter in comparison to monsoon and summer. The female covered very small area during monsoon i.e. 2.0 km<sup>2</sup>.

#### **6.4 Discussion**

Home range is a well-understood biological concept; however a plethora of methods exist for the estimation of home range size and the estimates from different methods can vary. Methods which are mathematically complex need not necessarily give greater biological insight (MacDonald *et al.*, 1979). The minimum-area method (Mohr, 1947) was chosen for the estimation of home range among the other methods available for this study. The minimum area covers all radiolocations for individual pigs, is biased by sample size and is sensitive to movements on the periphery of the home range. Theoretically, this minimum-area should approach the actual home range more closely with increased frequency of locations and with time. The minimum-area has good statistical stability, is graphically the simplest, is the most widely used home range size estimator and has been used by other workers for estimating home range areas in feral pigs (Barrett, 1971, 1978; Kurz and Marchinton, 1972 and Wood and Brenneman, 1980).

Topographic features also influenced shapes of home ranges. Straight line boundaries in animals whose home ranges were bordered by the central escarpment were real, as verified from ground checks. However, the actual home range configurations are most likely to be amoeboid. Studies in South Carolina showed similar elongated polygonal home range configurations in the feral populations (Kurz and Marchinton, 1972 and

Wood and Brenneman 1980), but circular home ranges have been reported for the wild boar in Tennessee (Singer *et al.*, 1981).

In Kundal, Rajbag, Malik Talab, Patwa Bawari and Guda areas of Ranthambore National Park, two male and five female wild pigs were captured and radio-collared. All these neck collars mounted on wild pigs did not appear to produce discomfort on head or body movements, but appeared to accept the collars after 1-2 days. Movements of tagged wild pigs during the study period were unlikely to have been influenced by the collar transmitter. The home ranges of these wild pigs estimated using minimum convex polygon method (Mohr, 1947) and Kernel method (Worton, 1989) showed varied movement and ranging pattern in different vegetation and landuse categories, namely, *Anogeissus pendula* mixed, *Anogeissus pendula* forest, *Anogeissus pendula* with shrub, Degraded grassland, Tropical dry mixed, Tropical moist mixed, Scrub forest, Water bodies and Agriculture to varying extent in different seasons without showing any territoriality. The home ranges of wild pigs studied in different countries are indicated in **Table 7**.

The home range of Kundal female 1 was 14.3 km<sup>2</sup> and Rajbag female 2 was 0.5 km<sup>2</sup> by using 100% MCP. Among the animals collared in 2009, the male in Lakarda showed a home range of 18.5 km<sup>2</sup>. The home range of the three females in Patwa Bawari, Rajbag and Guda using 100% MCP was 24.3 km<sup>2</sup>, 6.5 km<sup>2</sup> and 21.5 km<sup>2</sup> respectively. Whereas the home ranges these three females in Patwa Bawari, Rajbag and Guda using 95% confidence level was 19.3 km<sup>2</sup>, 3.8 km<sup>2</sup> and 6.0 km<sup>2</sup> respectively. And the home ranges of the three females using 75% MCP were 13.4 km<sup>2</sup>, 0.6 km<sup>2</sup> and 1.6 km<sup>2</sup> respectively. Whereas the core area 50% Kernel home range size of the three females in Patwa Bawari, Rajbag and Guda was 1.4 km<sup>2</sup>, 0.2 km<sup>2</sup> and 0.7 km<sup>2</sup> respectively. The female 3 in Patwa Bawari and the female 5 collared in peripheral area, Guda showed larger home ranges as compared to the home range of female 4 in Rajbag which was collared in core area. This could be due the reason that the female 4 in Rajbag was using prime habitat of the park having water bodies, plenty of food resources and shelter. Whereas the females in peripheral areas Patwa Bawari and Guda had to move far of distances in and around the park

frequently in search of food, shelter and water; their core areas were 1.4 km<sup>2</sup> and 0.7 km<sup>2</sup> respectively.

The animal movement analysis extension was also used in ArcView (Hooge and Eichenlaub, 1997) to calculate the 95% Fixed Kernel (Worton, 1989) home ranges. Estimates of 95% Kernel home range size of the three females in Patwa Bawari, Rajbag and Guda was 14.0 km<sup>2</sup>, 1.9 km<sup>2</sup> and 4.4 km<sup>2</sup> respectively. Whereas the estimates of 75% Kernel home range size of the three females in Patwa Bawari, Rajbag and Guda was 3.8 km<sup>2</sup>, 0.5 km<sup>2</sup> and 1.4 km<sup>2</sup> respectively.

The home ranges of these wild pigs are comparable with home range size of feral pigs in tropical rain forests on the island of Hawaii (Giffin, 1978) and wild and feral populations in other habitats. Thus, home range size range of feral pigs varied from 1.57-50 km<sup>2</sup> (Barrett, 1971, 1978 and Giles, 1978). In Southeast pig population, there was no difference in size of home ranges between sexes (Kurz and Marchinton, 1972 and Wood and Brenneman, 1980). Boars showed larger home ranges than sows but the home ranges of both sexes in high elevation Ohia forest were larger than the home ranges of pigs from the lower elevation Koa forest. Home range size of feral hogs was often attributed to food abundance (Kurz and Marchinton, 1972; Russo *et al.*, 1997; Singer *et al.*, 1981; Saunders and Kay, 1991 and Massei *et al.*, 1997). So the spatial distribution of resources, particularly shelter and food, apparently accounted for home range size differences.

Saunders and Kay (1991) and Caley (1997) reported MCP home range sizes from 1,070 to 3,500 ha for males and 490 to 2,410 ha for females in Australia. In Texas, Gabor *et al.*, (1999) reported kernel estimates for female home ranges of 590 ha. Baber and Coblenz (1986) reported MCP home ranges of 244 ha for males and 146 ha for females on Santa Catalina Island in California. Estimates of home range size for feral hogs in other locations within South Carolina also appear to be slightly larger or in some cases similar to (but not smaller than) estimates from this study. Kurz and Marchinton (1972) in upstate South Carolina and Wood and Brenneman (1980) in coastal South Carolina found MCP home range sizes for hogs in bottomland

hardwoods forests and marshes to be between 123 and 799 ha and 181 and 226 ha respectively.

Several population variables can influence movements. Some breeds of pigs are more sedentary than others (Hafez and Signoret, 1969). Density of pigs is known to affect home range size (Jewell, 1966). Hunting pressure was reported to produce forced movements and increase home range area. High biological productivity and the availability of living requirements in the Norv-seasonal rainforest were the most plausible reasons for the localized movements and smaller home ranges of pigs in Kipahulu valley. Several studies have shown a relationship between spatial distribution of resources and home range size. In arid environments such as the Sierra foothills in California and the dry flood plains in Girilambone, Australia, movements of feral pigs involved long travels for food and water (Barrett, 1971, 1978 and Giles 1978).

Spatial distribution of foods was reported to affect the size of home range of pigs (Jewell, 1966). When food was abundant in an area, feral pigs preferred to move in the vicinity of the food source and thus showed smaller home ranges (Barrett, 1978 and Pavlov, 1980). In the montane rain forest in Kipahulu, water was never scarce at anytime of the year. Soils and herbaceous plants were wet continuously from rain or fog drip. These factors reduced the need to move over a larger area, since energy needs could be met within a small area. Most studies on feral pig movements showed that boars had larger home ranges than sows (Pine and Gerdes, 1973; Barrett, 1971, 1978 and Giles, 1978). Barrett (1978) attributed home range size dimorphism to the boars in search for breeding opportunities.

The seasonal home ranges of female wild pig in Patwa Bawari using 100% MCP were 8.8 km<sup>2</sup>, 2.0 km<sup>2</sup> and 4.4 km<sup>2</sup> in winter, monsoon and summer seasons respectively. These home ranges were much smaller than the annual home ranges of 24.3 km<sup>2</sup>. Larger area was covered by this wild pig during winter than monsoon and summer season. Reason for larger home range in winter could be attributed to the fact that in winter, pigs were attracted to wheat, groundnut and gram crops grown in nearby villages. This female along with her group frequently ventured in village areas for crop raiding. The female covered very small area during monsoon i.e. 2.0 km<sup>2</sup>. This

was due to the fact that during monsoon adequate food and water was available everywhere within the park, and the pigs were not required to traverse in distant places. They could feed on grasses and roots and tubers of herbaceous plants in small area. Further it was the breeding time for pigs in the park, and there was reduction in home range and daily movement as parturition time approaches and the females were observed only after giving birth to the piglets. So in monsoon, the home range was found to be less. Whereas in summer, this female showed larger home range than monsoon but it was less than winter. In summer, there were no crops in the field, and there was scarcity of food and water in the park, so they had to move a lot in search of food resources.

The home ranges of the female pigs in Rajbag were 4.3 km<sup>2</sup>, 3.3 km<sup>2</sup> and 0.8 km<sup>2</sup> in winter, monsoon and summer seasons respectively, which were also smaller than the annual home range i.e. 6.5 km<sup>2</sup>. The ranging pattern of this wild pig was more during winter as compared to areas covered during monsoon and summer. The reason for smaller home range in summer as compared to monsoon could be due to the fact that the home range of this female fell into the core area of the park i.e. Rajbag which remained the prime habitat and there was plenty of food and shelter available and the female was not moving much. The home ranges of the female in Guda were 15.9 km<sup>2</sup>, 2.0 km<sup>2</sup> and 6.3 km<sup>2</sup> in winter, monsoon and summer seasons respectively, which were also smaller than the annual home range of 21.5 km<sup>2</sup>. In this case, the reason for larger home range in winter could be attributed to the fact that the movement of this female was both in the National park and peripheral area in search of food resources.

Season had a significant effect on home range size and core range size (Gaston *et al.*, 2008). During winter and summer months, wild pigs were mainly observed feeding on fruits, and in monsoon season, they were mainly feeding on tubers etc. In search of food, wild pigs covered larger areas during nights without any disturbance and threats. Home ranges were found smaller when the pig's living requirements were provided in a smaller area (Sanderson, 1966), and when food was scarce during the winter, home range size increased (Kurz and Marchinton, 1972 and Singer *et al.*, 1981). Maillard and Fournier (1995) showed that the pig home ranges and movements increased with

the onset of hunting pressure in the winter, then decreased when hunting pressure subsided.

The movement and ranging pattern of pigs was also found to be related to their diurnal activity patterns. Several observations of pigs resting in early afternoon hours concluded that the pigs were engaged in foraging activity in the morning and evening and they were found to rest in the afternoon and night. Rain storms reduced their activities by confining pigs for seeking shelter. Crepuscular activity patterns were observed in feral pigs on the island of Hawaii (Baker, 1975 and Giffin, 1978), California (Barrett, 1971, 1978) and Australia (Giles, 1978). In several studies, the activity patterns of pigs were found to change with the seasons, being preponderantly diurnal during winter, nocturnal in summer and crepuscular in autumn (Kurz and Marchinton, 1972 and Barrett, 1971, 1978).

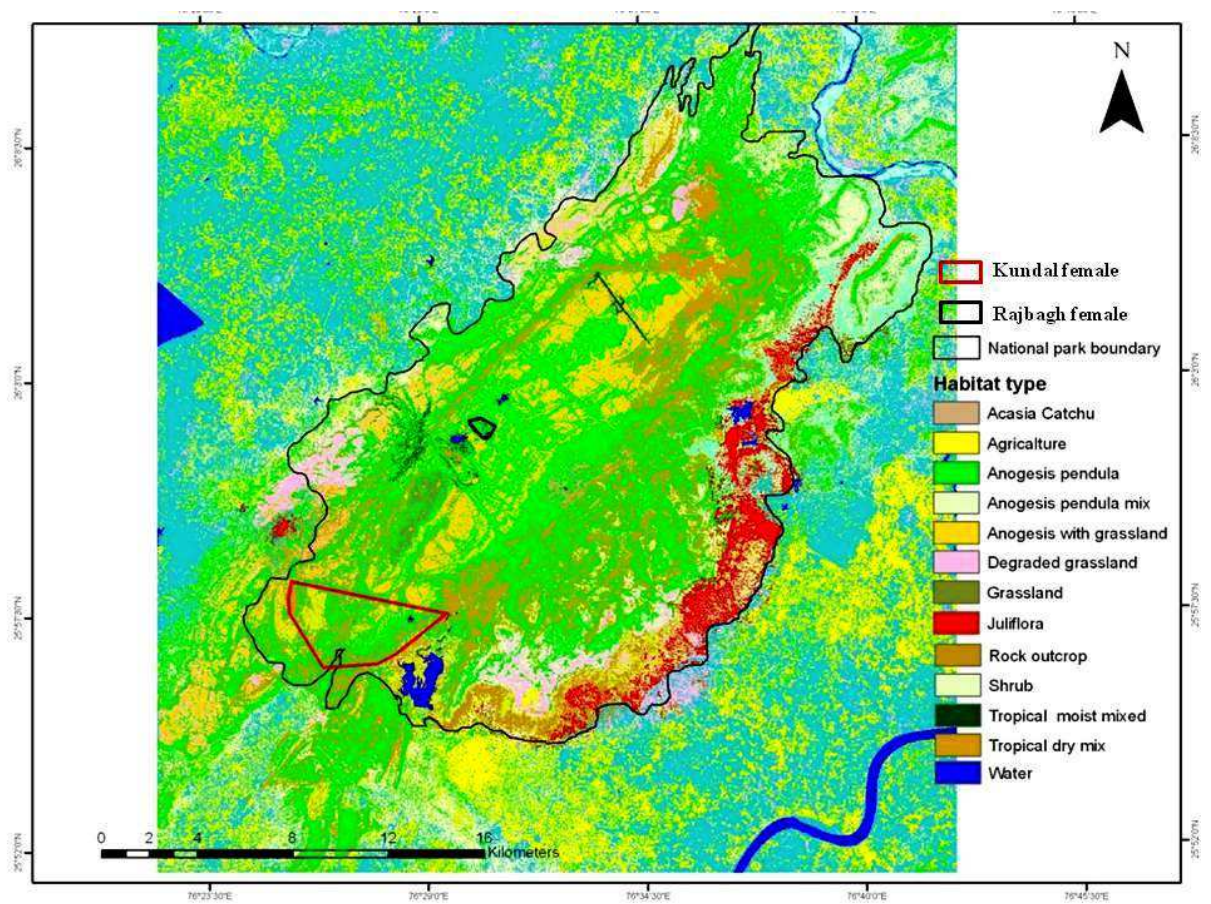
Several management and ecological implications could be drawn from this study. Small, compact and sedentary home ranges with stable seasonal centres of activities and extensive home range overlap showed that a small area of the habitat types had sufficient biological productivity and physical components to meet the maintenance needs of wild pigs. Small home ranges and restricted movements will increase inbreeding tendencies, more so if the life time range of the pig does not differ substantially from its annual home ranges monitored in this study.

The small home ranges observed in this study could be a function of field protocol in that all relocations were collected during daylight hours. Hogs were known to be nocturnal with an increase in activity from dusk to dawn (Boitani *et al.*, 1994; Saunders and Kay, 1991 and Caley, 1997). This nocturnal activity could also be influenced by seasons. When temperature was cool in winter months, hogs spent a greater percentage of their activity time in daylight hours as opposed to summer when they were mainly nocturnal (Kurz and Marchinton, 1972; Singer *et al.*, 1981 and Massei *et al.*, 1997). Relocations of hogs were collected during all seasons in CNP, which hopefully allowed for relocations during high activity periods and encompassed their entire home ranges. Nocturnal activity in hogs was thought to have evolved from human influence and hunting pressure (Kurz and Marchinton, 1972; Giles, 1980 and

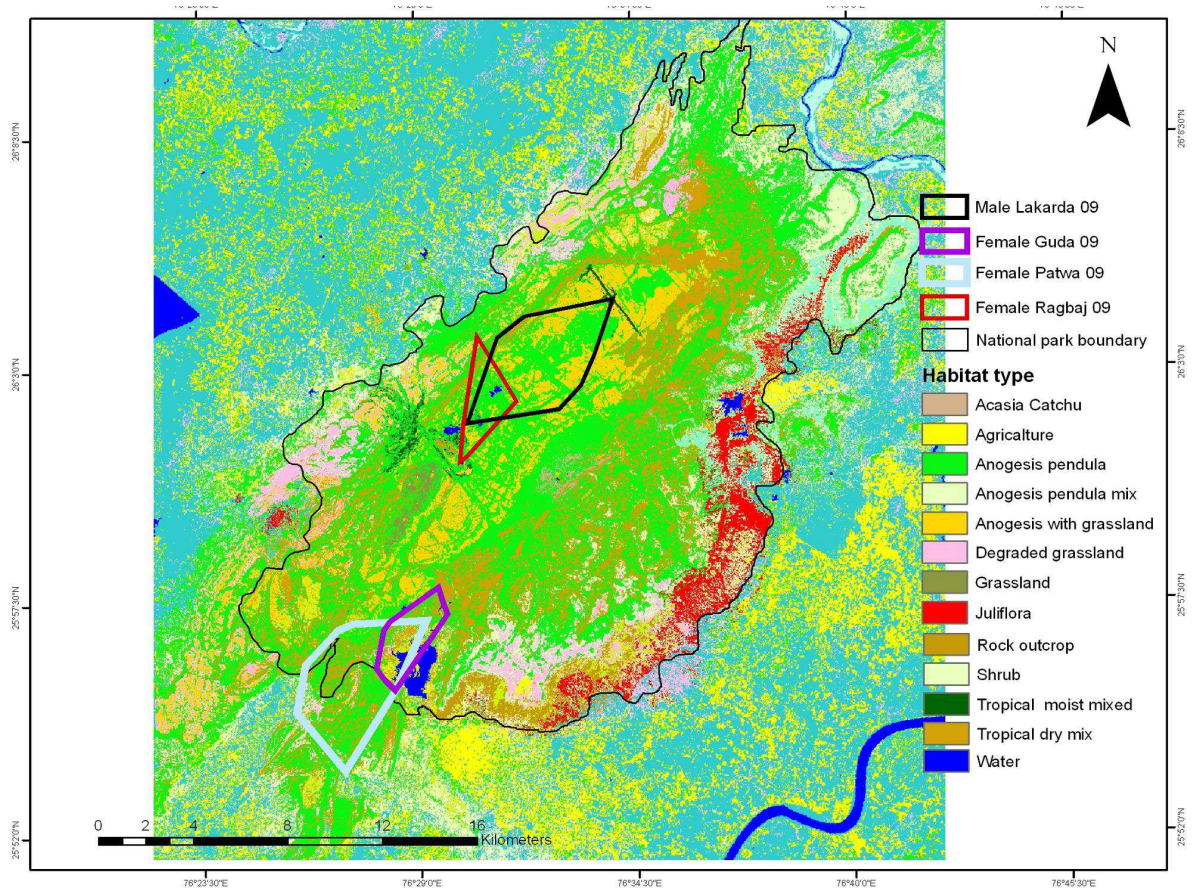
Singer *et al.*, 1981). Since there was no hunting pressure in CNP and its designation as a wilderness area restricted human contact with hogs, it was possible that hogs spent a larger percentage of their activity time during daylight hours in CNP.

Wild hogs were known to travel beyond the boundaries of a park or established wildlife management area (Gabor *et al.*, 1999; Saunders and Kay, 1991 and Caley, 1997). Saunders and Kay (1991) reported that two hogs established their home ranges beyond the Sunny Corner state forest boundaries in Australia.

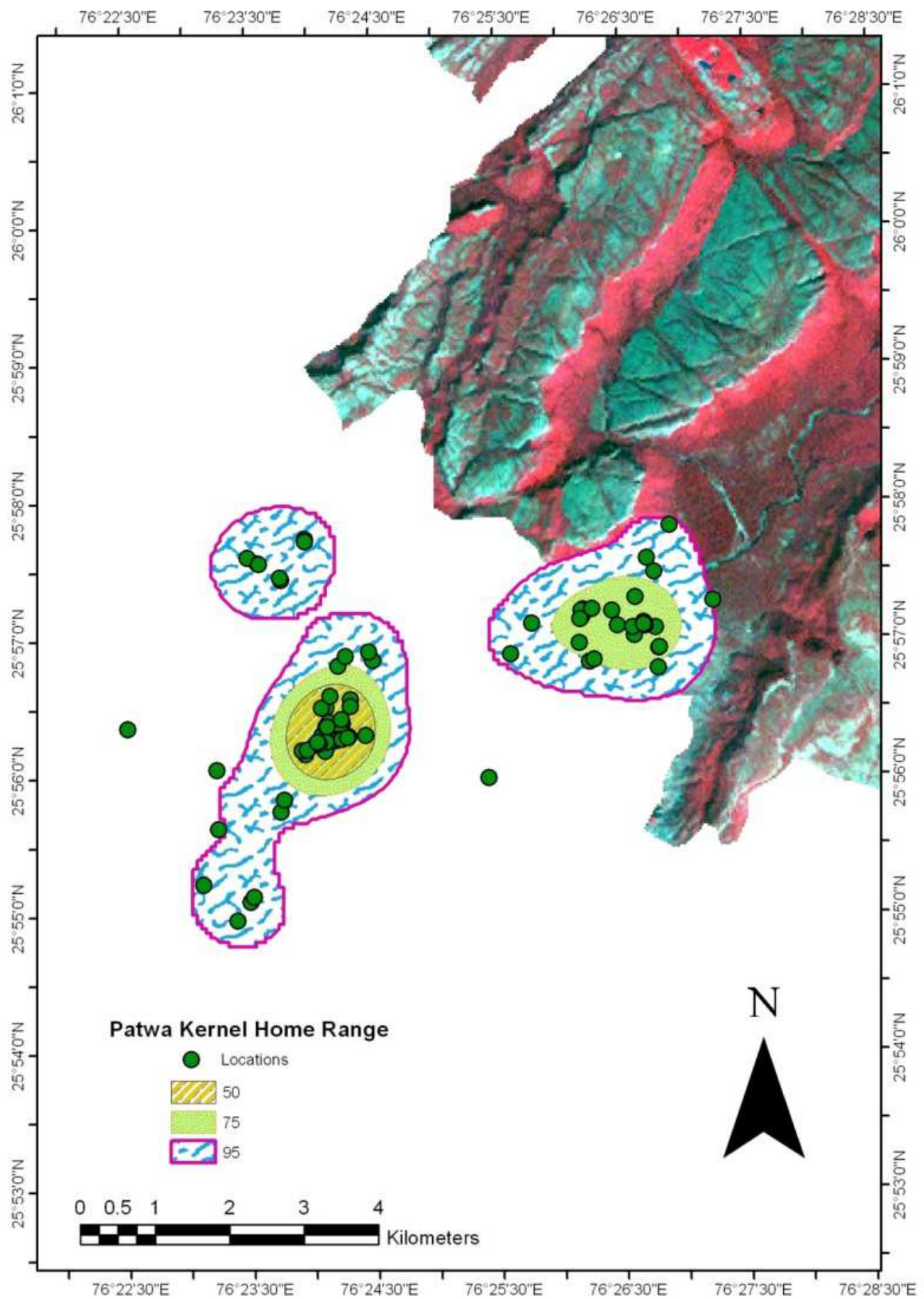
**Map 1: Home range of Kundal female 1 and Rajbagh female 2 collared in 2008.**



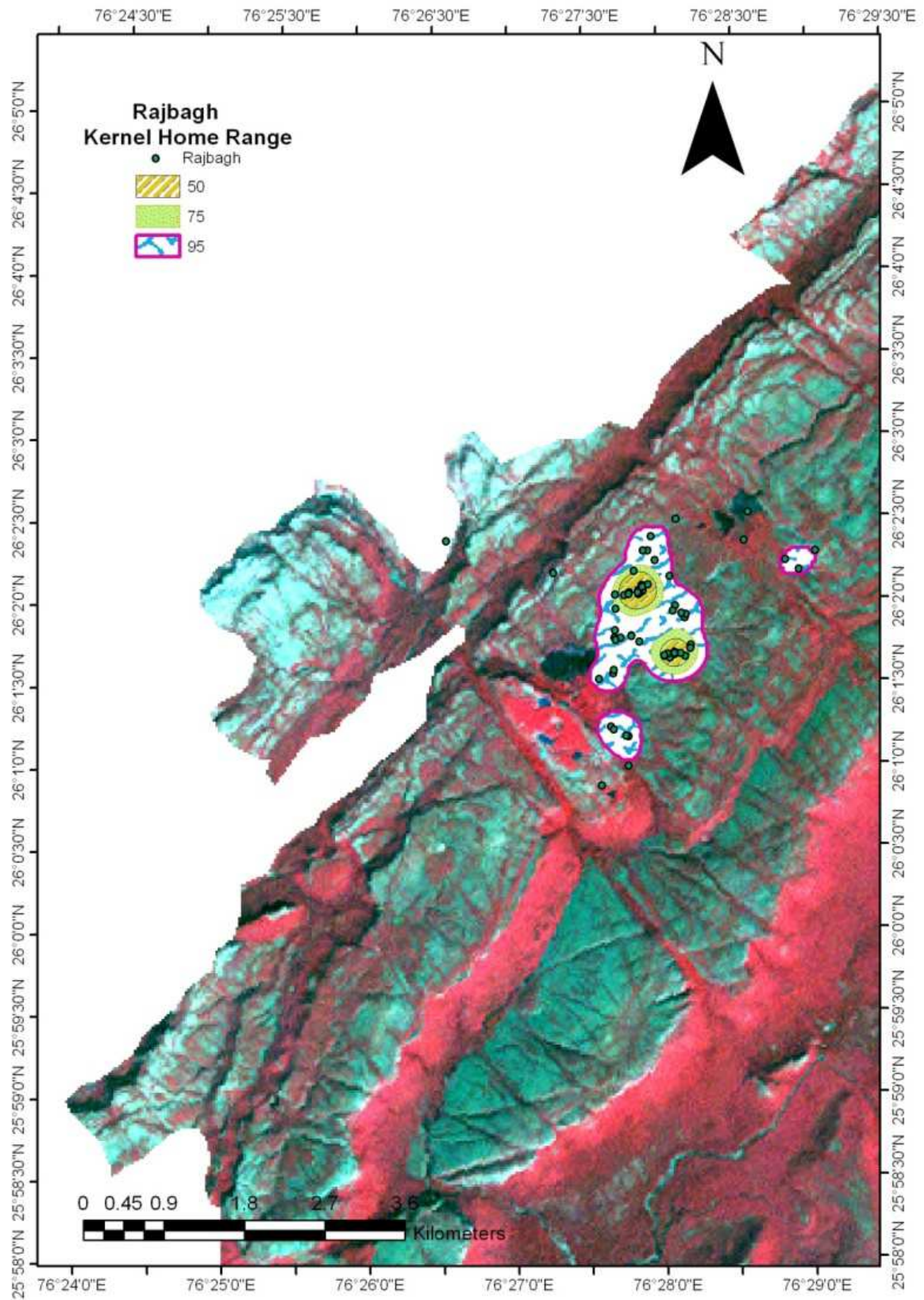
**Map 2: Home range of Lakarda male, Patwa Bawari female 3, Rajbag female 4 and Guda female 5 collared in 2009.**



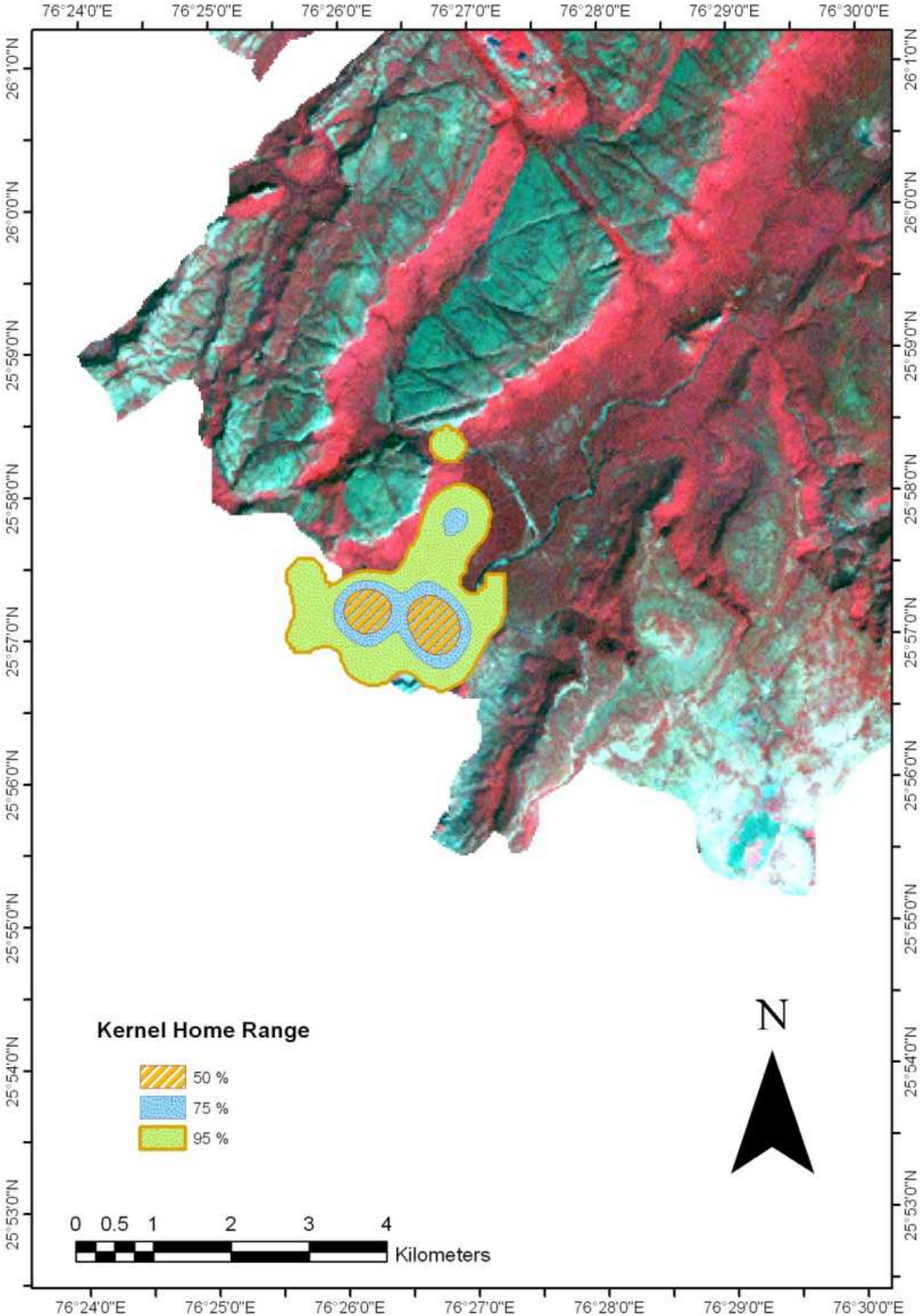
**Map 3: Annual Kernel home range of Patwa Bawari female.**



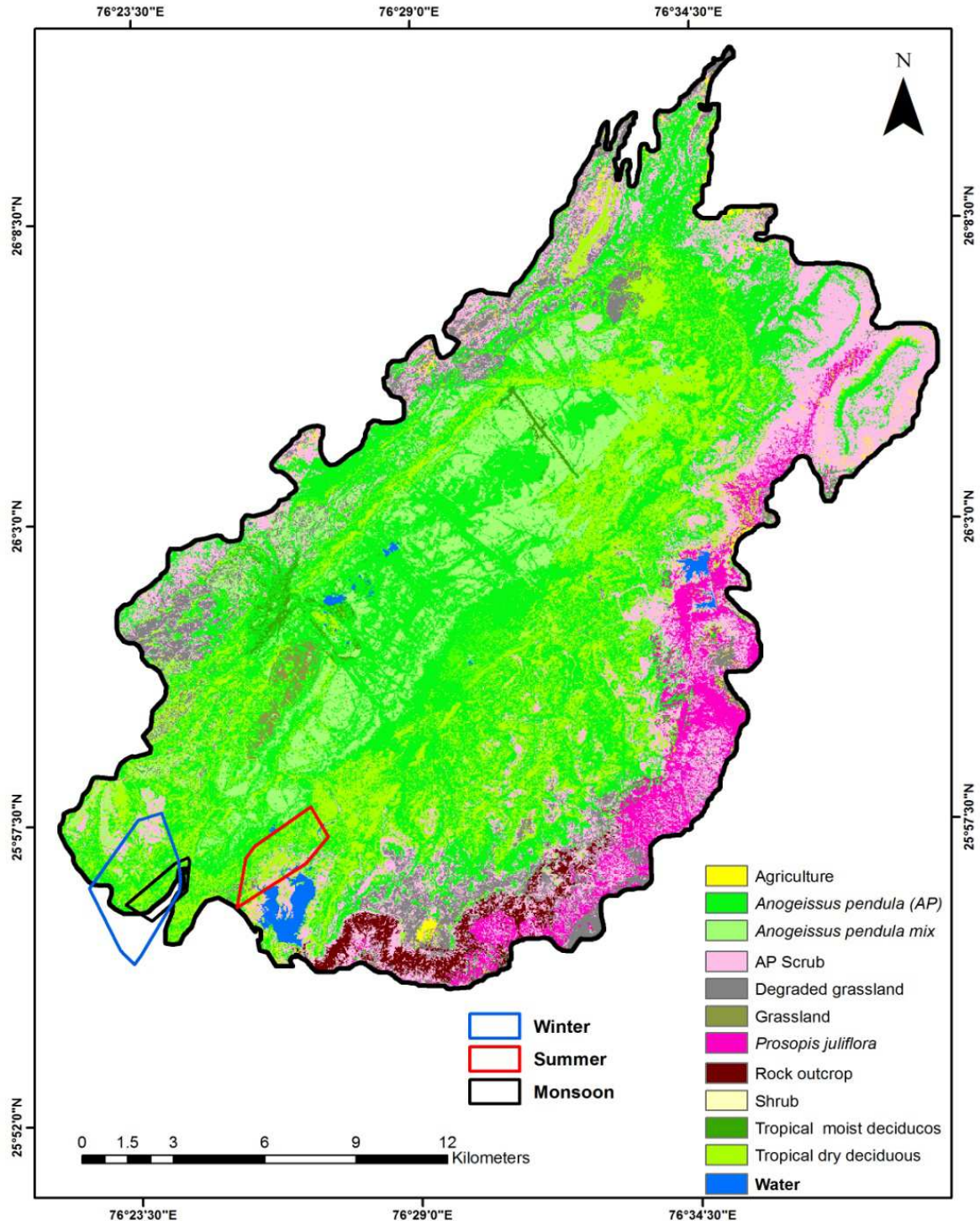
**Map 4: Annual Kernel home range of Rajbagh female.**



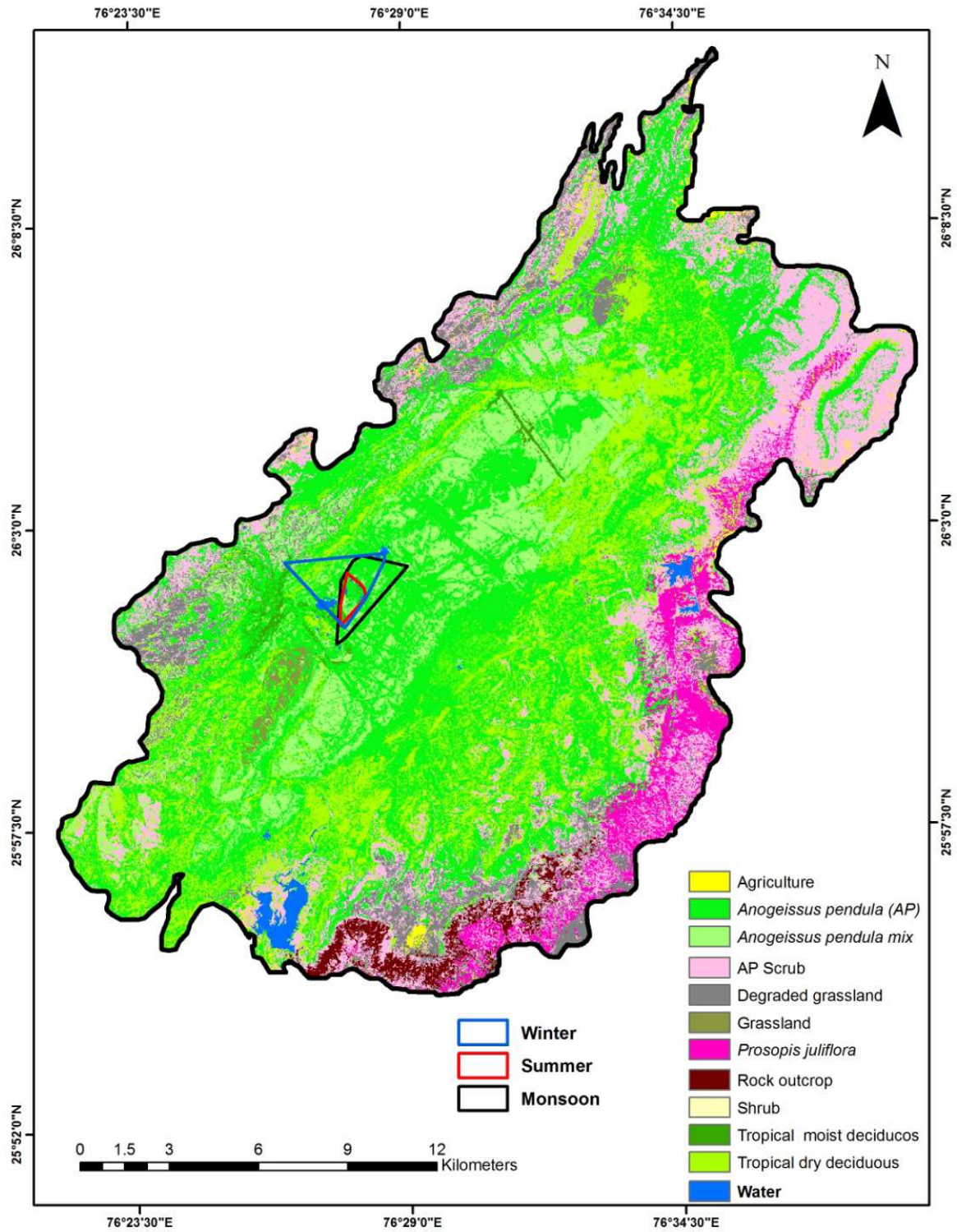
**Map 5: Annual Kernel home range of Guda female.**



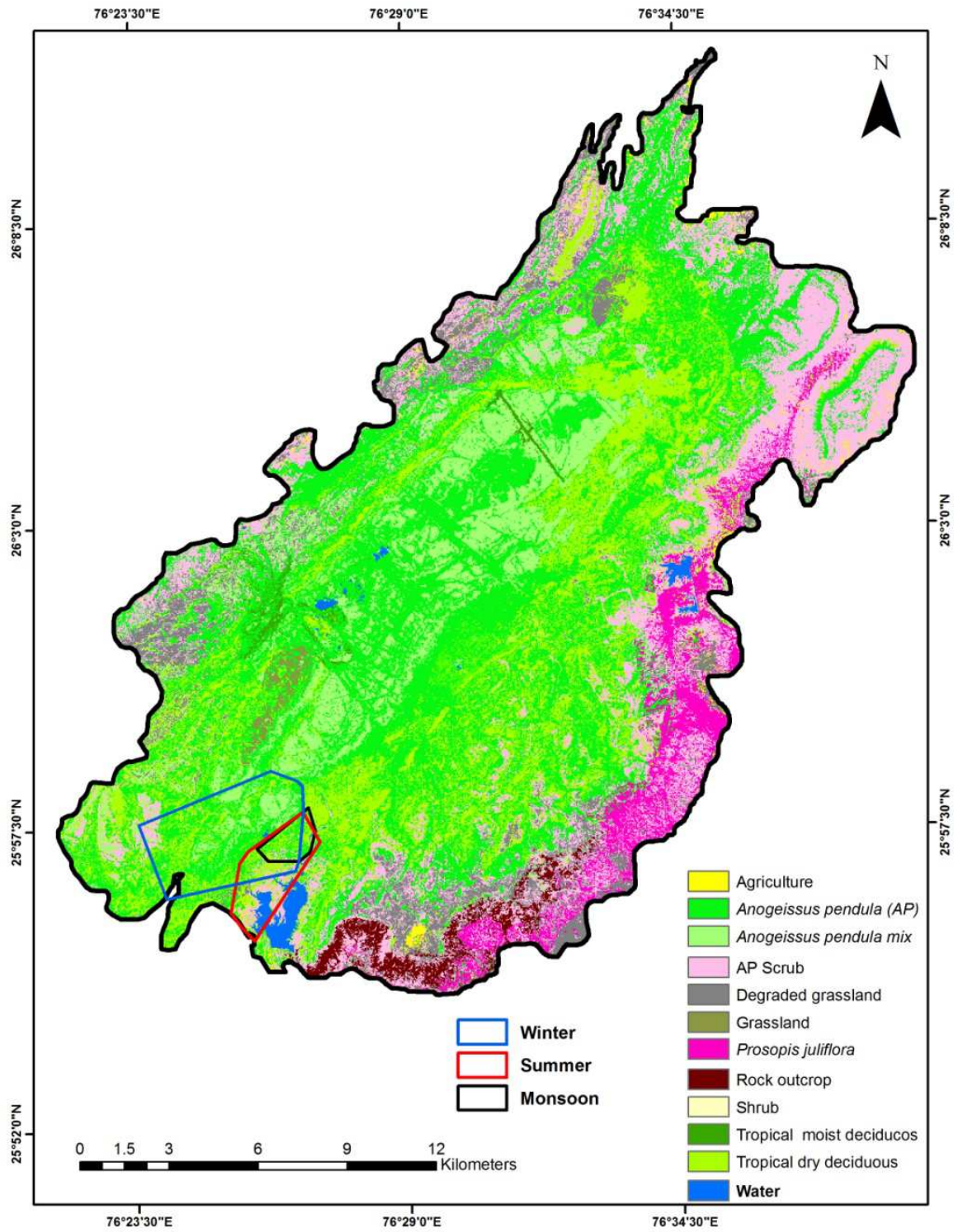
Map 6: Seasonal home range of Patwa Bawari female.



**Map 7: Seasonal home range of Rajbag female.**



**Map 8: Showing seasonal home range of Guda female.**



**Table 1: Place of radio-collaring and frequency of collars mounted on wild pigs in Ranthambore National Park.**

<b>Date</b>	<b>Sex</b>	<b>Location</b>	<b>Frequency (MHz)</b>
04.04.2008	Male 1	Kundal	151.340
06.04.2008	Female 1	Kundal	151.620
08.04.2008	Female 2	Rajbag	151.800
26.01.2009	Male2	Malik Talab	151.510
27.01.2009	Female 3	Patwa Bawari	151.780
28.01.2009	Female 4	Rajbag	151.860
30.01.2009	Female 5	Guda	151.600

**Table 2: Tracking period, number of radio-locations and home range of wild pigs in Ranthambore National Park.**

<b>Animal</b>	<b>Place</b>	<b>No. of radio-locations</b>	<b>Tracking period</b>	<b>100% MCP (km<sup>2</sup>)</b>
Female 1	Kundal	31	Apr 08 - Jul 08	14.3
Female 2	Rajbag	25	Apr 08 - Jul 08	0.5
Male 2	Lakarda	26	Jan 09- May 09	18.5
Female 3	Patwa Bawari	133	Feb 09- Jan 10	24.3
Female 4	Rajbag	139	Feb 09 - Jan 10	6.5
Female 5	Guda	136	Feb 09 - Jan 10	21.5

**Table 3: Home range of wild pigs collared in Patwa Bawari, Rajbag and Guda areas.**

Place	No. of radio-locations	Home range (km <sup>2</sup> )			
		100%MCP	95%MCP	75%MCP	50%MCP
Patwa Bawari	133	24.3	19.3	13.4	4.2
Rajbag	139	6.5	3.8	0.6	0.4
Guda	136	21.5	6.0	1.6	0.5

**Table 4: Seasonal variation in home range of wild pigs at 100% MCP in Patwa Bawari, Rajbag and Guda areas.**

Place	Home range (km <sup>2</sup> )			
	Annual	Winter	Monsoon	Summer
Patwa Bawari	24.3	8.8	2.0	4.4
Rajbag	6.5	4.3	3.3	0.8
Guda	21.5	15.9	2.0	6.3

**Table 5: Seasonal variation in Fixed Kernel home range of wild pigs in Patwa Bawari, Rajbag and Guda areas.**

Season	Fixed Kernel (%)	Home range (km <sup>2</sup> )		
		Patwa Bawari	Rajbag	Guda
Summer	95	3.8	0.9	5.5
	75	1.1	0.2	1.5
	50	0.5	0.1	0.8
Winter	95	7.6	2.5	8.1
	75	1.8	0.6	2.4
	50	0.8	0.3	1.5
Monsoon	95	1.7	4.4	3.1
	75	0.5	1.2	1.2
	50	0.2	0.5	0.4
Annual	95	14.0	1.9	4.4
	75	3.8	0.5	1.4
	50	1.2	0.2	0.7

**Table 6: Home range of wild pigs using MCP and Fixed Kernel in Patwa Bawari, Rajbag and Guda areas.**

Range	Home range (km <sup>2</sup> )		
	Patwa Bawari	Rajbag	Guda
<b>100% MCP</b>	24.3	6.5	21.5
<b>95% MCP</b>	19.3	3.8	6.0
<b>75% MCP</b>	13.4	0.6	1.6
<b>50% MCP</b>	4.2	0.4	0.5
<b>95% Kernel</b>	14.0	1.9	4.4
<b>75% Kernel</b>	3.8	0.5	1.4
<b>50% Kernel</b>	1.4	0.2	0.7

**Table 7: Home range of wild pigs studied in different countries.**

<b>Author</b>	<b>Country</b>	<b>Boar (km<sup>2</sup>)</b>	<b>Sow (km<sup>2</sup>)</b>
Kurz and Marchinton (1972)	Upper coastal plain of South Carolina	979 acre	58 acre
Singer <i>et al.</i> (1981)	Great Smoky Mountains National Park, Tennessee.	3.5	3.1
Baber and Coblentz (1986)	Santa Catalina, California	2.04	0.90
Saunders and Barry Kay (1996)	Sunny corner, New South Wales	10.7	4.9
Saunders and Barry Kay (1996)	Kosciusko National Park, New South Wales	35.0	11.1
Caley (1997)	Tropical habitat, New Zealand	33.5	24.1
Adkins and Harveson (2007)	Chihuahuan Desert, Texas	48.3 ± 4.4	34.0 ± 4.4
Gaston <i>et al.</i> (2008)	Lowndes County Wildlife Management Area, Alabama	403.6± 65.6 ha	278.6± 64.5 ha
Friebel and Jodice (2009)	Congaree National Park, South Carolina, USA.	218 ± 43 ha	191 ± 31 ha

**Annexure I**

**Activity pattern of radio-collared wild pigs**

**Date:** .....

**Range/Locality:** .....

Frequency	GPS location	Time		Activities							Distance from	
		From	To	Feeding	Digging	Wallowing	Moving	Water	Resting	Others	Water	Habitation

**Activities/Remarks:** Feeding - F; Sleeping - S; Moving - M; Suckling - SK; Resting - R

**Plate 1: Radio-collared wild pig with harness in Ranthambore National Park.**



**Plate 2: Radio-collared wild pig resting in Ranthambore National Park.**



**Plate 3: Mounting radio-collar on wild pig and monitoring physiological parameters.**



**Plate 4: Mounting radio-collar and monitoring physiological parameters.**



**Plate 5: Measuring body weight of an immobilized wild pig fitted with collar.**



**Plate 6: Monitoring physiological parameters of radio-collared wild pig.**



**Plate 7: Testing transmitter and monitoring physiological parameters.**



**Plate 8: Pouring water on immobilized wild pig for thermo-regulation.**



**Plate 9: Radio-collared wild pig with complete sedation.**



**Plate 10: Reviving radio-collared wild pig in Kundal area.**



**Plate 11: Radio-collared wild pig with collaring team.**



**Plate 12: Tracking radio-collared wild pigs.**



**Plate 13: Radio-collared wild pig with its sounder.**



**Plate 14: Radio-collared wild pig resting with its group.**



## **Chapter 7**

### **Assessment of the nature and extent of human-wild pig conflicts: Qualitative and quantitative assessment of crop damage by wild pigs in different seasons**

#### **7.1 Introduction**

In India, exponential increase in human population during the last five decades has caused tremendous pressure on almost all the natural resources including forests and wildlife. Most of the protected areas are fragmented and disturbed from human activities, cattle grazing and exploitation of resources. Unaware about the future natural repercussions, vast areas of forests, marginal lands, pastures and wastelands were brought under cultivation in order to sustain increased demand of cereals and other food products. The process of encroachment on forest land is still continuing (The State of Forest Report, 1995). The situation in rural areas is very much characterised by irrational and unsustainable land use pattern.

The dictum that “nothing operates in a vacuum,” is especially applicable to the management of human-wildlife conflicts. We live and work in environments that are continually being reshaped by social, cultural, and political forces. Human-wildlife conflict occurs when the needs and behaviour of wildlife impacts negatively on the well-being of humans or when human well-being negatively impacts the existential needs of wildlife. Human-Wildlife Conflict (HWC) is fast becoming a serious threat to the survival of many endangered species in the world. According to world conservation union (world park congress 2003), it occurs when wildlife requirements overlap with those of human populations, creating costs to residents and wild animals. Direct contact with wildlife occurs in both urban and rural areas, but it is generally more common inside and around protected areas, where wildlife population density is higher and animals often stray into adjacent cultivated fields or grazing areas.

Human-wildlife conflict is a growing problem for communities located at the borders of protected areas. Such conflicts commonly take place as crop-raiding events by wild animals, among other forms (Ogra and Badola, 2008). Wild animals often destroy standing crops, causing economic losses to farmers. Crop and wildlife damage are becoming serious for many Indian protected areas. Agricultural crop damage by locally over-abundant wildlife populations has been widely reported from many parts of the country. Crop depredation by nilgai, blackbuck and wild boar have also been widely reported from Rajasthan (Rajpurohit, 1993), Haryana (Chauhan and Sawarkar, 1989; Chauhan and Singh, 1990 and Singh, 1994), Maharashtra (Indurkar *et al.*, 1994; Mankadan and Rahmani, 1994 and Sinha and Jha, 1994), Madhya Pradesh (Chandra, 1994; Dwivedi, 1994; Singh, 1994 and Chauhan and Rajpurohit, 1996), Gujarat and Punjab, but data on nature and extent of damage are required to be documented scientifically. Due to above damage problems, conflict between man and wildlife is constantly increasing and thus, acceptance of conservation ideals by people is greatly affected.

The wild pig (*Sus scrofa*) is one of the most widely distributed large mammals. It has always been associated itself with man, and successfully utilises the human altered landscape (Fadeev, 1981 and Erkinaro *et al.*, 1982). Being a resilient and fast breeding animal, it is capable of expanding and establishing its population in new areas (Erkinaro *et al.*, 1982 and Ahmed, 1991). The species is also known for its biological and ecological plasticity (Tisdell, 1982 and Ramdas, 1987).

Agricultural crop depredation by wild animals is a major problem in many parts of India, and wild pig is one such species causing extensive damage. Wild pigs raid crops and utilise the agro-ecosystem for food resource and shelter. The wild pigs notoriety as a crop pest is universal (Tisdell, 1982). Damage to the agricultural crops by wild boar in peripheries of forest areas has become a problem of severe nature in the recent past. This is mainly because of rapid multiplication of this species and its wide preference for habitat. Presently the wild pig populations are fragmented and relatively isolated all over. Some of these isolated populations became locally overabundant and depend upon agricultural crops especially in and around protected areas and managed forests - village interface areas for a major part of their food requirement.

There is paucity of information on ecology and conflict aspects of wild pigs from Indian sub-continent; the available information is of general nature and fragmentary (Anonymous, 1890; Mason, 1893; Brander, 1923; Ali, 1927; Morris, 1929; Rao, 1957; Schaller, 1967; Santaipillai and Chambers, 1982; Prater, 1980; Tiwari, 1985; Shafi and Khokhar, 1986; Ramachandran *et al.*, 1986; Ramdas, 1987; Ahmed and Samant, 1989, 1991). In the western ghats of Maharashtra state, man and wild pigs interaction has been briefly studied by Ahmad (1991).

The problem of crop damage by wild pigs has been widely reported from Rajasthan and Madhya Pradesh (Rajpurohit and Chauhan, 1996, 1998; Chhangani and Mohnot, 2004 and Chauhan *et al.*, 2009). According to Mackin (1970), Andrzejwski and Jezierski (1978) and Genov (1981), the damage to crops increases when there is less natural food available in forest and artificial feeding of wild pigs could reduce crop damage. Besides agricultural crops, it causes damage to ground vegetation, orchards, forest plantations and possibly acts as carrier of some infectious diseases. As a result, there has been increasing trend in the human-wild pigs conflict in and around protected areas, managed forests and human settlements throughout the country. Despite of this fact, management of this species hitherto has not been attempted in India because the information available on ecology and behaviour is inadequate for management of this species. This task has become even more difficult and challenging in situations where people's interests come in way of wildlife needs. Consequently, people have developed antagonistic attitude towards the wild pigs and which is adversely affecting the conservation efforts for endangered species are also badly affected everywhere.

Thus, man-wildlife conflicts have assumed different dimensions at the interface of wildlife habitats and human use dominated landscape. Though improvement in agricultural technology and practices and rural community development, approaches to the eco-development planning and integrated forest management practices are in progress in the areas where human-wildlife conflicts exist. However, these measures alone will not help attain the long term solution to the above conflicts leading to balanced natural system.

Crop raiding can reduce farmers' tolerance towards wildlife. Despite higher human population densities in rural areas, and more rapid conversion of forest to farmland, much less is known about crop raiding in Asia than in Africa. In and around Kerinci Seblat National Park, Sumatra, farmers considered either the wild boar (*Sus scrofa*) (80%) or the pig-tailed macaque (*Macaca nemestrina*) (20%) as the two most destructive crop pests. From 5125 crop raids by 11 species of mammal, most raids were indeed made by the wild boar (56%) and the pig-tailed macaque (19%). For all species combined, temporal crop raiding peaks were positively correlated with periods of high rainfall. Spatially, most crop raids occurred nearest to the forest edge and the local guarding strategies used were ineffective. However, raids by wild boars were more extensive than raids by pig-tailed macaques (Linkie *et al.*, 2007).

Strategies for reconciling human needs and conservation interests in areas abutting nature preserves are critical to the success of conservation plans. Crop depredation by wildlife can occur more frequently. Over the years farmers have developed a variety of measures such as fencing, culling, dogs, firecrackers, fire and drum beating to chase away pest species and reduce the crop loss by wild animals. Today, many crop raiding species are protected by laws and are focal point for conservation, the need for effective and long term control method is felt. Some of control measures include physical barriers, selective culling and environmental control methods such as providing better habitat in the interior of forest, away from human habitation.

According to Mackin (1970), Andrzejwski (1978) and Genov (1981), the damage to crops increases when there is less natural food available in forest and artificial feeding of wild pigs could reduce crop damage. Hone and Atkinson (1983) reported fencing to control feral pig movement. They suggested fencing as an effective technique and also use of techniques to trap wild pigs has the potential to develop as effective applicable management tool. These days, electric fencing is becoming one of the common methods to prevent crop loss from wild animals by private farmers and government agencies. In predominantly agricultural and densely populated country like India, conflicts between humans and wild animals are frequent, and preventing conflict should be conservation priorities. Poisoning campaign was adopted to

eliminate wild pigs in the sugarcane area of Pakistan (Shafi and Khokhar, 1986). Reduction in feral pig density by snaring has been reported by Anderson and Stone (1993) and Choquenot *et al.* (1993). Development of trapping technique to manage wild pigs has the potential to develop as effective applicable management tool. In and around protected areas, the farmers employ different crop protection measures to protect their farm from wild pig raids. They manually guard their farms, use ingenious noise making systems, fire crackers and even guns to create psychological barrier, to physically isolate wild pigs from farms (Ahmed, 1991). At times pig bombs are also employed to eliminate wild pigs.

Very little scientific information is available on the genesis of wildlife damage problems and control aspects in different states. Only a part of information on damage problems has been documented, which is also not systematically elaborated. Even though damage causing species may be the same, problems vary from one state to another and at different locations in the same state depending on habitat type and prevailing circumstances. At the present, various wildlife damage problems are subjectively and vaguely defined. Due to which problem mitigation strategies are haphazard. Scientific information on the genesis of wildlife damage problems and their control aspects are not properly documented.

Despite local efforts to control the wild pigs, it continues to remain a problem animal. The propensity of wild pigs to overcome deterrents is a behavioural adaptation, about which very little is known. Wild pigs getting used to firework bluff is again a behavioural adaptation acquired after learning that the noise is not physically harmful. This aspect of behaviour makes it a difficult animal to manage. There was no empirical data that could help us understand how wild pigs develop behavioural adaptation, which has enabled it to use agro-ecosystem despite crop protection measures. So it is important to understand the behaviour of wild pigs to use agro-ecosystem, nature and extent of human-wild pig conflict and assess qualitatively and quantitatively the damage to agricultural crops in and around Ranthambore National Park.

## 7.2 Methods

In order to collect information on the human-wild pigs conflicts, a reconnaissance survey was conducted in and around the Ranthambore National Park. Information on nature and extent of human-wild pig damage problems was collected from the villages located in and around protected areas. Wild pigs-human conflict: human casualties by wild pigs and nature and extent of crop damage problem has been evaluated based on the information collected from the office record of forest department, questionnaire survey of the villages and interview of the victims or their families and analysis of human casualty cases. Field managers were also contacted to know about the gravity of the problem in their areas of jurisdiction.

In order to investigate the population trends, past and present status of wild pig and human dimension of the study, survey research method was employed as described by the Raj (1972). Stratified random sampling was adopted. The interviews were conducted in a cordial atmosphere. The questions were direct and simplified depending upon the respondent. The language used was vernacular and wording was simple. The respondent was given the opportunity to answer in his own terms and his own frame of reference. Rapid assessment by surveying villages was carried out to find out spatial distribution of the problem. Extent of area and productivity of various crops grown was recorded. Since there was no compensation scheme for crop damage by wild animals, crop raiding cases were invariably not reported to the forest department.

Prior to conducting the survey in the villages, wildlife damage problem issues were discussed with the forest department officials and staff. Based on their information, villages in the periphery of the park were selected for conducting the study. The selected villages were visited to collect the information on the area profile, human casualties, and circumstances of attacks, and compensation paid, agricultural cropping pattern, and nature and extent of crop damage by wild pigs, collection of non-timber forest produce and fuel wood by the villagers and traditional control methods etc. in well-designed questionnaire formats through interaction with local people. Broadly, the formats include information on problem area and species, nature and extent of damage

including agricultural crop damage; landuse practices and traditional control methods etc. (**Annexure I**).

### **7.3 Crop damage assessment**

Information on crop damage by wild pigs and other animals was collected. Magnitude of crop damage problem in spatial terms was determined. This required collection of primary data on seasonal basis and review of available information on the distribution, relative abundance, and activity pattern of pigs in relation to crop damage problem. Information on 'rabi' and 'kharif' crops, their sowing and harvesting time and field locations and sizes was collected in the formats.

To assess crop damage qualitatively and quantitatively, 'control' and 'un-control' plots were used and randomly laid in crop fields. For this, eighty eight 'control' plots and eighty eight 'un-control' plots of 2m x 2m dimension each were randomly laid in crop fields of six different villages to assess the damage to rabi and khariff crops during December 2006 to March 2008. To fence these plots, wire mesh of one inch mesh openings were used so that no damage could take place inside. These 'control' plots were constructed in grain fields immediately after the sowing to avoid trampling of sprouting plants. Similarly in all these fields, 'un-control' plots of 2m x 2m were marked on the ground using small pegs. Information on crop phenology, crop damage, number of plants eaten or damaged through trampling, fighting or resting and nesting out of total plants and part eaten or damaged, within each plot was recorded. After maturation of crops, crops within the 'control' plots and 'un-control' plots were harvested. Grains from the harvested crops were thrashed out and weight was taken. The husk part was also weight. Similarly the grains and husk of the 'un-control' plots was also weight. The crop yield difference between 'control' and 'un-control' plots was calculated to know the extent of losses to different crops. An average yield difference was also calculated for all the plots in a given field to calculate the losses.

## 7.4 Results

In the periphery of Ranthambore National Park, villages were surveyed and information on human-wild pig conflict, attacks on humans, agricultural crop pattern, nature and extent of damage to agricultural crops, time of depredation and protection methods was collected. Out of 90 villages located in the periphery of the park, 41 villages were surveyed and there were 236 respondents. Most of these villages were located within two kilometres from the park boundary and they were reported to have severe crop damage problem. Among 41 villages, thirty two villages were located within 2 km from the park boundary, five villages were located within 3-5 km, and four villages were within 6-10 km. Some of the worst affected villages due to wild pigs were Indala, Khatuli, Padara, Jaitpur, Mai, Kushalpura, Chhan, Halonda, Ulliyana, Anda and Shyampura. The list of the villages which were surveyed to assess the human-wild pig conflict, are given in **Table 1**.

### 7.4.1 Wild pig population

One good estimate of wild animal's population trends is to study population over a long period or to analyse data available over 10-15 years. Besides, the viable approach is to elicit information from local people. Local people were interviewed and information on past and present status of wild pig was elicited. A large majority of local people reported that wild pig which used to occur less frequently in past, were now very common and population is increasing.

The opinion of the 236 respondents regarding the population trends of wild pig in the study area revealed that about 75% landholders felt that wild pig population was on increase in the recent past. Out of total, very few respondents (8.1%) were non-responsive regarding wild pig population. There were few pockets in the study area where respondents felt that population was slightly declined, it became less by 3.6%. This could be due to movement of wild pig from such areas to other areas or due to some disease(s) wild pigs were dying and perhaps this could be a temporary situation. About 3.4% expressed ignorance about the wild pig number in their area.

However with better management and increased protection, though wild pig population had been fluctuating and it remained more or less stable over the years from 1974 to 2002 as shown in the Management plan of Ranthambhore Tiger Reserve (**Table 2**). The number of wild pigs was as low as 300 in the year 1974, and it increased to 3196 in 1999.

#### **7.4.2 Human casualties**

In the study area, there were few incidents of wild pig attack on humans. During the study period i.e. 2005-2009, a total 13 human casualties were caused by wild pigs in nine villages, namely, Neemali, Halonda, Bhid, Gopalpura, Katuli, Mai, Indala, Mordungari and Sherpur (**Table 3**). Wild pigs accounted for human injuries only; there were no death cases. All these cases were verified while interviewing respondents in different villages. In Neemali, Katuli, Mai and Mordungari villages, two cases (15.38%) occurred in each village, followed by Halonda, Bhid, Gopalpura, Indala and Sherpur where only one case (7.69%) occurred in each village.

Wild pigs were responsible for injuring 8 males, and 5 females in these villages. Among victims, there were only two male children. As such there was no trend of increase or decrease in human casualties in these years. In Neemali village, a lady and her five year son were attacked in broad daylight a few metres from their house in the fields (**Plate 1 and 2**).

#### **7.4.3 Place of casualties**

Wild pigs were responsible for maximum human casualties in crop fields (n=9, 69.2%), followed by forest (n=2, 15.4%) and two incidences occurred in the vicinity of villages (15.4%).

#### **7.4.4 Age of victims**

Out of total 13 human casualties by wild pigs, age group of all the 13 cases was recorded while interviewing respondents in different villages. Among these cases, highest number of 7 human casualties occurred in the age group of 41-50 years. There were 2 casualties each in the age group of 31-40 years and 21-30 years and two children of less than 12 years.

#### **7.4.5 Time of attacks**

The time of attacks by wild pigs was recorded for all the cases. Highest number human casualties (n=5) by wild pigs occurred between 0801-1200h, followed by 3 cases between 1601-2000h and two cases between 0401-0800h. There was only one injury case each between 1201-1600h, 2001-2400h and 0001-0004h.

#### **7.4.6 Agricultural practices**

The people residing in and around Ranthambore National Park were found to be mainly dependent on agriculture and livestock. The staple crops grown in this region were wheat, bajra, maize and jowar. Millets such as guar and urad were also cultivated. Til and mustard also constituted the large proportion of cultivated land. Til, jowar, urad, groundnut and gram crops were grown especially by those farmers who had large land holding than average. Chilli was also one of the major crops in this area. Groundnut and gram were also sown in small areas near the villages and such cultivation was far less. In the areas where wild pigs were found to move frequently and raid fields penetrating deep into the crops, groundnut and gram cultivation had been abandoned. The irrigation was generally rain dependent and some people had dug wells in their fields for irrigation purpose.

There were two major crops in the region, the 'rabi' crops and 'kharif' crops. Different agricultural crops grown in villages are shown in **Table 4**.

**‘Rabi’ Crops:** Also known as winter crops were mainly the crops depended on ground water and irrigation. The ‘rabi’ crops grown were wheat (*Triticum aestivum*), mustard (*Brassica campestris*), gram (*Cicer arietinum*) and til (*Sesamum indicum*). These crops were cultivated in the month of October and November and were harvested in the months of March and April.

**‘Kharif’ Crops:** The ‘kharif’ crops cultivated were maize (*Zea mays*), bajra (*Pennisetum glaucum*), jowar (*Sorghum bicolor*), groundnut (*Arachis hypogaea*), urad (*Vigna mungo*) and chilli (*Capsicum annum*). These were rain fed crops sown in the month of June and July, and harvested in the month of September and October.

#### **7.4.7 Cropping pattern**

According to all 236 respondents, the main crops grown in villages were wheat, maize, gram, mustard, bajra, jowar, chilli, til, groundnut and urad. During the survey, we found that all the respondents interviewed were growing wheat, bajra and mustard (**Figure 1**). Out of total respondents, 95 respondents were growing jowar, 65 respondents were growing chilli, 70 respondents were growing til, 60 respondents were growing gram, 53 respondents were growing groundnut and nearly 40 interviewers were growing urad.

#### **7.4.8 Crop productivity**

In the study area, the major crop growing seasons were found to last for about 150 days. According to respondents, the average land holding per individual was very small, it was about 2.5 bigha per household. The average production of wheat per bigha was reported to be 3.5 quintals, average yield of mustard per bigha was 1.30 quintals, bajra per bigha was 4.0 quintals, jowar per bigha was 3.75 quintals, chilli per bigha was 10 quintals and average yield of til per bigha was one quintal. The damage caused to various agricultural crops was found to be of varying extent.

#### 7.4.9 Agricultural crop damage

Wild pigs showed diurnal activity, but they were more active in night time. They were reported to come out of forest in the late evening or night time and invade crop fields in groups to feed on crops.

All the respondents from 41 villages were interviewed to assess damage to agricultural crops by wild pigs. The villages situated within 2 km from the park boundary were Mai Khurd, Niwadi, Goth, Swalpur, Gopalpura, Shayampura, Halonda, Neemali, Pawndi, Anda, Khandoj, Chan, Padara, Ulliyana, Jaitpur, Jamulkhera, Ramsinghpura, Talawada, Kachala, Mohanpura, Khawa, Bhid, Mukundpura, Khushalipura, Olawada, Khandewal, Naipur, Banpur, Indala, Sawta, Katuli and Sherpur. The villages situated within 3-5 km from the park boundary were Pilandi, Kundera, Gothra, Barnwada and Dabich. Whereas the villages situated within 6-10 km from the park boundary were Surwal, Pipalda, Bodna and Sonkuch. Locations of these villages are shown in **Map 1**.

Agricultural crop raiding by wild pigs, individual or group of animals, caused severe damage due to extensive feeding activity at one or many sites. Crop fields which were located in close proximity of forests were badly affected. Wild pigs and nilgai were the main crop depredating species. Wild pigs were found to cause extensive damage by uprooting plants with their snout and trampling. Crops most affected were gram and wheat. When wild pigs were found to visit crop fields occasionally, damage to crops was less severe compared to raiding, but losses could be significant to farmers. Plants could cope up with the damage and rejuvenate. Damage to some crops such as *Cicer arietinum* and *Sorghum* crops, in early growth stages might be beneficial as the damaged area of plants sprout profusely. But it could also result in stunted growth and poor quality of yield, if the damage took place in older growth phases. Generally this type of damage was reported to be caused by ungulates and small mammals.

Wild pigs were found to cause damage to agricultural crops in variety of ways. Damage to crops was caused by rooting, trampling, eating crops and wallowing

activities of wild pigs. The extent of damage was found to fluctuate seasonally, degree of infestation, efficacy of control measures etc. Of the 41 villages sampled, 30 villages were subject to annual crop losses by wild animals.

#### **7.4.10 Assessment of crop damage**

To assess and quantify the agricultural losses by wild pig was found not very easy. Although respondents reported seven crop raiding species, namely, nilgai, wild pig, sambar, chital, chinkara, porcupine and sloth bear but nilgai and wild pigs were the main crop raiding species (**Figure 2**). According to 236 respondents, the mean percent damage to agricultural crops by nilgai, wild pig, deer, chinkara and other species was reported to be 42%, 37.8%, 9.9%, 5% and 5% respectively in peripheral villages.

Damage to wheat, maize, gram, mustard, bajra, jowar, chilli, til, groundnut and urad crops as reported by respondents, was of varying extent (**Figure 3**). The percent damage to groundnut crop as reported by 53 respondents ranged from 30-80% and the mean percent damage was found to be the highest ( $43.3 \pm 9.3\%$ ). Damage to gram crop as reported by 60 respondents ranged from 25-60% and the mean percent damage was found to be  $37.3 \pm 6.98\%$ . According to 95 respondents, damage to jowar crop ranged from 15-100% and the mean percent damage was  $31.21 \pm 13.21\%$ . According to 236 respondents, damage to bajra crop ranged from 10-80% and the mean percent damage was  $30.1 \pm 12.83\%$ . Damage to til crop as reported by 70 respondents ranged from 10-100% and the mean percent damage was found to be  $28.1 \pm 13.89\%$ . Whereas damage to wheat crop as reported by 236 respondents ranged from 5-60% and the mean percent damage was found to be  $27.9 \pm 9.9\%$ . Damage to urad crop as reported by 40 respondents ranged from 10-35%. According to 236 and 65 respondents, damage to mustard and chilli crops ranged from 5-50% and 5-30% and the percent mean damage was  $9.15 \pm 5.57\%$  and  $9.07 \pm 4.32\%$  respectively.

#### 7.4.11 Village-wise crop damage

Assessment of wheat crop damage was done in villages located at varying distance from the park boundary. The villages situated within 2 km from the park boundary were Mai Khurd, Niwadi, Goth, Swalpur, Gopalpura, Shayampura, Halonda, Neemali, Pawndi, Anda, Khandoj, Chan, Padara, Ulliyana, Jaitpur, Jamulkhera, Ramsinghpura, Talawada, Kachala, Mohanpura, Khawa, Bhid, Mukundpura, Khushalipura, Olawada, Khandewal, Naipur, Banpur, Indala, Sawta, Katuli and Sherpur (**Table 5**). According to 191 respondents in these villages, loss to wheat crop due to wild pigs ranged from 20-60%; the mean percent damage was  $29.6 \pm 9.19\%$ . In Pilandi, Kundera, Gothra, Barnwada and Dabich villages, situated between 3 and 5 km from the park boundary, the damage to wheat crop ranged from 10-30% according to 25 respondents; the mean percent damage was  $20.2 \pm 6.84\%$ . Whereas the villages situated within 6-10 km from the park boundary, namely, Surwal, Pipalda, Bodna and Sonkuch, the damage to wheat crop ranged from 5-25% as reported by 20 respondents; the mean percent damage was  $11.66 \pm 2.5\%$ .

For the assessment of damage to gram crop, Mai Khurd, Swalpur, Shayampura, Halonda, Neemli, Ulliyana, Ramsinghpura, Talawara, Olawara and Sherpur villages situated within 2 km from the park boundary were selected. According to 53 respondents, damage to gram crop ranged from 25-70% in these villages (**Table 5**). The mean percent damage to gram crop was  $38.3 \pm 6.63\%$ . In Kundera village situated within 3-5 km from the park boundary, the damage to gram crop according to 7 respondents was found to range from 25-35%; the mean percent damage was  $29.2 \pm 3.45\%$ . In Gopalpura, Halonda, Anda, Ulliyana, Talawada, Mohanpura, Khawa, Khandewal, Indala and Katuli villages situated within 2 km from the park boundary were taken for assessment of damage to til crop. According to 66 respondents, the damage to til crop ranged from 15-100%. The mean percent damage to til crop was  $28.56 \pm 14.19\%$  (**Table 5**). In Kundera village, situated within 3-5 km from the park boundary, the damage to til crop ranged from 20-25% according to respondents.

Damage to bajra crop was assessed in villages located at varying distance from the park boundary (**Table 6**). The villages situated within 2 km from the park boundary were Mai

Khurd, Niwadi, Goth, Swalpur, Gopalpura, Shayampura, Halonda, Neemali, Pawndi, Anda, Khandoj, Chan, Padara, Ulliyana, Jaitpur, Jamulkhera, Ramsinghpura, Talawada, Kachala, Mohanpura, Khawa, Bhid, Mukundpura, Khushalipura, Olawada, Khandewal, Naipur, Banpur, Indala, Sawta, Katuli and Sherpur. According to 191 respondents, the reported loss to bajra crop due to wild pigs in these villages ranged from 20-80%; the mean percent damage was  $32.63 \pm 12.39\%$ . In Pilandi, Kundera, Gothra, Barnwada and Dabich villages, situated between 3 and 5 km from the park boundary, damage to bajra crop ranged from 10-25% according to 25 respondents; the mean percent damage was  $20.2 \pm 6.69\%$ . The villages situated within 6-10 km from the park boundary, namely, Surwal, Pipalda, Bodna and Sonkuch, damage to bajra crop ranged from 10-25% as reported by 20 respondents; the mean percent damage was  $15.5 \pm 3.59\%$ .

For the assessment of damage to jowar crop, Swalpur, Gopalpura, Pawndi, Anda, Ulliyana, Khawa, Mukundpura, Khushalipura, Olawada, Khandewal, Naipur, Banpur, Indala and Katuli villages situated within 2 km from the park boundary were taken. According to 79 respondents, damage to jowar crop ranged from 20-100% in these villages. The mean percent damage to jowar crop was  $32.97 \pm 13.58\%$  (**Table 6**). Kundera village which was situated between 3 and 5 km from the park boundary, damage to jowar crop according to 12 respondents was found to range from 20-30%; the mean percent damage was  $23.75 \pm 3.77\%$ . Pipalda village situated between 6 and 10 km from the park boundary, damage to jowar crop ranged from 15-25% as reported by 4 respondents; the mean percent damage was  $18.75 \pm 4.79\%$ . Whereas for the assessment of damage to groundnut crop, Mai Khurd, Swalpur, Shayampura, Halonda, Neemli, Ulliyana, Jamulkhera, Ramsinghpura and Sherpur villages situated within 2 km from the park boundary were selected. According to 49 respondents, damage to groundnut crop ranged from 30-80% (**Table 6**). The mean percent damage to groundnut crop was  $44.2 \pm 9.1\%$ . In Kundera village, situated within 3-5 km from the park boundary, damage to groundnut crop ranged from 30-35% according to 4 respondents; the mean percent damage was  $36.25 \pm 2.5\%$ .

Damage to urad crop was assessed in villages located at varying distance from the park boundary (**Table 7**). The villages situated within 2 km from the park boundary were

Halonda, Anda, Khandoj, Ulliyana, Jamulkhera, Khawa, Khandewal and Sherpur. According to 36 respondents, damage to urad crop ranged from 10-35%. The mean percent damage to urad crop in these villages was  $29.3 \pm 3.62\%$ . In Kundera village, situated between 3 and 5 km from the park boundary, damage to urad crop as reported by 4 respondents ranged from 10-20%; the mean percent loss was  $15 \pm 4.08\%$ .

For the assessment of damage to mustard crop, Mai Khurd, Niwadi, Goth, Swalpur, Gopalpura, Shayampura, Halonda, Neemali, Pawndi, Anda, Khandoj, Chan, Padara, Ulliyana, Jaitpur, Jamulkhera, Ramsinghpura, Talawada, Kachala, Mohanpura, Khawa, Bhid, Mukundpura, Khushalipura, Olawada, Khandewal, Naipur, Banpur, Indala, Sawta, Katuli and Sherpur villages situated within 2 km from the park boundary were selected. According to 191 respondents, damage to mustard crop due to wild pigs ranged from 5-50% (**Table 7**). The mean percent damage to mustard was  $9.47 \pm 5.81\%$ . In Pilandi, Kundera, Gothra, Barnwada and Dabich villages situated between 3 and 5 km from the park boundary, damage to mustard crop as reported by 25 respondents ranged from 5-15%; the mean percent damage was  $9.4 \pm 2.04\%$ . Whereas in Surwal, Pipalda, Bodna and Sonkuch villages situated between 6 and 10 km from the park boundary, damage to mustard crop according to 20 respondents ranged from 5-10%; the mean percent damage was  $5.75 \pm 1.38$ .

Similarly, damage to chilli crop was assessed in villages located at varying distance from the park boundary. The villages situated within 2 km from the park boundary were Mai Khurd, Goth, Swalpur, Pawndi, Chan, Jaitpur and Naipur. According to 60 respondents, damage to chilli crop in these villages ranged from 5-30% (**Table 7**). The mean percent damage to chilli crop was  $9.4 \pm 4.33\%$ . Whereas in Pipalda village, situated between 6 and 10 km, damage to chilli crop as reported by 5 respondents was found to be 5%.

#### **7.4.12 Damage to phenological stages**

Data collected by interacting with the villagers revealed varying extent of damage to different phenological stages of agricultural crops. Wild pigs showed strong preference for all phenological stages of groundnut, urad, bajra, gram and wheat

crops. On the other hand, mustard crop was rarely eaten. It was damaged mainly by trampling when groups of animals moved through mustard fields. The trails of diggings of wild pigs could be seen in crop field. They were found to excavate plants and roots were exposed; many plants were lying withered or dead. From many other matured plants, nuts were removed by pigs. Presence of wild pigs could easily be identified by their tracks.

Out of 236 interviews in 41 villages, 178 respondents indicated the damage to different phenological stages of crops by the wild pig (**Table 8**). According to respondents, damage to groundnut crop by the wild pig was considerably high, followed by gram, bajra, wheat, urad and til. In case of wheat crop, damage was quite conspicuous during the growth stage and it continued till maturation stage. In case of bajra crop, respondents indicated the occurrence of damage during the sprouting stage and at the time of ripening of corn when the crop was matured and ready to harvest. In case of groundnut and gram, damage was reported to be more as compared to other crops; crop losses occurred just from the sowing time and continued till the harvesting time. Thus wild pigs were found to damage all phenological stages of groundnut and gram crops. Wild pigs dug the roots out by scooping out a depression and fed on groundnuts. There was hardly any remains of groundnuts left as wild pigs generally consumed both shell and nuts. They preferred to feed on groundnut when they were soft and sweet, before the shells hardened.

According to respondents, damage to til and urad crops occurred mainly from the growing to the maturation stage. Extent damage to mustard and chilli crops by wild pigs was less compared to other crops. Highest levels of damages were reported during the matured stage of most of the crops. Damage to chilli crop, out of the mean percent damage i.e. 9.07%, was highest (50%). Damage to wheat, bajra and jowar was 45% each out of the mean percent damage i.e. 27.9%, 30.1% and 31.2% respectively. There was 40% damage each to mustard and gram crops out of the mean percent damage i.e. 9.15% and 37.3% respectively, followed by til, groundnut and urad with 35% damage each of the mean percent damage i.e. 28.1%, 43.3% and 27.9% respectively (**Table 8**).

The study revealed that majority people grew wheat, bajra and mustard. Maximum damages were reported to wheat and bajra crops during the crop maturation time. Damage to wheat and maize crops was highest during seed formation stage when spikes and corn or comb were developed. The time of wheat maturation was coinciding with summer season; there was less availability of food resource and water in forest area. Wild pigs increasingly moved towards easily available food resource like wheat in crop fields and chances of encounter with human was more when people were in crop fields for farming activities. Bajra and wheat plants were trampled more than eaten. In other crops like til and udad, damage was almost the same as it was to wheat crop, while in chilli and mustard damage was very less. In case of crops like groundnut, gram and jowar, damage was high.

#### **7.4.13 Mode of crop damage**

According to respondents, wild pigs were found to cause damage to agriculture crops in different stages of the crop cycle and in variety of ways (**Table 9**). Damage to different crops was mainly due to feeding, digging, trampling, crushing and wallowing activities of wild pigs. Indirect evidences like presence of fecal matter, hoof marks, digging signs and wallowing bed indicated the activities of wild pigs, and also the extent of crop damage. Feeding activity of wild pig was found to be peculiar. Agricultural crops were preferred more during early growth stages, and also during maturation stage. The spikes were nibbled and chewed well. Wild pigs were extensively found to cause damage to crops by their rooting and trampling activities.

Young plants were more susceptible to damage due to trampling activity of pigs. According to respondents, tall and profusely growing crops such as bajra, maize, jowar and mustard were used as bedding sites. Plants were increasingly knocked down which was reported to affect the crop yield. In case of heavy infestation, the damages were often high due to wild pig activities. Rooting or digging by wild pigs was more when fields were irrigated. As indicated by the 53 respondents, maximum damage was reported to growing groundnut.

Damage to different agricultural crops viz. wheat, bajra, mustard, groundnut, gram and urad crops, was caused not only by foraging but also due to various activities of wild pigs such as trampling, digging, wallowing, resting and movement of the animals (**Table 9**). Damage to wheat crop was mainly due to feeding activity of wild pigs (50%), followed by trampling (30%) and uprooting (20%) activities. Similarly bajra crop was found to be damaged mainly due to feeding activity, followed by trampling (20%), uprooting (20%) and wallowing (20%) activities. Mustard crop was mainly damaged due to trampling activity of wild pigs, 20% damage to this crop was due feeding activity. Damage to chilli crop was reported to be the highest (50%) due to trampling activity; 20% damage was due to wallowing and 10% was due to uprooting activity. Groundnut crop was mainly damaged due to feeding (50%) and uprooting (50%) activities. Similarly, damage to gram crop was reported to be mainly due to feeding (50%) and uprooting (50%) activities. Damage to urad crop was highest i.e. 40% each due to feeding and uprooting activities.

#### **7.4.14 Monthly variation**

There was marked monthly variation in the extent of damage to wheat and gram crops by the wild pigs. According to respondents, damage to these 'rabi' crops was found to be persistent right from sowing to harvesting time i.e. from October to March months. Damage to wheat and gram crops was highest during March; it was 40% and 30% of the mean percent damage i.e. 27.9% and 37.3% to wheat and gram crops respectively (**Figure 4**). This level of damage coincided with the harvesting stage of the two crops. During February, damage to wheat and gram crops was 30% and 25% of the mean percent damage, followed by 20% to each crop in January. Gram crop was found to be damaged in October after sowing. Both wheat and gram crops were also damaged during growth phase of plants in November and December.

According to respondents, damage to bajra and jowar crops was persistent during all stages of growth and maturation. These crops were sown in August and harvested in November; the damage was reported from the sowing time to harvest time. Damage to bajra and jowar crops was highest during October; it was 45% and 50% of the mean

percent damage i.e. 30.1% and 31.2% to bajra and jowar crops respectively (**Figure 5**). In November, damage to bajra and jowar crops was 30% and 35% respectively of the total mean percent damage. During sowing and growth stages in August and September, damage to bajra and jowar crops was 5% to 15% of the mean percent damage respectively.

Damages to groundnut, til and urad crops were conspicuous in their sowing, growth and maturation stages; they showed marked monthly variation. According to respondents, damage to groundnut crop was highest before the maturation stage in October; it was 30% of the mean percent damage i.e. 43.3% (**Figure 6**). In November coinciding with maturation and harvesting stages, damage to groundnut crop was 25% of the mean percent damage, followed by levels of damage in September, August and July i.e. 20%, 15% and 10% respectively.

According to respondents, til crop was reported to be highly susceptible to damage from wild pigs. Damage to til crop was high throughout its growth and maturation period; it was highest i.e. 25% each of the mean percent damage of 28.1% during January, February and March respectively (**Figure 6**). During November and December, damage to til crop was reported to be 10% and 15% of the mean percent damage.

Damage to urad crop was reported to be the highest (25%) of the mean percent damage i.e. 27.9% during the maturation stage (**Figure 6**). Damage to urad crop was 20% of the mean percent damage each during September, October and December. During sowing time in August, damage to urad crop was exceptionally high i.e. 15% of the mean percent damage.

#### **7.4.15 Quantitative assessment of crop damage**

The quantitative assessment of crop damage was done in Mei khurd, Halonda, Ulliyana, Kundera, Shayampura and Sherpur villages situated in the periphery of Ranthambore National Park (**Map 1**). By using ‘control’ and un-control’ plots of 2 m

x 2 m each, extent of damage to different agricultural crops was calculated. **Plate 3** showing control plot fenced with wire mesh in wheat field in Padra village. In total, eighty eight 'control' plots and eighty eight 'un-control' plots were randomly laid in crop fields of six different villages and comparison of crop yield of these plots during the harvest time showed varied losses to rabi and kharif crops. **Plate 4 and 5** showing removal of wire mesh from the 'control' plot during harvesting time of wheat in Padra and Katuli villages. **Plate 6** shows separation of wheat grains and husk after harvesting crop from the 'control, plot in Mei khurd village.

The mean productivity of wheat, bajra, mustard, groundnut, gram and urad crops in 'control' and 'un-control' plots was calculated in different villages and shown in **Table 10 and 11**. The extent of seeds/grains losses for each of the crops and the percent losses i.e. yield difference between the 'control' and 'un-control' plots were also calculated. The mean losses per bigha to grains/seeds of wheat, mustard, gram, bajra, groundnut and urad crops due to various activities of wild pigs were estimated to be 56.64 kg, 9.9 kg, 53.49 kg, 105.3 kg, 84.6 kg and 9.56 kg respectively in all six villages (**Tables 10 and 11**). Similarly the mean losses to grains/seeds of wheat, mustard, gram, bajra, groundnut and urad due to various activities of wild pigs were 12.01%, 5.97%, 19.03%, 25.65%, 40.06%, and 35.68% respectively. The levels of damages to 'rabi' and 'kharif' crops calculated using 'control' and 'un-control' plot method were compared with the crop losses as reported by respondents during villages survey (**Table 12**). According to respondents, the mean damage to wheat, mustard, gram, bajra, groundnut and urad was 27.7%, 8.7%, 36.4%, 30%, 43.5% and 24.4% respectively. Though the damages reported by respondents were on higher side, the pattern of damages to different crops was more or less the same. Both the methods indicated highest level of damage to groundnut crop and least to mustard crop.

## 7.5 Discussion

The wild pig is one of the most widely distributed large mammals. It has always been associated itself with man, and successfully utilizes the human altered landscape (Fadeev, 1975; Erkinaro *et al.*, 1982). Wild pigs raid crops and utilises the agro-ecosystem for food resource and shelter. Agricultural crop damage by wild pigs has been widely reported from many states (Rajpurohit and Chauhan, 1996 and 1998). In the periphery of Ranthambore National Park, villages were surveyed to understand the severity of human-wild pig conflict. Out of 90 villages located in the periphery of the park, 41 villages were surveyed and there were 236 respondents.

A total 13 human casualties were caused by wild pigs in Neemali, Halonda, Bhid, Gopalpura, Katuli, Mai, Indala, Mordungari and Sherpur villages located in the periphery during 2005-2009. Wild pigs were responsible for injuring 8 males, and 5 females in these villages. People were found to move extensively inside forest for collection of non timber forest produce and they were engaged more in agricultural fields for farming activity. Perhaps males were exposed more and succumbed to wild pig attacks than the females.

Wild pigs were responsible for more human injuries in crop fields, followed by forest and two incidences occurred in the vicinity of villages. Out of total 13 human casualties by wild pigs, 7 human injuries occurred in the age group of 41-50 years. Perhaps people of this age group were more active and involved in farming activity and other outdoor jobs which exposed them more to encounters with wild pigs and other animals. The time of attacks by wild pigs showed that highest number human injuries occurred between 0801-1200h, followed by 3 cases between 1601-2000h and two cases between 0401-0800h. This could be related to the human activities in the vicinity of villages, crop field and forests in morning time and also activity of wild pigs. Wild pig habitats interspersed with villages and crop fields resulted in frequent encounters with humans. During this period, most of the human injuries by wild pigs occurred in the periphery of the protected areas and a few occurred inside. Most of these attacks were accidental and occurred when these victims ventured into the forests for collection of non-timber forest produce in forests, fuelwood, fodder,

medicinal plants, or to graze their livestock and while working in their crop fields or providing crop protection or moving in vicinity of villages.

### **7.5.1 Crop depredation**

Wild pig populations are fragmented and relatively isolated all over. Some of these isolated populations became locally overabundant and dependent upon agricultural crops especially in and around protected areas or managed forests-village interface areas for a major part of their food requirement. Besides agricultural crops, they cause damage to ground vegetation, orchards, forest plantations and possibly act as carrier of some infectious diseases. As a result, there has been increasing trend in the wild pigs-man conflict in and around protected areas, managed forests and human settlements throughout the country.

The people residing in the vicinity of Ranthambore National Park were found to be mainly dependent on agriculture and livestock. Two major crops sown in the region are 'rabi' crops and 'kharif' crops. According to 236 respondents interviewed, the main crops grown in villages were wheat, maize, gram, mustard, bajra, jowar, chilli, til, groundnut and urad. Out of total, 95 respondents were growing jowar, 65 respondents were growing chilli, 70 respondents were growing til, 60 respondents were growing gram, 53 respondents were growing groundnut and nearly 40 interviewers were growing urad. Damage to the agricultural crops by wild pigs in these areas inflicted a serious problem. This was mainly because of rapid multiplication of this species and its wide preference for habitats.

According to respondents, damage to wheat, maize, gram, mustard, bajra, jowar, chilli, til, groundnut and urad crops was of varying extent. According to respondents, the mean percent damage to agricultural crops by nilgai, wild pig, deer, chinkara and other species was reported to be 42%, 37.8%, 9.9%, 5% and 5% respectively in peripheral villages. The percent damage to groundnut crop as reported by 53 respondents ranged from 30-80% and the mean percent damage was found to be the highest. Crop fields which were located in close proximity of forests were badly

affected. Wild pigs showed diurnal activity, but they were more active during night time. They were reported to come out of forest in the late evening or night time and invade crop fields in groups to feed on crops. The extent and intensity of damage caused by pigs might vary depending upon the cropping patterns, wildlife population density and behaviour, and feed availability in wild habitats (Maikhuri *et al.*, 2000).

Damage to wheat, maize, gram, mustard, bajra, jowar, chilli, til, groundnut and urad crops in villages located at varying distance from the park boundary showed differential extent of damage. According to respondents, loss to wheat crop due to wild pigs in villages located within 2 km from the park boundary ranged from 20-60% with the mean percent damage was  $29.6 \pm 9.19\%$ . Damage to gram and mustard crops in villages located within 2 km from the park boundary ranged from 25-70% and 5-50% respectively. Damage to groundnut crop in villages located within 2 km from the park boundary ranged from 30-80%. In villages, situated between 3 and 5 km from the park boundary, damage to wheat and gram crops ranged from 10-30% and 25-35% and with the mean percent damage  $20.2 \pm 6.84\%$  and  $29.2 \pm 3.45\%$  respectively. The villages situated within 6-10 km from the park boundary, damage to wheat crop ranged from 5-25% with the mean percent damage of  $11.66 \pm 2.5\%$ . Damage to bajra crop in villages within this range of distance varied from 10-25%. Most of the surveyed villages were located within two kilometres from the park boundary showed severe crop damage problem.

Distance of field boundaries from the forest and other habitats was found to be an important factor in determining the likelihood of incursion by wild animals (Hill, 1997, 2000; Hoare, 1999; Kagoro-Rugunda, 2004; Sitati *et al.*, 2005). According to Sitati *et al.* (2005), two aspects of farm location were required to be considered: the nearest food habitat from farm boundaries and the distance between habitat types and field boundaries. Other physical factors or guarding measures had no effect on crop raiding incidence (Sitati *et al.*, 2005). Linkie *et al.* (2007) showed that the spatial patterns of crop raids by pig-tailed macaque raids were not as widespread as those of wild boar, implying that various animals had different extents of raiding. In a field trial. All farms within 50m experienced crop raiding by mammals. However, farms closest to the forest edge were most frequently raided by wild boar, nilgai and sambar individually and by

all species combined. Wild boar instead, acted at night, while other ungulates such as sambar and chital were usually confined to forest cores. The percentage ranked so broadly as distance between reserve boundary and household survey varied from 0-3 km and in general the depredation increased with closer proximity to the reserve (Sekhar, 1998).

Interaction with the villagers revealed varying extent of damage to different phenological stages of agricultural crops. Wild pigs showed strong preference for all phenological stages of groundnut, urad, bajra, gram and wheat crops. Mustard crop was hardly eaten but it was damaged mainly by trampling. Wild pigs were found to excavate plants, and as a result, roots were exposed. Many plants were lying withered or dead. Presence of wild pigs in crop fields could easily be identified by their tracks.

According to respondents, damage to groundnut crop by the wild pig was considerably high during sowing and maturation time, followed by gram, bajra, wheat, urad and til. In case of wheat crop, damage was quite conspicuous during the growth stage and it continued till maturation stage. In case of bajra crop, respondents indicated the occurrence of damage during the sprouting stage and also at the time of ripening of corn when the crop was ready to harvest. Wild pigs were found to damage all phenological stages of groundnut and gram crops. They dug the roots out by scooping out a depression to feed on groundnuts. There was hardly any remains of groundnuts left as wild pigs generally consumed both shell and nuts. Damage to til and urad crops occurred mainly during the growing and maturation stages. Damage to wheat and maize crops was highest during seed formation stage when spikes and corn or comb were developed. Wild pigs increasingly moved towards easily available food like wheat in crop fields and chances of encounter with human was more when people were in crop fields for farming activities.

In Kalakad-Mundanthuri Tiger Reserve, wild pigs identified as major crop pest were also found to cause severe crop losses (Jeyasingh and Davidar, 2003). The number of wild pigs was not correlated with the extent of crop damage. Extent of damage might be a factor of time spent in the paddy field, suggesting that wild pig might raid the paddy field for the habitat requirements rather than their nutritional requirements. The

extent of raiding was found to dependent on the crop availability. Hill (1997) reported that groundnut was raided at all stages of its development from the newly sown seeds to the time when the cobs were mature.

Wild pigs were found to cause damage to agriculture crops in different stages of the crop cycle and in variety of ways. Damage to different crops was mainly due to feeding, digging, trampling, crushing and wallowing activities of wild pigs. Young plants were more susceptible to damage due to trampling activity of pigs. Indirect evidences like presence of fecal matter, hoof marks, digging signs and wallowing bed indicated the activities of wild pigs, and also the extent of crop damage. Agricultural crops were preferred more during early growth stages and also during maturation stage. Young plants were more susceptible to damage due to trampling activity of pigs. When there was heavy infestation, the damages were often high due to activities of wild pigs. Rooting or digging by wild pigs was more at the time when fields were irrigated. Damage to wheat and bajra crops was mainly due to feeding activity of wild pigs, followed by trampling and uprooting activities. Mustard crop was mainly damaged due to trampling activity of wild pigs. Ways of crop damage by wild pigs were determined due to their preference to different crops, activity pattern, shelter and hiding activities and the palatability of different crops.

The changing landuse pattern in the peripheries of Ranthambore National Park due to demographic changes i.e. increasing human population and number of livestock, has adversely affected the wildlife habitats. These biotic pressures forced wild pigs to become homeless and which in turn severely affected their activity and movement pattern and habitat utilization and behaviour leading to increasing human-wild pig conflict. The surrounding agricultural fields in different villages provide good source of forage to wild pigs especially during the monsoon and post monsoon period. So agricultural crop raiding by wild pigs became an important people-protected area interface issue. In the villages located in the vicinity of the Park, wild pigs caused considerable damage to agricultural crops, which resulted in the economic losses and hardships to the affected people.

There was marked monthly variation in the extent of damage to wheat and gram crops by the wild pigs. According to respondents, damage to the 'rabi' crops was found to be persistent right from sowing to harvesting time i.e. from October to March months. Damage to wheat and gram crops was highest during March. Damage to bajra and jowar crops was persistent during all stages of growth and maturation. These crops were sown in August and harvested in November. Seasonal variation in crop raiding incidences was found to be mostly attributed to forage availability. In dry season, farms suffered more crop raiding. Rainfall was found to determine the growth of the farm-bush mosaic that was so attractive (Barnes *et al.*, 2005). It also promoted the growth of maize and it was the maturing maize crop that draws crop raiders (Chiyo *et al.*, 2005). Barnes *et al.* (2007) correlated rainfall frequency with incidence of elephant raiding and found the former to be an important predictor.

The quantitative assessment of crop damage done by using 'control' and un-control' plots in Mei khurd, Halonda, Ulliyana, Kundera, Shayampura and Sherpur villages situated in the periphery of Ranthambore National Park. The mean losses to grains/seeds of wheat, mustard, gram, bajra, groundnut and urad due to various activities of wild pigs were 12.01%, 5.97%, 19.03%, 25.65%, 40.06%, and 35.68% respectively. Though the damages reported by respondents were on higher side, the pattern of damages to different crops remained more or less the same. Both the methods indicated highest level of damage to groundnut crop and least to mustard crop.

Such crop damage activities caused by wild animals were found to be a prevalent form of human-wildlife conflict along protected area boundaries (Naughton-Treves, 1998). The individual economic losses suffered from crop raiding could be relatively high in developing countries because farmers were poor and rarely compensated for their losses (Sekhar, 1998 and Rao *et al.*, 2002). These crop losses could make communities antagonistic and intolerant towards wildlife, which might result in retribution killing of problem species as well as undermining and impeding conservation strategies (Nyhus, Tilson and Sumianto, 2000). However, in order to mitigate this form of human-wildlife conflict more effectively, it was necessary to understand the temporal and spatial factors that could predict crop raiding, and the

effectiveness of current guarding strategies (Sitati *et al.*, 2003; Sitati, Walpole and Leader-Williams, 2005).

Many a times, crop damage incidences were not reported. The reason cited was that no response to their plight had been forthcoming in the past and there was still no provision for compensation. Although human-wild pigs conflict might not be resolved completely but the extent of occurrence of problem could be minimized by taking effective damage control measures and by making easier compensation procedures. To provide relief for the losses occurring in the form of human life, the state government has been paying compensation, but compensation scheme does not exist for damage to agricultural crops. Today, these problems have aggravated beyond tolerable limits and have resulted into direct conflicts between people and wild pigs.

### **7.5.2 Mitigation strategies**

Agricultural fields in different villages provided good source of forage to wild animals especially during the monsoon and post monsoon period. Agricultural crop raiding by nilgai, wild pigs and other animals was found to be an important people-protected area interface issue. In the villages located in the vicinity of protected areas, wild animals were found to cause considerable damage to agricultural crops, which resulted in the economic losses and hardships to the affected people. To provide relief for the losses occurred in the form of human life and agricultural crop damage, the government is paying compensation to affected people in many states.

Many a times, crop damage incidences were generally not reported. Verification of damage was essentially required for obtaining compensation, which remained a matter of concern for affected people. These human-wildlife conflicts could not be contained fully as the wild animals along the fringes of forest were found to come out and increasingly cause extensive damage to crops. But these conflicts could be minimised taking effective wildlife damage control measures by making easier compensation procedures for various damages including agricultural crops.

People should remain alert and vigilant while moving in forests and crop fields especially at the time when wild pigs are active. Use of local protective methods, co-operative guarding of matured crops is necessary.

For protection of agricultural crops, villagers use different traditional methods. Crop guarding using 'machans' or 'huts' in crop fields, live fences, brushwood fencing, trenches and walls was extensively used by farmers to prevent the crop damage. Wire fences with white, flying, flashing ribbons or plastic strips that produce scaring sounds and other frightening devices should be used in and around crop fields. Use of pig-proof barriers for crop protection and elimination or population control strategies for wild pigs in affected areas also required to be experimented. Villagers should avoid cultivating crops which are highly susceptible to damage near forests and should try changing cropping patterns by growing other cash crops.

In some impacted areas, some help in the form of providing crop protection, distributing torch batteries and crackers was reportedly given to scare away wild animals. Apart from guarding and lighting fire in crop fields to scare away wild animals, farmers were also using crop protection methods such as drum beating, crackers and scare-crows. Crop damage by wild pigs, nilgai, monkeys etc. could generally be contained by lighting fire in crop fields and guarding crop fields from elevated platforms during nights with light. These protection strategies in combination were found to considerably help in reducing crop damage.

The forest department might consider providing help for some incentives for crop protection in vulnerably-impacted areas by providing torches and fire crackers to farmers in few places to scare away wild animals from crop fields. Barbed wire fences were also used to contain crop damage by wild pigs in some areas. Crop protection trench with 1m depth, 1.2m breadth and 1m bund height and rubble wall 1.5m height and 1m breadth were the two commonly used barriers for crop protection. If used regularly, these barriers could help protect the crop fields from the wild animals to considerable extent.

Wild pig-proof power fence could be an effective barrier to control crop damage by wild pigs. Besides, a number of traditional methods such as haka, drum or tin beating, driving

away, bursting crackers and scare crows (dummy) were used by farmers for crop protection. Some rich farmers were found to dig trench or erect barbed wire fence around their fields to protect their crops from wild animals. Brush wood fencing was another most common method used by farmers to protect their crops from wild animals. Based on field experience, both mechanical and psychological barriers have been found very effective in controlling movement of wild pigs and thus greatly help in reducing crop damage.

Under the given socioeconomic and political framework, one way to mitigate human-wild pig conflict is to minimize the ill effects of socio-ecological conditions. Education and awareness programs on the ecology and behaviour of wild pigs and on mitigation strategies should be initiated for villagers in affected areas. In the fragmented and degraded forest areas, habitat protection should to be carried out to sustain the existing wild pig population. Discouraging payment of compensation for human casualties within protected areas, and research on ecology and management of wild pigs is proposed.

**Table 1: Villages with wild pig problem, their distance from park boundary and number of respondents.**

<b>Village</b>	<b>Distance from park boundary (km)</b>	<b>No. of Respondents</b>
Mai khurd	0-2	5
Niwadi	0-2	6
Goth	0-2	6
Swalpur	0-2	9
Gopalpura	0-2	6
Anda	0-2	14
Halonda	0-2	7
Neemali	0-2	10
Pawandi	0-2	4
Shayampura	0-2	5
Khandoj	0-2	9
Chan	0-2	5
Padara	0-2	7
Uliyana	0-2	5
Jaitpur	0-2	7
Jamulkhera	0-2	4
Ramsinghpura	0-2	5
Talawada	0-2	4
Kachala	0-2	6
Mohanpura	0-2	4
Khawa	0-2	6
Bhid	0-2	8
Mukundpura	0-2	4
Kushalipura	0-2	5
Olwada	0-2	5
Khandelwal	0-2	4
Naipur	0-2	4
Banpur	0-2	4
Indala	0-2	13
Sawta	0-2	4
Katuli	0-2	4
Sherpur	0-2	5
Pilandi	0-5	5
Kundera	0-5	5
Gothra	0-5	5
Barnawada	0-5	5
Dabich	0-5	4
Surwal	0-10	5
Pipalda	0-10	5
Bodna	0-10	4
Sonkach	0-10	5

**Table 2: Year-wise census of wild pigs in Ranthambhore Tiger Reserve.**

<b>Year</b> <b>1974</b>	<b>Year</b> <b>1977</b>	<b>Year</b> <b>1978</b>	<b>Year</b> <b>1979</b>	<b>Year</b> <b>1980</b>	<b>Year</b> <b>1981</b>	<b>Year</b> <b>1982</b>
300	2237	1800	2278	1941	815	623
<b>Year</b> <b>1984</b>	<b>Year</b> <b>1985</b>	<b>Year</b> <b>1986</b>	<b>Year</b> <b>1987</b>	<b>Year</b> <b>1988</b>	<b>Year</b> <b>1989</b>	<b>Year</b> <b>1990</b>
568	403	342	350	418	466	410
<b>Year</b> <b>1991</b>	<b>Year</b> <b>1993</b>	<b>Year</b> <b>1995</b>	<b>Year</b> <b>1997</b>	<b>Year</b> <b>1999</b>	<b>Year</b> <b>2001</b>	<b>Year</b> <b>2002</b>
632	1088	1825	1936	3196	-	1870

(Source: Management plan Ranthambhore Tiger Reserve)

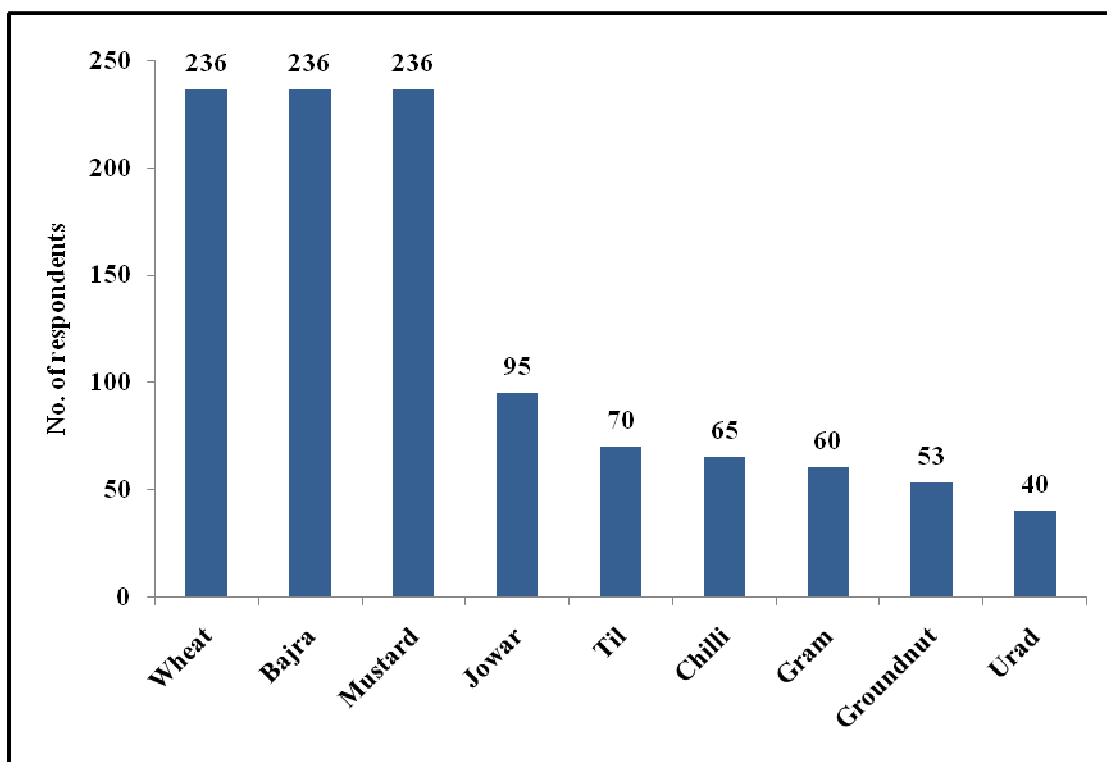
**Table 3: Human casualties by wild pigs in different villages.**

<b>Village</b>	<b>No. of injuries</b>
Neemali	2
Halonda	1
Bhid	1
Gopalpura	1
Katuli	2
Mai	2
Indala	1
Mordungari	2
Sherpur	1
<b>Total</b>	<b>13</b>

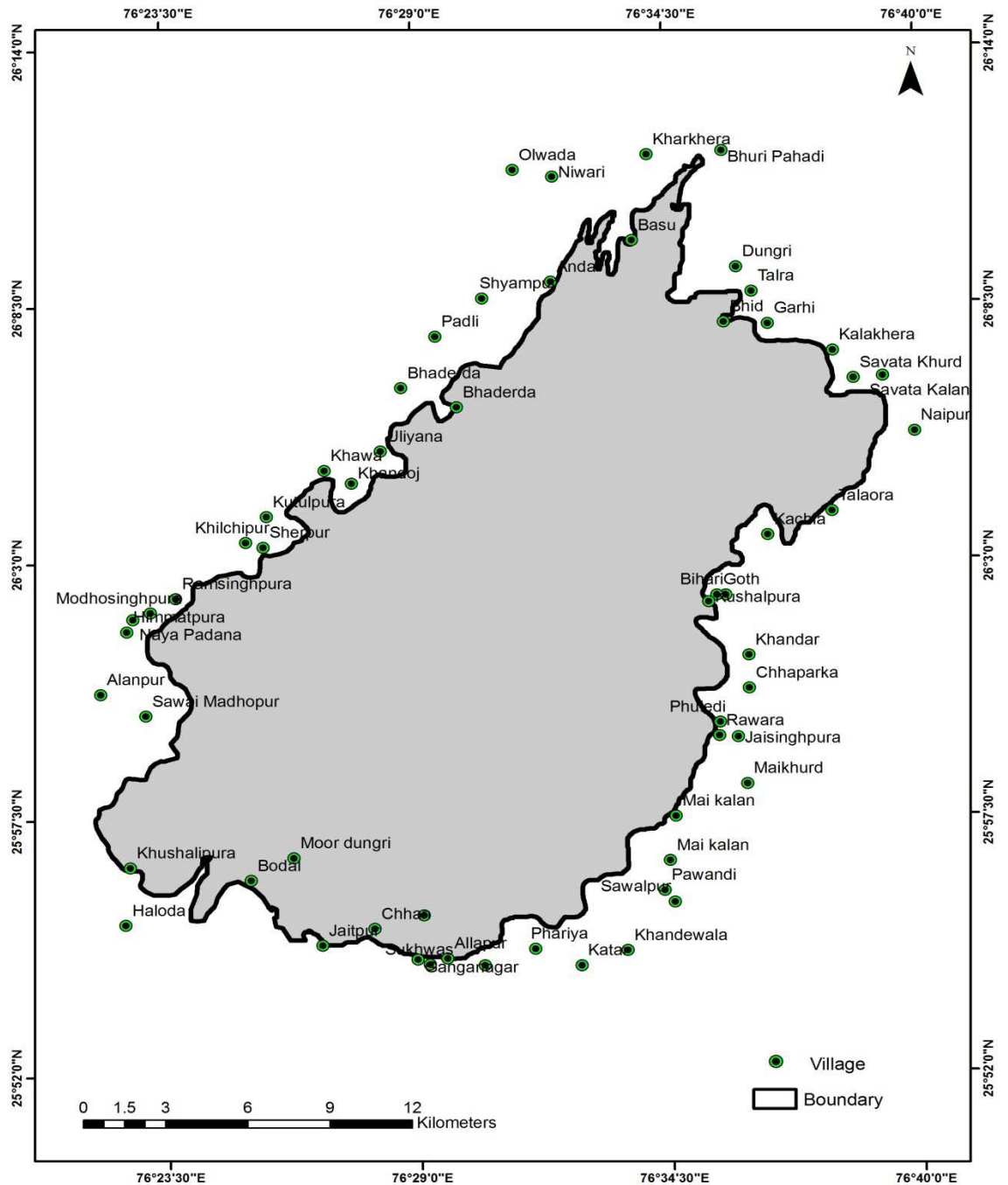
**Table 4: List of ‘rabi’ and ‘kharif’ crops grown in villages Ranthambhore NP.**

<b>Common name</b>	<b>Botanical name</b>	<b>Crop</b>
Bajra	<i>Pennisetum glaucum</i>	Kharif
Jowar	<i>Sorghum bicolor</i>	Kharif
Maize	<i>Zea mays</i>	Kharif
Groundnut	<i>Arachis hypogaea</i>	Kharif
Urad	<i>Vigna mungo</i>	Kharif
Guar	<i>Cyamopsis tetragonaloba</i>	Kharif
Chilli	<i>Capsicum annuum</i>	Kharif
Wheat	<i>Triticum aestivum</i>	Rabi
Gram	<i>Cicer arietinum</i>	Rabi
Mustard	<i>Brassica campestris</i>	Rabi
Til	<i>Sesamum indicum</i>	Rabi

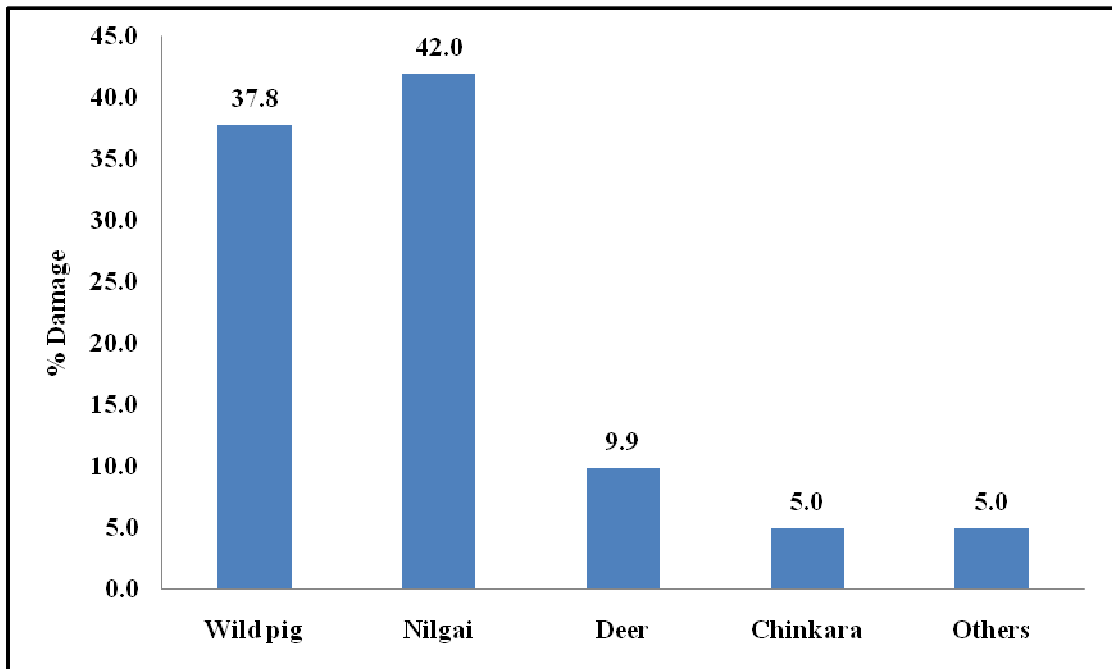
**Figure 1: Crop growing pattern in RNP.**



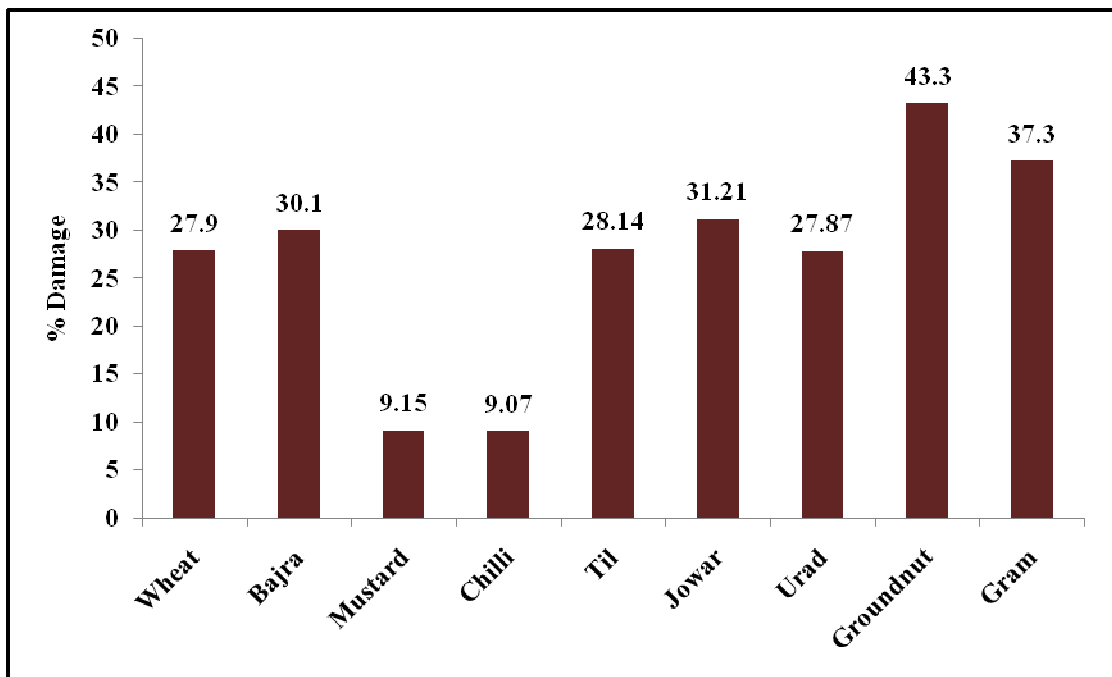
**Map 1: Location of villages surveyed for crop damage assessment.**



**Figure 2: Damage to agricultural crops by different problem species.**



**Figure 3: Extent of damage to different agricultural crops. (Respondents)**



**Table 5: Mean percent damage to agricultural crops in villages situated at varying distance from park boundary. (n=No. of respondents)**

<b>Distance (km)</b>	<b>Wheat (Mean±SD)</b>	<b>Til (Mean±SD)</b>	<b>Gram (Mean±SD)</b>
<b>0-2</b>	29.6 ± 9.19 (n=191)	28.56±14.19 (n=66)	38.3 ± 6.63 (n=53)
<b>3-5</b>	20.2 ± 6.84 (n=25)	21.25 ± 2.5 (n=4)	29.2 ± 3.45 (n=7)
<b>6-10</b>	11.66 ± 2.5 (n=20)	-	-
<b>Total</b>	27.9 ± 9.9 (n=236)	28.14±13.89 (n=70)	37.3 ± 6.98 (n=60)

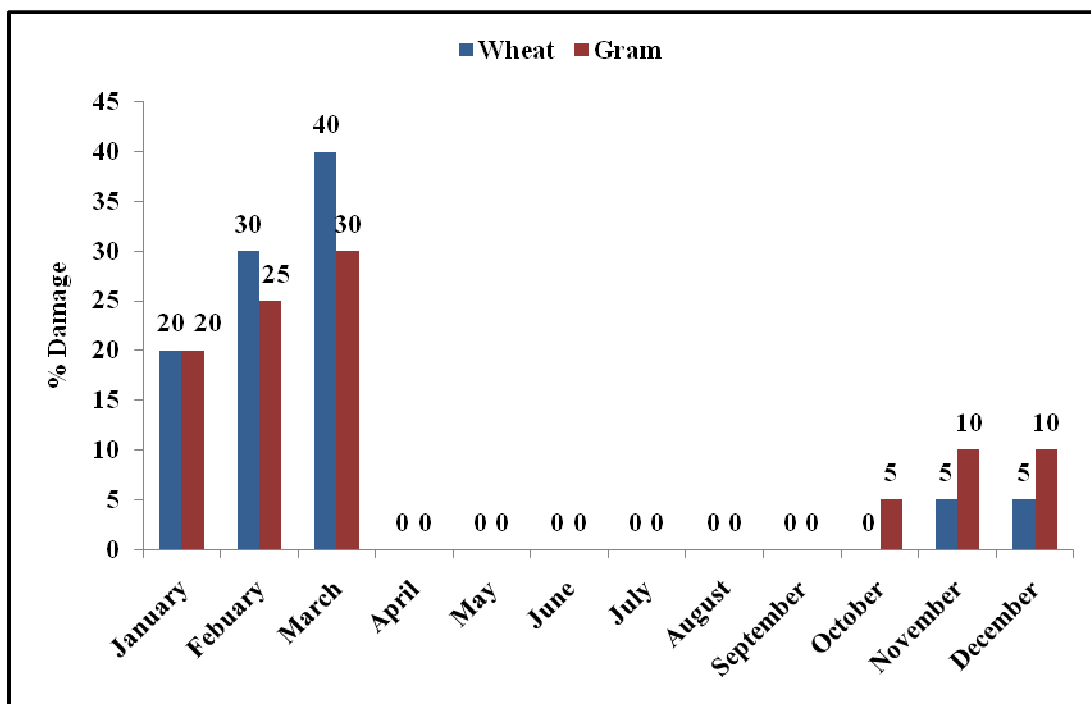
**Table 6: Mean percent damage to agricultural crops in villages situated at varying distance from park boundary. (n=No. of respondents)**

<b>Distance (km)</b>	<b>Bajra (Mean±SD)</b>	<b>Jowar (Mean±SD)</b>	<b>Groundnut (Mean±SD)</b>
<b>0-2</b>	32.63± 12.39 (n=191)	32.97 ± 13.58 (n=79)	44.2 ± 9.1 (n=49)
<b>3-5</b>	20.2 ± 6.69 (n=25)	23.75 ± 3.77 (n=12)	36.25 ± 2.5 (n=4)
<b>6-10</b>	15.5 ± 3.59 (n=20)	18.75 ± 4.79 (n=4)	-
<b>Total</b>	30.1 ± 12.88 (n=236)	31.21 ±13.21(n=95)	43.3 ± 9.3 (n=53)

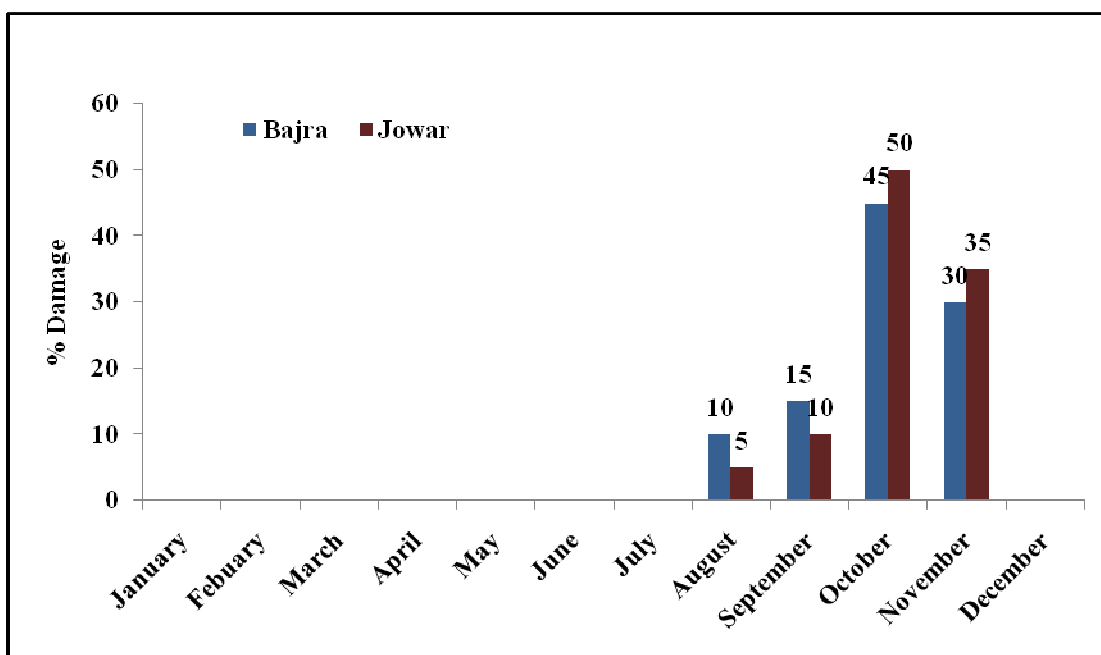
**Table 7: Mean percent damage to agricultural crops in villages situated at varying distance from park boundary. (n=No. of respondents)**

Distance (km)	Urad (Mean±SD)	Mustard (Mean±SD)	Chilli (Mean±SD)
0-2	29.3 ± 3.62 (n=36)	9.47 ± 5.81 (n=191)	9.4 ± 4.33 (n=60)
3-5	15 ± 4.08 (n=4)	9.4 ± 2.04 (n=25)	-
6-10	-	5.75 ± 1.38 (n=20)	5 ± 0 (n=5)
<b>Total</b>	27.87 ± 5.65 (n=40)	9.15 ± 5.57 (n=236)	9.07 ± 4.32 (n=65)

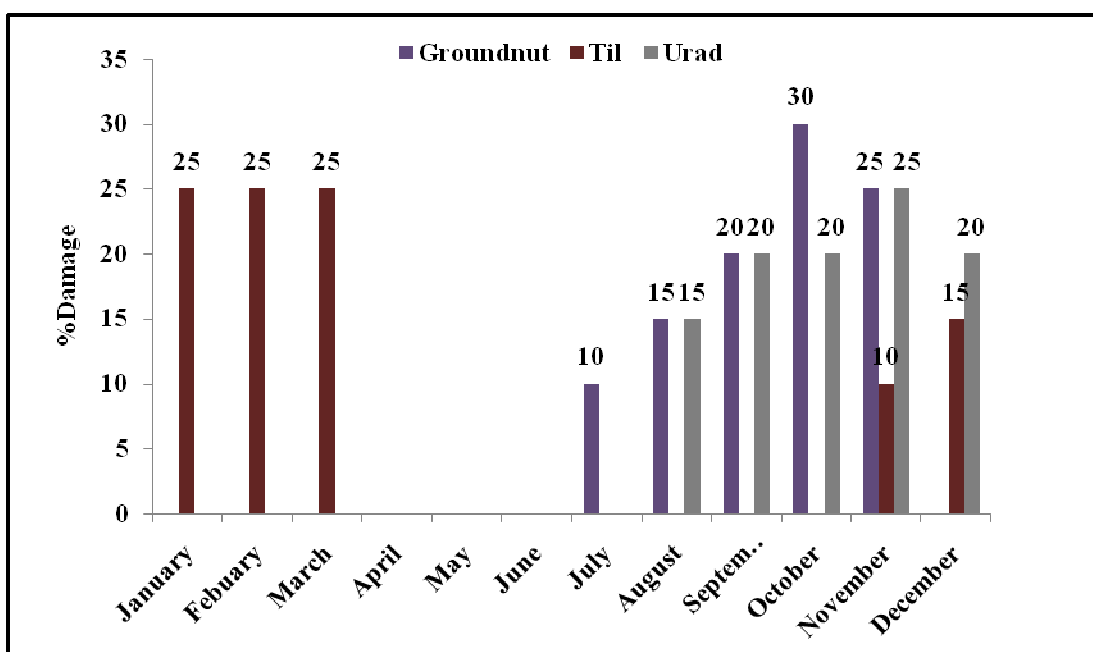
**Figure 4: Monthly variation in the extent of damage to wheat and gram crops.**



**Figure 5: Monthly variation in the extent of damage to bajra and jowar crops.**



**Figure 6: Monthly variation in the extent of damage to groundnut, til and urad crops.**



**Table 8: Percent damage to phenological stages of actual estimated crop losses according to respondents.**

<b>Crop</b>	<b>Wheat (%)</b>	<b>Bajra (%)</b>	<b>Jowar (%)</b>	<b>Mustard (%)</b>	<b>Chilli (%)</b>	<b>Til (%)</b>	<b>Urad (%)</b>	<b>Groundnut (%)</b>	<b>Gram (%)</b>
<b>Sowing stage</b>	5	5	5	5	5	5	5	15	15
<b>Growing stage</b>	20	15	15	25	20	30	25	20	15
<b>Flowering stage</b>	30	35	35	30	25	30	35	30	30
<b>Maturation stage</b>	45	45	45	40	50	35	35	35	40

**Table 9: Mode of damage to agricultural crops by wild pigs according to respondents.**

<b>Crop</b>	<b>Feeding (%)</b>	<b>Trampling (%)</b>	<b>Uprooting (%)</b>	<b>Wallowing (%)</b>	<b>Others (%)</b>
<b>Wheat</b>	50	30	20	0	0
<b>Bajra</b>	40	20	20	20	0
<b>Mustard</b>	20	70	10	0	0
<b>Chilli</b>	5	50	10	20	15
<b>Til</b>	40	30	20	10	0
<b>Urad</b>	40	20	40	0	0
<b>Groundnut</b>	50	0	50	0	0
<b>Gram</b>	50	0	50	0	0

**Table 10: Losses to agricultural crops using ‘control’ and ‘un-control’ plots in different villages.**

<b>Crop</b>	<b>No. of plots (2 x 2 m each)</b>	<b>Yield in control plot (g) Mean <math>\pm</math>SD</b>	<b>Yield in un- control plot (g) Mean <math>\pm</math>SD</b>	<b>Crop loss (g) Mean</b>	<b>Loss/bigha (kg) Mean</b>	<b>% loss/bigha Mean</b>
Wheat	20 (control)  20 (un-control)	2071.75 $\pm$ 304.58	1820 $\pm$ 250.18	251.75	56.64	12.01
Mustard	20 (control)  20 (un-control)	721.5 $\pm$ 81.14	677.5 $\pm$ 72.81	44	9.9	5.97
Gram	11 (control)  11 (un-control)	1100.45 $\pm$ 256.81	862.72 $\pm$ 205.24	237.73	53.49	19.03

**Table 11: Losses to agricultural crops using ‘control’ and ‘un-control’ plots in different villages.**

<b>Crop</b>	<b>No. of plots (2 x 2 m each)</b>	<b>Yield in control plot (g) Mean <math>\pm</math>SD</b>	<b>Yield in un- control plot (g) Mean <math>\pm</math>SD</b>	<b>Crop loss (g) Mean</b>	<b>Loss/bigha (kg) Mean</b>	<b>% loss/bigha Mean</b>
Bajra	20 (control)  20 (un-control)	1811 $\pm$ 158.04	1343 $\pm$ 127.78	468	105.3	25.65
Groundnut	10 (control)  10 (un-control)	938 $\pm$ 91.14	562 $\pm$ 80.80	376	84.6	40.06
Urad	7 (control)  7 (un-control)	118.75 $\pm$ 20.97	76.25 $\pm$ 13.77	42.5	9.56	35.68

**Table 12: Comparison of losses to ‘rabi’ and ‘kharif’ crops between quantitative assessment and reported by respondents.**

<b>Crop</b>	<b>Crop loss based on respondents (%)</b>	<b>Crop loss based on ‘control’ and ‘un-control’ plots (%)</b>
Wheat	27.7	12.01
Mustard	8.7	5.97
Gram	36.4	19.03
Bajra	30	25.06
Groundnut	43.5	40.06
Urad	24.4	35.68

## Annexure I

### QUESTIONNAIRE

#### SURVEY: CROP DAMAGE BY PIGS & CONTROL

Date .....

#### A. PROBLEM AREA

1. Forest Division/Range: .....

Village: .....

If outside, distance from forest boundary: ..... (m)

2. Land-use practices in or around:

a. Protected Area/Managed forests

Forest area: Total ..... (km<sup>2</sup>), Core ..... (km<sup>2</sup>)

Buffer ..... (km<sup>2</sup>), if any.

Plantation area: ..... (km<sup>2</sup>)

Forestry practices: .....

Agricultural land: ... (km<sup>2</sup>)

Villages: No. .... Total area ..... (km<sup>2</sup>)

b. Outside Protected Area/Managed forests

Agricultural area: ..... (km<sup>2</sup>)

Wasteland: ..... (km<sup>2</sup>)

Plantations or Orchards: ..... (km<sup>2</sup>)

(Tree species).....

No. of peripheral villages: ..... (Within 2 km)

**3. Problem species:**

Carnivores: Tiger/Leopard/Hyena/Wolf/Any other Species

Herbivores: Nilgai/Blackbuck/Chital/Sambar/Chinkara/Wild boar/Any other species

.....

Omnivores: Sloth bear/Any other species:.....

**B. NATURE AND EXTENT OF DAMAGE**

**4. Human casualties**

Human	Nature of Damage	No. of casualties by various species				
		Tiger	Leopard	Bear	Wild pig	Other
Adult	Killed					
	Killed & Eaten					
	Mauled					
Child	Killed					
	Killed & Eaten					
	Mauled					

**5. Circumstance(s) of human casualties**

Date	Forest				Village		Crop field	
	Adult/ Child	Killed/ Mauled	Activity	Time	Activity	Time	Activity	Time

**6. Agricultural crops grown**

Season	Crop	Sowing	Harvesting
Rabi	Wheat		
	Mustard		
	Gram		
Kharif	Rice		
	Sugarcane		
	Jowar		
	Bajra		
	Maize		
	Groundnut		
	Moong		
	Moth		

7. Agriculture crop damage by different wild animals.

Crop	Tick mark yes ( ) or no ( x )							Total damage (%)
	Nilgai	Chinkara	Chital	Sambar	Wild pigs	Monkey		
Wheat								
Mustard								
Taramira								
Gram								
Rai								
Rice								
Jowar								
Bajra								
Maize								
Moong								
Moth								
Arhar								
G'nut								
Sugarcane								
Any Other								



**10. Damage to plantations by wild animals.**

Plantation	Tick mark yes ( ) or no ( x )						
	Nilgai	Chinkara	Chital	Sambar	Wild pig	Monkey	
Teak							
Sal							
Bamboo							
Any Other							

**11. Crop damage month-wise: Tick mark yes ( ) or no ( x ).**

Crop	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Wheat												
Mustard												
Taramira												
Gram												
Rai												
Rice												
Jowar												
Bajra												
Maize												
Moong												
Moth												
Arhar												
Groundnut												
Sugarcane												
Any Other												

**12. Do crop compensation scheme exists? (Yes/No), if yes, details.**

Crop	Rate (Rs./Beegha)
Wheat	
Mustard	
Gram	
Rice	
Jowar	
Bajra	
Maize	
Moong	
Groundnut	
Sugarcane	
Any Other	

**C. DAMAGE CONTROL METHODS**

**1. Traditional methods used.**

Method	(y/x)	Specify animals
Haka	[ ]	[ ]
Drum beating	[ ]	[ ]
Crackers	[ ]	[ ]
Gun shots	[ ]	[ ]
Driving away	[ ]	[ ]
Brush-wood fence	[ ]	[ ]
Animal Proof-trench	[ ]	[ ]
Barbed wire fencing	[ ]	[ ]
Rubble wall	[ ]	[ ]
Any other	[ ]	[ ]

**2. Protection provided by Forest Department.**

<b>Method</b>	<b>(√ or x)</b>	<b>Cost/km</b>	<b>Animal(s)</b>
Trench	[    ]	[    ]	[    ]
Barbed wire fence	[    ]	[    ]	[    ]
Electric fence	[    ]	[    ]	[    ]
Rubble wall	[    ]	[    ]	[    ]
Any other	[    ]	[    ]	[    ]

**Plate 1: A lady and boy injured by wild pig in Neemali village.**



**Plate 2: showing a boy injured by wild pig.**



**Plate 3: ‘Control’ plot fenced with wire mesh in wheat field in Padra village.**



**Plate 4: Removing wire mesh from the ‘control’ plot during harvesting time of wheat in Padra village.**



**Plate 5: Removing wire mesh from the ‘control’ plot during harvesting time of wheat in Katuli village.**



**Plate 6: Separation of wheat grains and husk after harvesting crop from the ‘control’ plot in Mei khurd village.**



## **Chapter 8**

### **To evaluate the use and efficacy of power fence in controlling crop damage caused by wild pigs.**

#### **8.1 Introduction**

With increasing human population, biotic pressures and encroachment on forest land, wildlife populations are greatly impacted and now occur in fragmented forest areas all over. Huge areas of marginal lands, pastures, forest were converted to cultivation areas irrespective of their suitability for sustained agriculture. Due to increasing irrational conversion of forest lands and later encroachment on forest lands and loss of habitats and habitat quality, there has been a drastic reduction of wildlife in the country. Most species have become ecologically dislocated over their former range and several of these cause damage to varying degree involving some loss of human life and destruction to man-property. Rural people can ill-afford to have their cultivation raided by elephant, deer, nilgai, blackbuck, wild pigs, monkey etc. and sustain livestock depredation by large carnivores. It is not simply a matter of attitude, but in essence a matter of survival. As a result man-wildlife conflicts have attained serious proportions in the affected areas. The situation for both wildlife and rural people is tragic especially in and around protected areas and managed forests. Today human-wildlife conflicts have reached to an alarming proportion in different states in India. Acceptance of conservation tenets by people is jeopardised. So there is an urgent need for development of strategies that can reduce the man-wildlife conflict to tolerable levels.

Much of these conflicts can be alleviated with proper management of the areas set aside both for animals and human beings. For mitigation of these problems, use of various methods such as local protective methods, wildlife barriers such as brushwood fence, chain-link fence, wire netting fence, barbed-wire fence etc. for crop protection, elimination or capture and translocation and fertility control methods in controlling of problem species populations and crop insurance or compensation schemes are useful.

Besides usual practices, power fence is known to be the most cost-effective wildlife barrier.

Traditionally, wild pigs have been kept out of cultivations by scaring them away or restricting them with barriers. Scaring wild pigs with flash lights, fire, fire-crackers, crop protection guns, stone slings etc may effectively deter them sometimes, but these methods lead to habituation of wild pigs to such measures. In addition, change in crop pattern and alertness or to keep vigil to restrict or divert movements of wild pigs are few potential options at present where culling of wild pigs is not possible. Control measures based on shooting or culling will, at best, only reduce wild pig numbers and will not prevent depredation or losses caused by wild pigs. Public education, support and their acceptance in effective control of wild pig damage problems are important.

Most forms of effective barriers for wildlife such as trenches, rubble wall or conventional fences, are expensive to construct and maintain. Driving crop raiding wild pigs away from agricultural fields using fire crackers and drum beating etc is only partially effective and time consuming for the farmers who have many other household works to perform. Hence there has been a great need for an effective wildlife barrier which can be easily erected, modified and cost-effective and is not too demanding in terms of maintenance. Under variable conditions of climate, species behaviour and other site specific problems, pulsating current electric fencing, appropriately designed, constructed and maintained; is an effective and economic barrier not only for wild pigs but for a number of other wild animals.

## **8.2 Power fence**

A power fence is purely a psychological barrier. Power fence is a relatively new control technique and not fatal for animals and only restricts their movements. The power fencing is essentially a tool which teaches animals to experience pains and shock on contact with the fence. Thus the electric fence becomes a psychological barrier to the animals. Power fencing is most effective and safe to animals and to humans. If properly constructed and maintained, it can effectively keep most of the animals out.

Power fencing system provides an economic and a practical solution to achieve maximum protection through effective control of animal trespass. The main role of power fencing is to provide an economic means of excluding crop raiding animals from agricultural areas or human settlements. Though initially the cost of power fence is quite high, its benefits over the years are much more than the investment. It has been successfully used to keep away elephants, nilgai and wild pigs in many states, and thus, the power fence greatly help in the crop protection and in reducing human-wildlife conflict. As a control measure, the power fencing is rapidly gaining an importance to managers.

### **8.3 History of power fence**

The concept of power fence was started in the year 1932 in Germany. It soon became popular in Europe due to its simplicity and effectiveness. Revolutionary changes were effected in its construction from time to time to make it safe and simple, and yet effective over long distances. The present solid state energizers are extremely frugal in its power consumption and long lasting without any moving parts. Its impact is such that wild animals including elephants and wild pigs respect the barrier and keep off after initial experience of shock.

In the early 1930s, William Gallagher of Hamilton, New Zealand discovered that it was possible to control animals by administering electric shocks. In 1936, the first electric fence energizers were commercially available in New Zealand. After many revolutionary changes in the field of electronics, the power of fencing improved and then it was accepted as a standard method of fencing all over the world. In countries like West Germany, all forms of fencing are prohibited except electric fencing. Australia has a separate wing in the government to promote power fencing. In Africa, power fencing is increasingly used to keep wildlife within reserves. In Europe, New Zealand and Australia, it is used to keep livestock within pastures and for strip grazing, thereby making optimum use of pastures. In Malaysia and other South-East Asian countries, it is popularly used for crop protection against wild animals. Now it is used in more than 165 countries all over the world.

The MAFF\_ADAS Bulletin No. 147 published in 1976 stated that the electric fence alone or in conjunction with other forms of fencing has been used to control wild animals effectively. Power fencing has also been successfully used for controlling depredations caused by a wide variety of wild animals including wild boars, porcupines, skunk, opossum, foxes, racoons, bears, nilgai, buffalo and elephants (Blinksell and Leggatt, 1985; Fitzwater, 1972; Finnie, 1985; Forster, 1975; Gates, 1978; Gates *et al.*, 1978; Hendrie, 1985; Howard, 1978; Kilgour, 1983; Lewis and Wilson, 1977; Ling, 1983, 1985; Linhart *et al.*, 1982; Lund and De Silva, 1985; Mitchell *et al.*, 1977; Piesse, 1985; Plant, 1985 and Singh and Chauhan, 1992). In many cases, it was successful, whereas in others, evaluations of effectiveness were subjective. The report entitled 'Wildlife proof barriers in India' by Piesse (1982) recommends the effective use of electric fencing system as a management tool for problematic wildlife viz. elephants, deer, wild pigs and tigers etc. It is proving effective for restricting elephants and protecting agricultural crops and villages from their depredations. Many elephant-proof power fences were constructed under the WII-FAO Project in different states to control crop raiding elephants (Schultz, 1988 and Chauhan, 2010).

Barrier fences have been used to control problematic wildlife species since ancient times. Historical accounts in Africa (Thomas and Kolbe, 1942), Australia (McKnight, 1969), Europe (Fitzwater, 1972), Asia (Kumar *et al.*, 1963) and America (Bartlett and Boyce, 1954) revealed not only the global nature of the practice, but also the changes in the fencing materials used. Electric fencing in use since the 1960s (Gates *et al.*, 1978), represents the latest technological advancement in man's attempts to control problematic wildlife species and its efficacy has been a subject of intensive research in recent years (Seamans and VerCaunteren, 2006).

Available literature states that advantages of electric fencing include reduced cost in comparison to the conventional wire fence, reduced labour during building and maintenance and if made from poly-wires, electric fences can be removed, moved and reused easily (Reidy *et al.*, 2008). It also offers a non-toxic solution to animal damage problems around highly valuable crops or installations (Fitzwater, 1972).

Disadvantages of electric fencing include regular short out when in contact with snowdrifts or damp vegetation. Also, this method of problematic animal control is

based on the animal's capacity to remember the effect of touching the fence, thereby rendering it a psychological rather than a physical barrier. Other disadvantages include reduced efficiency of electric fencing during dry conditions due to poor grounding (Fitzwater, 1972) and if made of steel, fences are relatively permanent and cannot be moved or reused easily (Reidy *et al.*, 2008) .

The role of fencing in the management of human-wildlife conflicts, although recognized, has neither been adequately quantified nor clearly documented. In the opinion of farmers and hunters, wild boar (*Sus scrofa* L., Mammalia, Suidae) is the most damaging wildlife species, which in some areas of Europe and Slovenia cause more than 50% of the estimated damage to plants. Feeding and other activities of wild boar are very important reduction factors regarding the quantity and quality of cultivated and wild-growing plants (Schley and Roper, 2003). The damage which is done by wild boar on agricultural land often leads to disagreements between representatives of the local hunting association and farmers. The state is responsible for damage if the damage is spread over more than 50% of agricultural land and for damage which does not exceed this share; the regional hunting association which manages the hunting grounds where damage is noticed, it is obliged to pay compensation. In the opinion of many people, the solution lies in culling a greater number of this wildlife species, which is more and more widespread in Europe. But experts are unanimous that it is not possible to improve the present situation only by means of harvesting.

Currently wild boar has colonized 55% of the territory of Slovenia and its potential habitat comprises 67% of the country. The distribution and number of wild boar will likely further increase, particularly if the present trends of environmental changes continue (increasing temperature, woodiness, reduction of coniferous trees) (Jerina, 2006). With regard to the mentioned problems, the question is raised of how farmers can protect their arable fields in a way which is friendly to animals, nature, and people, and which is effective and reliable enough and also economically justified since silage and grain maize represent the greater part of the feedstuffs on dairy and beef farms in Slovenia (Oresnik and Logar, 2001). Thus the yield loss of maize represents an additional problem to stock farmers, which forces them to purchase supplemental feed or diminishes the number of animals on their farms.

Both solutions burden the farm budget and threaten its existence, even more so if the damage occurs over several consecutive years. Until now farmers have used many different measures for damage prevention on cultivated or wild-growing plants due to wildlife species, namely conventional nonelectric wire (barbed, smooth, high tensile, woven) fences, either with different repellents (Boh *et al.*, 1999) or intensive harvest throughout the year. More recently farmers have started to erect electric fences, which are a known tool for keeping farm animals enclosed while grazing (McKillop and Sibly, 1988) and which has shown promising results regarding preventing wild boar from entering fields (McKillop *et al.*, 1992 and Santilli and Stella, 2006). But the construction of permanent electric fences as one of a group of electric fences on small arable fields was not suitable with regard to other activities such as crop rotation, the migration of wildlife species during the non-vegetative period, and high building and maintenance costs. In another study, electric fence was used to prevent wild boar from entering a maize field in the area of Šmihel near Postojna (Slovenia) (Vidrih and Trdan, 2008). No breaks through fencing were observed until the harvesting time of the maize for silage, although boar tracks on the outside of the fenced field were observed.

Human-wild pig conflict refers to the negative interactions between humans and wild pigs. Some of the negative effects of wild pigs to humans include crop-raiding and injuries to humans. On the other hand, wild pigs are killed and their range severely altered by human activities. Human-wildlife conflict is increasingly jeopardizing conservation efforts as many got killed by farmers in attempts to reduce conflict.

Electric fences are increasingly being used to reduce crop damage by elephants (Andau and Payne, 1992 and Thouless and Sakwa, 1995). The fences act as physical as well as psychological barriers to separate elephants from settled areas (Sukumar, 1986). Electric fences are expensive to install and maintain and most community fence projects in Africa are funded externally or by corporations. While electric fences are considered effective in reducing crop-raiding (Hoare, 2003), literature on the use of electric fencing to manage crop-raiding by elephants suggest that a number of factors including fence design, voltage, maintenance, elephant pressure and behaviour may influence their success (Seidensticker, 1984; Thouless and Sakwa, 1995; Garai and Carr, 2001 and Hoare, 2003). Considering the high installation and

maintenance cost of electric fencing, there is a need for more research to establish the factors that determine the effectiveness of electric fences in deterring crop-raiding by wild pigs.

In this study, we developed the pig-proof power fence by construction of fence line around the crop fields in Jaitpur village situated on the boundary of Ranthambhore National Park, and evaluated its efficacy in reducing crop damage. We compared the extent of wild pig crop-raiding in the fenced and adjacent unfenced areas. Attitude of villagers towards power fencing as a tool for controlling wild pig depredations on their crops was also studied. In addition, we assessed the performance of the power fences by comparing the yield of crops within fenced crop fields and outside the fenced areas.

## **8.4 Materials and methods**

Agricultural crop damage by wild animals is a severe problem in and around forest areas. Wild pigs, nilgai and sambar were found to cause extensive crop damage in villages situated in and around Ranthambore National Park. In order to develop a pig-proof and pig and nilgai-proof power fences and reduce crop damage, we constructed power fence at two sites where the crop field belonged to Radhey shayam, Munaf, Shakeel and Hafeez in Jaitpur village in June, 2006 (**Table 1**). At one site, the fence was pig-proof and other site it was pig and nilgai-proof, and their lengths were 250m and 1200m respectively. The fences were solar-powered. The power unit had a solar panel, a 12 volt power battery, and an energizer to provide current to 1.5 km length of the two fences. Equipment and accessories used for construction of power fence are listed in **Table 2**.

## **8.5 Components of a power fence**

The vital components of a power fencing system were energizer, battery and earthing system. Brief description of these items is given below.

### **8.5.1 Energizer**

An energizer is the heart of the system. It is device which converts low voltage to pulses of high voltage, but of low current thereby making the shock harmless in terms of physical damage. The power input is from the DC energy from battery. Main function of the energizer is to produce short and sharp pulses of about 10,000 volts at regular intervals i.e. 40 to 55 pulses per minute. The pulses are generated at intervals of about 1 to 1.5 seconds each. The duration of 'on' time of a pulse is only for 0.0003 seconds.

### **8.5.2 Battery**

Energizers are powered by lead acid batteries of 12 volt configuration. The 12 volt battery is used to store the power generated from the solar panel for use during nights and rainy days, when the power generation by solar panel is not adequate. A battery of 130 Ah with 19 plates can be charged to meet the power requirement for nearly 20 days without any damage to battery. Batteries are charged using A.C. mains current.

### **8.5.3 Earthing system**

Good earthing is good fencing. Effectiveness of a fence i.e. the amount of shock to animal will depend on the proper earthing system. The earthing system will also depend on the capacity of the energizer.

### **8.5.4 Tools and accessories**

The power fencing tools required for construction and maintenance are wire cutter, spanners of different sizes, cutting pliers, wire twister, screw driver and special spanners for tensioning. The special type of pliers and wire twister are used. The kit has leather pouch to hold the tools. Type of equipment and material and their quantity used for the construction of power fence are shown in **Table 3**.

## **8.6 Construction**

For construction of power fence, we selected a site in Jaitpur village in the periphery of Ranthambhore National Park. We erected the electric fence as per the designs specified above in June 2006 when the fields were prepared for sowing crops. Firstly the crop fields to be fenced by power fence were marked using chuna powder and then the ground was leveled. The ground was cleared of all vegetation and grasses in a belt form of 3 feet wide. We also marked points at equal distance of eight meters in linear direction on the sides. Along this line, we dug the holes of 2.50 feet each in the

middle of this belt. After that the posts were put in these holes and fixed them tightly. Then PP reel insulators were tied on the poles tightly and wires were passed through these PP reels insulators and tightened manually as well as by using wire tightner. Following this, a spring gate was installed to allow the movement of peoples in the crop field. This way the power fence of approximately 1.5 km length was constructed around crop fields in Jaitpur village. The layout of power fencing around crop fields in Jaitpur village is shown in **Figure 1**. This power fence had the following three main sections.

### **8.7 Monitoring of power fence**

From November 2006 onwards, the fences were monitored regularly to evaluate their effectiveness. Both the fences were maintained properly. The fenced areas were monitored during study period by walking the perimeter of electric fences. We made observations every alternate day while checking if the fence voltage was adequate; if it was not, we looked for faults or sometime changed the battery and wild pigs tracks could be observed.

The crop raiding activity of wild pigs was monitored by following their fresh tracks. We took Global Positioning System (GPS) coordinate readings of these sites. We maintained proper records on the status of fences and particularly noted if the fence wire strands were broken, intact, or had current or no current. These records were used to establish the status of the fences prior to wild pig entry into the fenced areas. We measured the voltage (KV) of each power unit on alternate basis using a digital fence voltmeter (Gallagher Group Ltd.) to check for battery output and the flow of electric current in each of the fence sections.

## 8.8 Results

In order to control movement of wild pigs and nilgai, we tested two types of fence designs:

- i. A fence design with posts at an interval of 8 meters and GI wires at the height 15, 37.5, 62.5, 100 and 135 cm was tested (**Table 4**).
- ii. A fence design with posts at an interval of 8 meters and GI wires at the height 15, 37.5, 62.5, 100, 135, 165, 195 and 225 cm was constructed (**Table 5**).

The fences were energized using a Ibex Gallagher energizer of 6 joules of stored energy, run on a battery of 55 Ah, as this was enough to maintain sufficient voltage of more than 5.5 KV in the wire strands. On the fence line, we also mounted a livelite, warning signs to indicate fence operation, in this case as it flashed each time, a pulse of more than 2.5 KV was sent from the energizer to the wires. Shorting-out of the fence by vegetation growth was prevented, when necessary, by trimming along the fence line to create a clear strip about 3 feet wide. Fence maintenance and voltage checks were conducted weekly and batteries replaced when voltage fell below 4.5 KV.

### 8.8.1 Pig-proof power fence

Pig-proof power fence having one gate was constructed around a small crop field of Radheshyam. The fence enclosed a rectangular field of about 0.5 hectares. The fence posts were fixed at the interval of 8 meters. The pig-proof fence was 4.5 feet in height with five strands; the first and third strands were connected to earthing, and the rest three i.e. 2<sup>nd</sup>, 4<sup>th</sup> and 5<sup>th</sup> strands were live strands (**Table 4**). This fence around the crop field covered all the sides. The crops grown in this field was chilly, cucumber and vegetables. **Plate 1** shows a pig-proof power fence around crop field in Jaitpur village. **Plate 2** shows a pig-proof power fence and monitoring team in Jaitpur village. **Plate 3 and 4** show monitoring of power fence and solar panel and energizer point respectively in Jaitpur village.

### **8.8.2 Connecting lines**

Connecting lines from the crop field of Radheshyam were extended to the main fence line along the eastern boundary of crop fields. This main fence of about 1 km was energized from the source of energy through pig-proof fencing for input of energy; the earthed and live wire were drawn from here and connected to the main fence.

### **8.8.3 Nilgai and pig proof power fence**

The pig and nilgai-proof fence was constructed enclosing crop fields of Munaf, Shakeel and Hafeez in Jaitpur village because both nilgai and wild pigs were responsible for the crop damage. By constructing only a pig proof fence, nilgai would have easily jumped the fence and evaluating the efficacy of this fence would have been difficult. The pig and nilgai-proof fence line was constructed along the forest boundary and crop fields, and it was 8.5 feet in height with 8 strands. The 1<sup>st</sup>, 3<sup>rd</sup> and 5<sup>th</sup> strands were connected to earthing system, and the rest five strands i.e. 2<sup>nd</sup>, 4<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> were live wires (**Table 5**). **Plate 5** shows a pig- and nilgai-proof power fence around crop fields in Jaitpur village. **Plate 6** shows a pig-proof power fence with wooden and angle-iron posts. **Plate 7** shows fence line crossing ‘nalah’ point on left side in Jaitpur village. **Plate 8** shows a pig-proof power fence constructed for crop protection in Jaitpur village. This fence was connected to pig proof fence for input of energy; the earthed and live wire were drawn from pig proof fence and connected to this fence.

This fence provided effective crop protection against wild pigs and large ungulates like sambar. **Figure 2** shows the 8-strand pig- and nilgai-proof fence with angle iron poles.

### **8.8.4 Monitoring power fence**

From November 2006 onwards, the fences were monitored regularly to evaluate their effectiveness. Both the fences were maintained properly. The fenced areas were

monitored during study period by walking the perimeter of electric fences. We made observations every alternate day while checking if the fence voltage was adequate; if it was not, we looked for faults or sometime changed the battery and wild pigs tracks could be observed. From November 2006 to May 2007, we recorded high range of voltage (7.9-8.1 KV) at the energizer point, whereas the voltage varied from 5.2-6.6 KV along the fence line. There was slight variation in voltage along the fence line. The voltage at 1000m fence length was higher than at shorter distances, which might be due to good earthing system. Overall the fences were found effective against pigs and nilgai.

While developing the above species-specific fences, we made some alterations in the fence designs and monitoring protocol. Out of eight strands in this fence, two strands viz. 1<sup>st</sup> and 5<sup>th</sup> were initially earthed and rest were live strands. But after monitoring it for some time and seeing them how they were breached, the 3<sup>rd</sup> strand was made earthed line. By doing this change, incidence of breaching did not occur.

Initially both the wild pig-proof and nilgai and pig proof power fences suffered some problems like some sections of the fence were severely damaged and a few angle iron poles got uprooted due to torrential rains and soil erosion. In some sections, faults like entangling live and earth wires knowingly by people were also recorded (**Plate 9 to 12**). Before sowing of crops, the fence line was not energized and there were fence breaching at two places. When the fences were not working, five angle iron poles were stolen and there was severe maintenance problem. Due to these reasons, power fence remained dysfunctional for a period of 3-4 months.

To ensure proper functioning of the fence, they were maintained regularly and monitored to keep track of the malfunctioning, and any fault encountered was repaired immediately. A log of each maintenance activity was maintained. To see the effectiveness of power fence against wild animals, areas along the fence line were regularly surveyed for evidences of wild animals coming to feed on crops. Thus efficacy of the power fence in term of reducing crop damage and developing pig- and nilgai-proof power fence was evaluated.

### **8.8.5 Working of fences**

These fences were found to be functionally effective as the pulsating current passing through the fence lines, inspite of some leakage, was sufficient to deter wild animals. Average output voltage of the main fence i.e. nilgai-pig proof fence ranged from 5.5 to 6.5 KV. The voltage of small pig-proof fence was slightly on the lower side i.e. 5.2 to 6 KV. But when the nilgai-pig proof fence was cut-off or disconnected from the pig proof fence, then pig proof fence always showed voltage output ranging from 7.9-8.1 KV. This voltage was found to be sufficient in controlling the movement of large ungulates and the fences were proved to be cost-effective.

### **8.8.6 Activity of wild pigs in the vicinity of crop fields**

Before erection of power fence, we observed wild pigs in the vicinity of crop fields a few times, and crop damage and soil diggings could be seen in many places of the experimental field. During winter months when 'rabi' crop was grown, there was lots of movement of wild pigs in the crop fields. Thus wild pigs preferred crops during early growing stage when crops had milky seeds till maturation of crops.

Wild pigs visits to the field areas became less and less during summer months when there was no crop available to them to feed, but after the commencement of rains, wild pigs again started visiting the fields as the soil became soft for digging and farmers had started sowing jowar (*Sorghum bicolour*), bajra (*Pennisetum glaucum*) and chilly (*Capsicum annuum*) in July and August. Then in September and October months, groundnut was also available. By this time, jowar and bajra had also grown high which provided wild pigs a easy cover for hiding and crop raiding.

By observing the tracks, a few times only piglets crossed the fence line for a short time and sows stayed on the other side because there were no breaks in the fence line. Otherwise they could have followed the young ones due to maternal instinct. We observed extensive damage to the vegetation in the vicinity of the power fence during crop season. But after fencing crop fields, tracks of wild pigs were not frequently seen near the fence, but there were few diggings outside these crop fields.

## 8.9 Fence costing

On the basis of the known facts regarding the differences between permanent and temporary electric fences (Conover, 2002) and the advantages which temporary electric fence designs have (Huygens and Hayashi, 1999), when erecting fencing around arable fields in the growing season, we wanted to further reduce the cost of erecting the latter fence by opting for the design as shown in **Figure 1**. The power fence design so constructed with the specified material appeared to be the least expensive.

## 8.10 Evaluation of power fences

Efficacy of power fence basically depends on its design with respect to the species that needs to be controlled. External factors such as environmental impacts, pressures from non-target species and people and local acceptability are important for functioning of the fences. So fences were evaluated by critically looking at the fence layout, fence design, fence components: energizer, battery condition (charged or poorly charged), size and thickness of posts, quality of insulators, wire and corrosion, if any, and wire connections, earthing system and their maintenance. Based on the voltage output from the energizer, with and without load i.e. by connecting or disconnecting to fence, voltage at earthing terminal and energy flow through earthing system (point); voltage along the fence line at 0.25, 0.5, 0.75, 1 and 1.2 km from the energizer point and the end point of the fence to measure the energy loss (voltage leakage), the power fence was found effective (**Table 6**). Suitability or effectiveness of the energizer used determined based on its voltage output and leakage through earth terminal was also good. In the pig-proof power fence, the load with and without fence line connected was 6.2 and 6.4 KV respectively at the energizer point. The earth point showed 0.01 KV power. There was no current leakage. In the pig- and nilgai-proof power fence, the load with and without fence line connected was 5.8 and 6.4 KV respectively at the energizer point. The earth point showed 0.1 KV power. There was some current leakage. In this fence line, damage to fence line was recorded in terms of leaning or broken or uprooted posts, insulator absent or broken and wires contact or falling on ground etc. Vegetation growing underneath the fence and touching live wire(s) resulting in voltage leakage or grasses and weeds was recorded.

Based on this, the technical and maintenance problems of the fences were detected. However both the fences were found as effective.

The power fence lines faced some maintenance problems; a brief account of these problems is given below.

- i. The most frequently occurring faults were mainly two. Wires become loose and getting entangled at some sections (**Table 7 and 8**), thus tripping the current. This problem occurred because of people passing by who wanted to make a way out. During day time, the fences were switched off; people could easily twist the wires together. The fences had loose strands along fence line and 'nallah' (**Plate 7**). The loss of voltage was due to broken insulators and tying of loose wires by people and poor maintenance. At this time, the voltage leakage was significant. In spite of the substantial voltage leakage along the fence line, the pulsating current was sufficient enough to deter wild pigs. In November 2006, power fence was repaired, and it was made functional. Since then the fences were functioning quite effectively.
- ii. The other problems were less technical and more of the social types. It resulted in having technical faults, which made power fence ineffective quite often bringing down its voltage. But people remained ignorant and small faults occurred quite frequently. Vegetation tripping due to not clearing vegetation along sides of the fence line was also frequent. The person in charge of power source was required to switch on and switch off the fence in evening and morning time as instructed. Also villagers were also required to reinforce the other sides of the field area especially the road side and Mansarovar side, from where invasion of wild animals was frequent.

So out of these eight faults, only two are technical faults and rest of the faults were due to negligence or carelessness of the people. In total, there were 41 faults in the fence lines. Out of which, 11 times wire strands were entangled, 3 times transmission lines were entangled, 5 times gate was wrongly opened and 2 times vegetation was touching live wires. These all faults were due to ignorance and constitute more than 50% of the faults. Though number of times the fences were found to have faults viz.

leaning corner post, tripping of jumpers, entangled or broken strands, broken or detached insulators or current leakage, these faults were timely corrected. Most of these faults were manmade and arose due to negligence of the users. Thus the design of the pig and nilgai fences was found suitable, and the effectiveness of the fences was dependent on their maintenance.

The solar power fencing benefited four farm families by protecting their agricultural crops from wild animals. By using the power fence, these families got more crop yield (**Table 9**). In the crop field of Radhey shayam, crop productivity before installation of power fence was 2.75 quintal, but after installation of power fence, it reached up to four quintals. In the crop field of Munaf, crop yield before installation of power fence was four quintal, but after installation of power fence, it reached up to six quintals. Whereas in the crop field of Shakeel, crop productivity before installation of power fence was 2.5 quintal, but after installation of power fence, it reached up to 3.10 quintals. In crop field of Hafeez, wheat productivity before installation of power fence was ten quintal, but after installation of power fence, it reached up to fourteen quintals.

For the cash crop like chilly, the farmers were getting good return after erection of power fences around their crop fields (**Table 10**). In Radhey shayam's crop field, the chillies were sold for Rupees 60,000 before installation of power fence, but after installation of power fence, the earning reached up to Rupees 75,000. In Munaf's field, the chillies were sold for Rupees 80,000 before installation of power fence, but after installation of power fence, the earning reached up to Rupees 100,000. Before installation of power fence, Shakeel used to sell chillies for Rupees 50,000, but after installation of power fence, the earning reached up to Rupees 70,000. Whereas in Hafeez's field, the chillies were sold for Rupees 1,60,000, before installation of power fence, but after installation of power fence, the earning reached up to Rupees 2,00,000.

## 8.11 Discussion

The power fences erected in Jaitpur village were found to be effective in reducing damage to wheat and chilly crops by wild pigs as well as by nilgai. During the study period, no wild pigs raided the fenced crop fields of wheat and chillies. Both the power fence designs were found effective in keeping wild pigs from entering in to the crop fields. Other studies on the use of electric fences also showed almost similar results and excluded wild animals like Asiatic black bear (*Ursus thibetanus*) (Huygens and Hayashi, 1999), Eurasian badger (*Meles meles*) (Poole *et al.*, 2002), and red deer (Gasparik *et al.*, 1993) from crop fields. However, the 100 % fence effectiveness in our study could be explained by the possibility that the wild pigs bypassed our experimental crop fields and invaded other unprotected crop fields. The fence designs tested by Goddard *et al.* (2001) were also found to be most effective, as beside the characteristics of the former two designs; it also had an additional characteristic, i.e. a third dimension (depth). And it was known for some time (VerCauteren *et al.*, 2006) that this fence design could reduce the possibility of all other wildlife species entering in to so-protected crop fields.

When erecting any kind of power fence, it is important to pay attention to some measures and also to keep the fence in good condition during the whole period of field protection. In particular, an opening between the ground and the first wire can present a chance for an animal to enter the field. As stated by those who had to a broader extent investigated damage on farmland caused by wildlife species which were found to root into the ground (Geisser and Reyer, 2004; Herrero *et al.*, 2006) than was carried out here, the methods which attempt to reduce the damage were intensive harvesting, supplemental food offered in the forest, and the installation of electric fences (Geisser and Reyer, 2004).

It was important to construct electric fences properly and to maintain them regularly (Ambrose and Sanders, 1978, Jorgensen *et al.*, 1978, Lord 1979, Brady and Maehr 1982). Maintenance checks might involve checking voltage, batteries, line tightness or tension and cutting weeds touching the fence. Problems encountered when electric fences had slacken lines, incorrect spacing between lines, insufficient number of lines and fence height, and leaning of posts. The type of energizer used in this study was

Ibex Gallagher B 600 and it was found to be very effective because it delivered the adequate voltage (6500-8000V) and could be powered by a 12 volt car battery with solar panel.

Power fences have been potentially effective method to reduce levels of depredation. However, it could be possible that extensive use of electric fences could cause crop depredation by wild pigs to shift to unprotected fields. Electric fences were inexpensive but labour intensive method of reducing wild pig depredation and their usage could possibly be rendered more efficient if combined with other methods. Extensive public awareness campaigns could possibly the surest way to ensure the development and adoption of effective methods of depredation control. Encouraging farmers to take more responsibility for protecting crops by giving them the option of electric fence and giving them financial and moral incentives could provide an effective solution. Results revealed that fencing effectively ameliorates the wildlife menace situation at the human-wildlife interface surrounding conservation areas. Fencing off wildlife provides an important physical barrier that effectively reduces human-wildlife encounters and hence conflicts.

The power fence technology was found very cost-effective. It could reduce crop damage to considerable extent in this case. By very use of power fence, economy of farmers dependent mainly on agricultural crops elevated due to saving of crops from depredation by wild pigs.

## **8.12 Suggestions and recommendations**

Considering the lacunae in the fence designs, constructional defects, equipments and technical and maintenance problems in study area, following suggestions are made for the improvement of the fences and protection of crops.

- i. The need of erection of power fencing must be decided based on the nature and extent of wildlife damage problem in an area. Whether the problem is seasonal or permanent and localised or widespread should also be considered.

- ii. The installation of power fence should be planned carefully before starting construction. It must be ascertained that the power fencing layout should not merely export the problems to the adjacent areas. Consider whether the animals have alternatives with respect to food, water and shelter elsewhere.
- iii. About the use and construction of power fencing, inform local people and take into account their ideas and attitude and involvement. Power fences must satisfy welfare criteria and environmentalists.
- iv. Ensure that the fences erected by the forest department or any other agency without the help of professionals are installed properly. It is advisable to take the help of the experts.
- v. The fence design must be species-specific and developed considering the prevailing site-specific conditions of animal pressure and human activities on the fence. Double fencing may be required where fences cross traditional movement paths or pressure points.
- vi. Designing the fence corresponds to selection of suitable energizer in relation to target species, fence length and height, quality of wire, posts and insulators; number of strands and spacing between them, soil type and earthing system. Often a cheap construction will incur comparatively high maintenance costs. Preserved wooden posts will last 10-12 years, while unpreserved posts will last only 1-3 years in most environments. Ordinary galvanised iron wire will start corroding after 2-3 years, while ACSR (Aluminium coated steel rod) or zinc coated wires will last longer. The fence should to be divided into sections of about 250m starting and ending with CP strain insulators. Thus when designing permanent fences a high cost of construction may well turn out to be the best alternative financially in the long run.
- vii. Use of the Smart power energizer and alarm system is recommended, the Smart power energizer will keep voltage output more or less constant. It is safest to procure energizers with replacement modules. If it is not possible, then it is recommended to procure an additional energizer as stand-by. It is necessary to

keep two batteries, one for operating the fence while the other is sent for recharging.

- viii. The fence design and live wires arrangement should be such that various age groups: adult, sub-adult and calves come in contact with live wire(s) and earth wire, if present, while negotiating the fence and receive deterrent shock.
- ix. Power fence is as vulnerable as any other type of wildlife barrier. The performance of the fence will very much depend on how well the entire installation is maintained. So the regular and constant maintenance of energizer, battery and fence line, and clearing vegetation along the fence line will make the fence very effective.
- x. A voltmeter is imperative for tracing faults in the fence line. It is necessary to keep maintenance tools and kit and record book.
- xi. A fault on the fence is indicated as malfunction of the fence, if the voltage drops significantly below the value specified for a species. It could be due to inadequate earthing system or dry soil; high resistance, shorting, exceeded capacity.
- xii. Defective, decaying or broken, posts should be replaced as soon as possible. Where live trees are used to support fence wires, the tie wires of insulators should be loosened periodically according to the radial growth of the trees.
- xiii. Due to various reasons, the wires can loose tension, thereby affecting the wire spacing. Rain or human traffic can cause hollows under the fence, allowing animals to pass under it. The need of immediate repairs of hollows or passages is obvious and vital. In order to get optimal control of the target species, the wire spacing should not deviate significantly from the original design. The distance between the ground, bottom wire and top wires should be consistent throughout the fence.

- xiv. Slack wires can be dangerous to animals. They might get entangled in them and get series of shocks, which could be fatal. Thus slack wires should be strained as soon as they are discovered.
- xv. Expansion and contraction of the fence wires due to temperature variations may require tension springs and wire tightener built into each strain section of the fence.
- xvi. Corroded wires will increase the electrical resistance in the fence. Extensively corroded wires should be replaced. Corrosion between wire and earth connectors will also increase the electrical resistance. All the connections should be clean and sealed with an anti-corrosive substance, eg. Aluminium paint or petroleum jelly.
- xvii. The power fence is only as good as its earthing system. The shock effect depends on a good earth return path to the energizer for the energy of impulses. The connection between the earth terminal of the energizer and the wire leading to the earthing rods and the connections between the individual earthing rods and the wire must be clean and as firm as possible.
- xviii. To maintain fence line, it is important to prevent growth of vegetation from underneath the fence to avoid energy leakage. Grass and weeds growing into the fence could be removed /cleaned regularly.
- xix. Check and record the voltage at test points, energizer terminals, earth point and along the fence line and end of the fence. The energizer with low pulse rate normally indicates need for the replacement of modules.
- xx. Defective insulators cause abnormal leakage of energy through fencing posts to the ground; they need to be replaced immediately.
- xxi. Based on the wild pig movement and seriousness of the problem of crop raiding, specific areas can be selected for erection of new fences or shifting some of the existing ones.

xxii. Serious thoughts should be given by the state governments to encourage construction of fences rather than paying compensation for wildlife damage on private properties.

**Table 1: Owner of crop fields, village and area enclosed by power fence.**

<b>Owner of crop field</b>	<b>Village</b>	<b>Size of crop field (Beegha)</b>
Radhey Shyam	Jaitpur	2
Munaf	Jaitpur	3
Shakeel	Jaitpur	2
Hafeez	Jaitpur	6

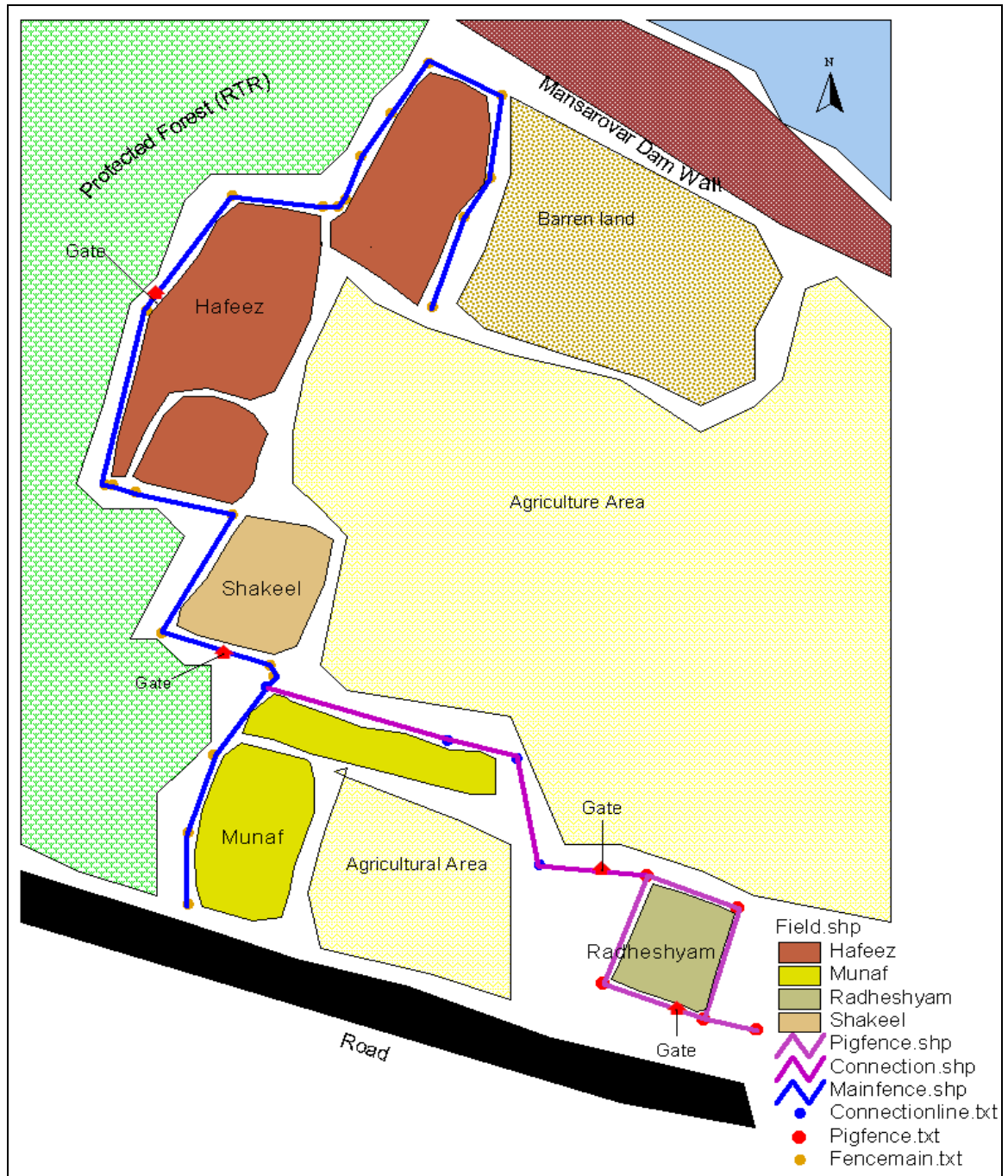
**Table 2: Equipment and accessories used for construction of power fence.**

<b>Equipment</b>	<b>Tools</b>	<b>Other items</b>
Energizer	Wire tightening tool	Pipe
PP reel	Wire tightner handle	Warning signs
Gay insulators	Sabal	Salt
Digital voltmeter	Earth auger	PVC pipe
Solar panel	Spade	Tape
Battery	Crow bar	Cement
Earthing kit	Hammer pliers and pincers	Double insulated cable
Earth stakes	Spanner	Wooden pole
Galvanized wire	Post driver	Angle iron
Joint clamps	Tools for wiring	Spring gate
Flexible connector		Cut off switch
Permanent tension spring		Neon tester
Permanent wire tightner		Livelite
Lightning diverter kit		Earth clamp

**Table 3: Specification of equipment and material used for power fence.**

Equipment/accessories	Unit	Quantity
Energizer B600	No.	1
Solar panel 30W	No.	1
Solar stand with pipe	No.	1
Neon tester	No.	1
DVM 3	No.	1
Tool kit	No.	1
Super earth kit	No.	15
Lightening diverter	No.	1
H.T. wire (in kg)	Kg	180
Ibex 14G wire	Kg	25
PP reel insulator	No.	2000
Super strain insulator	No.	150
Wire tightner	No.	60
Joint clamp	No.	120
Lead out cable	Mtr	50
Warning sign	No.	15
Rope gate kit	No.	10
Console box (Mounting box)	No.	1

Figure 1: Layout of power fencing around crop fields in Jaitpur village.



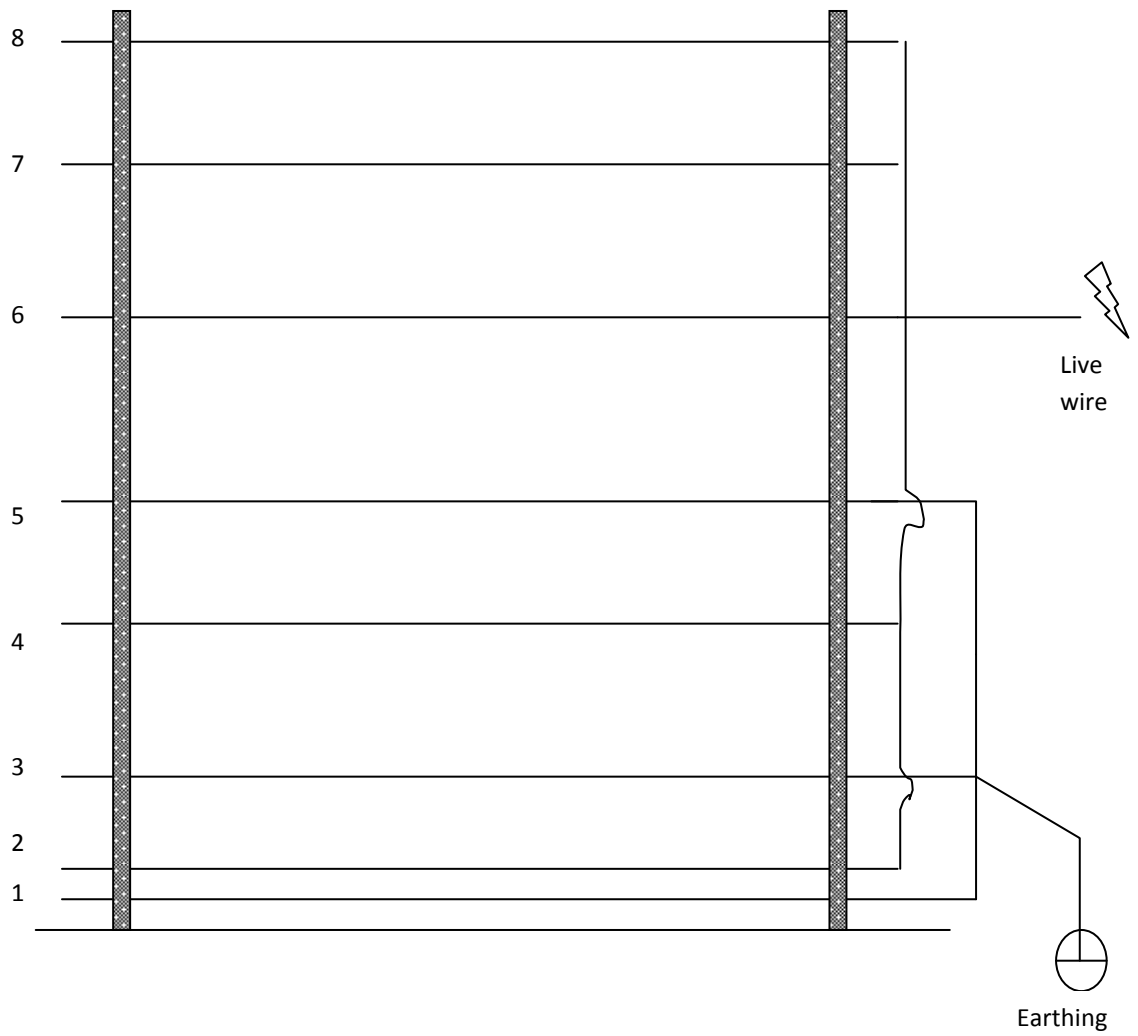
**Table 4: Spacing of wire strands in pig-proof power fence.**

<b>Wire strand</b>	<b>Height from ground (cm)</b>
Bottom strand (Earth)	15
Strand 2 (Live)	37.5
Strand 3 (Earth)	62.5
Strand 4 (Live)	100
Strand 5 (Live)	135

**Table 5: Wire strands in the pig- and nilgai-proof power fence.**

<b>Strand</b>	<b>Height from ground (cm)</b>
Bottom strand (Earth)	15
Strand 2 (Live)	37.5
Strand 3 (Earth)	62.5
Strand 4 (Live)	100
Strand 5 (Earth)	135
Strand 6 (Live)	165
Strand 7 (Live)	195
Strand 8 Live	225

**Figure 2: Eight-strand pig- and nilgai-proof fence with angle iron posts.**



**Table 6: Evaluation of power fences in Jaitpur village.**

Energizer voltage output (KV)		Battery Condition Charged/ Poor	Fence line voltage (KV) measurement							Damage to fence line	Voltage leakage Yes (+) No (-)	Effective (Yes/No)	Problem if any
Terminal (a)	Earth Pt.		Effective or Not	0.3km (b)	0.6km (c)	1km (d)	1.2km (e)	a-e					
Load (-)				Load (+)									
6.4	6.2	0.01	Effective	Charged	6.0	6.0	-	6.0	0.2	-	-- --	Yes	Maintenance
6.4	5.8	0.1	Effective	Charged	5.8	5.8	6.1	5.7	0.1	+	+ --	Yes	Maintenance

**Table 7: Type of faults recorded in power fencing.**

<b>Man-made faults</b>	<b>Point(s)</b>	<b>Technical faults</b>	<b>Point(s)</b>
People hanging cloths	1	Pp reel broken	1
Sickle tripping	1	Jumper tripped	1
Line entangled	3		
Transmission pole fallen	1		

**Table 8: Faults recorded in pig-proof and pig- and nilgai-proof fences.**

<b>Date</b>	<b>Fault</b>
04.12.2006	People hanging cloths
03.01.2007	Sickle tripping line
10.01.2007	Jumper tripped
31.01.2007	Pp reel break
19.02.2007	Line entangled
21.02.2007	Transmission pole fallen
05.03.2007	Line entangled
07.03.2007	Line entangled

**Table 9: Impact of power fencing on wheat crop productivity.**

<b>Owner of crop field</b>	<b>Fenced area (Beegha)</b>	<b>Production before erection of power fence (Quintal)</b>	<b>Production after erection of power fence (Quintal)</b>
Radhey Shyam	2	2.75	4
Munaf	3	4	6
Shakeel	2	2.5	3.10
Hafeez	6	10	14

**Table 10: Impact of power fencing on chilly crop economic losses.**

<b>Owner of crop field</b>	<b>Fenced area (Beegha)</b>	<b>Production before erection of power fence (Rupees)</b>	<b>Production after erection of power fence (Rupees)</b>
Radhey Shyam	2	60,000	75,000
Munaf	3	80,000	1,00,000
Shakeel	2	50,000	70,000
Hafeez	6	1,60,000	2,00,000

**Plate 1: Pig-proof power fence around crop field in Jaitpur village.**



**Plate 2: Pig-proof power fence and monitoring team in Jaitpur village.**



**Plate 3: Monitoring of power fence and measuring voltage by research team.**



**Plate 4: Solar panel and energizer point for power fencing.**



**Plate 5: Pig and nilgai-proof power fence around crop fields in Jaitpur village.**



**Plate 6: Pig and nilgai-proof power fence with wooden and iron posts.**



**Plate 7: Pig and nilgai-proof power fence crossing ‘nalah’ in Jaitpur village.**



**Plate 8: Pig and nilgai-proof power for crop protection in Jaitpur village.**



**Plate 9: Entangled live and earth wires in pig and nilgai-proof power fence.**



**Plate 10: Live and earth wires tied up in pig and nilgai-proof power fence.**



**Plate 11: Fence wires tied up in pig and nilgai-proof power fence.**



**Plate 12: Live and earth wires tied up in along power fence line.**



## **Chapter 9**

### **Recommendations for management of wild pigs and mitigation of human-wild pig conflicts.**

#### **9.1 Genetic hybridization**

In Ranthambore National park, it has been observed that wild pigs stray out of the park and raid agricultural crops and utilises the agro-ecosystem in peripheral villages for food resource and shelter. While this study was conducted from 2004 onwards, it was found that wild pigs were increasingly straying out of park into the forest-village interface areas and coming in contact with domestic pigs and perhaps breeding with them. As a result, there may be genetic hybridization between the wild and domestic pig populations. These domestic pigs have been found developing physical characteristics that resemble with wild pigs. Thus breeding and genetic hybridization between wild and domestic pigs is seriously impacting the wild population.

Therefore it is very important to conduct a study on genetic diversity in wild and domestic pigs to find level of hybridization between them in the vicinity of Ranthambore National park, and suggest strategies to check mixing up of wild and domestic pigs to avoid genetic hybridization between them for long-term conservation of wild pig populations.

#### **9.2 Human-wild pig conflict**

Based on the records of the forest department, survey of affected areas and interview with the residents in affected areas of Ranthambhore, the following general recommendations are made to minimize human-wild pig conflict.

### **9.3 Management/Action Recommendations**

- i. For mitigation of human-wild pig conflict under given socio-economic and political framework, one of the ways is to minimize the ill effects of socio economic constraints and socio-ecological constraints in and around protected areas. Crop raiding by wild boar is the socio-ecological constraint identified. To minimize their ill effects on people, education and awareness programmes related to ecology and behaviour of wild boar, genesis of pig menace problem, possible mitigation strategies need to be conducted for the villagers in the peripheries of all these forest areas.

### **9.4 Short Term**

- ii. The man-wild boar conflict occurring in the form of crop damage has been evaluated, and concluded that present status of conflict is manageable with the help and cooperation of affected people. Only in a few areas where extent of damage to agricultural crops is considerably high, and affects the poor farmers depending on this source of livelihood needs to be dealt systematically using combination of strategies.
- iii. To effectively mitigate the wild boar menace in villages located in different forest divisions and in and around protected areas, a combination of methods such as the use of local protective methods: dummies, noise producing flares or sound devices or scintillating objects or ribbons, polythene, fire crackers, guarding of crops by villagers at the time of crop maturation, wild boar proof-barriers in highly vulnerable village areas are important.
- iv. Traditionally, villagers scare away crop-raiding wild pigs by means of Gandhi guns and by bursting crackers. During crop maturation stage, villagers should remain vigilant and burst crackers in conjunction with other methods such as fences and scarecrows.

- v. The farmers protecting their crop fields from wild pigs must be provided with crackers free of cost particularly at the time when crops are matured. This will prohibit villagers to develop hostile attitude towards these wild pigs.

## **9.5 Medium Term**

- vi. A concrete wall of about 4-5 feet height along certain strategic village-protected area boundary or around at highly vulnerable crop fields to exclude wild boar will provide relief to the farmers on long term basis.
- vii. Power fencing along certain strategic village-protected area boundary or around at highly vulnerable crop fields can check the straying out of wild pigs and thus incidences of crop raiding could be minimized. Both concrete wall and fences must be properly designed, maintained to make them effective.
- viii. Under the Ecodevelopment participatory programme, if any, construction of wild boar-proof wall and power fence along the forest cropland interface can be considered. This has proved to be very effective in keeping wild pigs from foraging in crop fields and also in preventing domestic animals from straying into forests for grazing.
- ix. With the Central assistance and support from the state forest department, construction of model wild pig-proof power fences in highly damage prone areas or strategic locations along boundary of forests and villages as feasibility study must be planned and implemented and tested for use on long term basis with help of the WII. The expertise available in the WII can be used to plan and design such a study in controlling wild boar menace.
- x. Systematic survey of damage prone village areas in the periphery of these forest areas needs to be conducted by a team of experts to delineate areas where wild boar proof barriers can be constructed for protection of agricultural crops.

## **9.6 Long Term**

- x. Land use patterns outside the protected areas are changing constantly. Under such circumstances, some ameliorative action is required. Problem mitigation efforts should be made by way of protection and improvement of natural habitat of wild boar. In the fragmented and degraded forest areas in the fringe forest areas, habitat improvement activities such as reduction of biotic pressures and planting of trees of food and cover values to the wild animals including wild pigs need to be carried out to sustain their existing populations.
- xii. Emphasis should be given on growing non-preferred or less damaged crops by wild pigs such as oilseeds, sun flowers, late sugarcane variety, or even combination of crops by growing preferred ones in rows or guarded by non-preferred crops in impacted areas.
- xiii. It is well understood that increasing human population is responsible for the wild boar damage; the people have to be tolerant, and should come forward to help and participate in the planning and implementation of the strategy for mitigation of the problem.
- xiv. For conducting systematic research study on wild boar menace and economics of damage problems, we should take into account people's feelings, perceptions and attitudes towards the wild pigs menace, and in involve them. It would help in confidence building and creation of awareness among the residents of the affected areas.

## **9.7 Policy Recommendations**

- xv. The scheme for payment of compensation for damage to agricultural crops by elephants exists, but there is no compensation for damage caused by pigs. The payment of compensation for wild boar damage needs to be considered on priority. This state of affair at times lead to such a degree of antipathy that irate

villagers go to the extent of devising methods for eliminating the wild animal that has caused them harm

- xvi. Possibility of introducing crop insurance scheme in villages should be explored.
- xvii. Wild pigs are prolific breeders; their population grows very fast. In such situation, population management becomes very necessary. This is now the right time when experimental research for controlling increasing population of problematic animals including wild pigs can be planned and initiated.
- xviii. The study has briefly identified the occurrence and intensity of conflict problems. The detailed study of such site specific wild boar problem is very important for formulation of mitigation strategies on long-term basis. Essentially more information is required on economics of crop damage from most affected villages and socio-economic aspects, and accordingly, necessary planning and formulation of practical mitigation strategies are required immediately before the conflicts reach unmanageable proportions.

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