# SEASONAL CHANGE IN SOCIAL STRUCTURE, BEHAVIOUR AND HABITAT USE BY SARUS CRANE IN THE SEMI ARID REGION OF NORTH- WESTERN INDIA

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*By*

**TIN NWE LATT**


*Under the Supervision of*

**SHRI. B. C. CHOUDHURY**
**DR. S. A. HUSSAIN**


भारतीय वन्यजीव संस्थान
Wildlife Institute of India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

# CERTIFICATE

This is to certify that **TIN NWE LATT** of the Wildlife Institute of India has carried out an original piece of work titled "**SEASONAL CHANGE IN SOCIAL STRUCTURE, BEHAVIOUR AND HABITAT USE BY SARUS CRANE IN THE SEMI ARID REGION OF NORTH-WESTERN INDIA**" in partial fulfillment of the M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried under my supervision at the Wildlife Institute of India from November 2000 to June 2001. I also certify that this work has not been submitted for any other degree of any university.

Date :
Place :

***Principal Supervisor***
Shri. B. C. Choudhury
Head
Dept. of Endangered species management
Wildlife Institute of India

***Co-supervisor***
Dr. S. A. Hussain
Reader
Wildlife Institute of India

**Post Box No. 18, Chandrabani, Dehradun - 248 001. India**
**EPABX :** +91-135-640111 to 640115, 640990; **FAX :** 640117; **GRAM :** WILDLIFE
**E-Mail :** wii@wii.gov.in

# Contents

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# SUMMARY

The seasonal change in social structure and habitat use by sarus cranes was examined in the semi arid region of North- western India. The study was conducted in Keoladeo Ghana National Park and in the surrounding areas in Bharatpur district of Rajasthan. The methods involved censusing of cranes in the park and in surrounding areas by moving on motorcycle in preidentified routes. The detailed methodology included quantification of habitat availability and focal and scan sampling for studying the behaviour of sarus crane. Eight sarus groups were intensively monitored to examine parent and juvenile relationships and juvenile weaning process.

The mean encounter rate of sarus crane outside the park was greater than that of inside. Though the data was not tested for the lack of uniform effort in these two areas, the difference is likely to be statistically significant. The overall group composition during the study period differed inside and outside of the park. The agricultural areas outside had greater number of social family group sighted during the study period than within the park. The mean encounter rates had greater standard errors associated with them outside the park than inside the park. During the present study most of the social family, pair, congregation, and solitary crane were seen outside of the park except that of pair with juvenile.

The seasons (winter and summer) had an influence on the sarus crane group composition apart from the fact that the groups were either seen within the protected area or outside. With the data from the present study it is not possible to test the effects of these two variables on the sarus group composition. However, in winter sarus cranes were seen in social family and pair with juvenile more often inside the park than outside the park. The other forms of groups of sarus such as social group, pair and solitary members were not very different inside and outside the park. In winter season, juveniles were not able to fly more than 0.61m height and 45m distances restricting their movements within the park. During summer the juveniles could fly outside of the park in the Ist week of February onwards and were seen frequently outside of the park.

Sarus cranes spent more time outside the park than inside, except pairs with juveniles. Inside the park the safety, food and space supported small groups and pairs all through the year. The group composition showed a dramatic change in summer where greater number of

social family and pair with juveniles were observed outside the park than inside, while other forms of groups did not vary much in the two areas. During the study period a maximum of 67 sarus cranes were recorded inside the park in roosting areas.

During the study period, wetlands were the most used habitat by sarus cranes than any other habitat types. Grasslands and dry wetlands were used distinctly by sarus next to the wetlands, and the agricultural fields have the least utilization. The later could be because of bias in sampling more inside the park than in the agricultural fields outside the park. During summer, the sarus cranes occurred more often in wetland and grasslands than in dry wetland or agricultural fields. During winter and summer sarus cranes mostly used wetland habitat (winter 20.5 % & summer 35%). In late summer, as all agriculture field were harvested and there was no water patches outside the park.

The Forest Department pumped in water throughout the late winter and summer in the areas where group no.1 (Block L), group no.4 (Block D) and group no.5 (Block E) spent more of their time. During summer, sarus cranes used this shallow water. The area where group no.3 (Block K) sarus stayed much of the time had very large grasslands. Within this area the wetland was closer to road and sarus crane appeared to be stressed while foraging in this wetland. The large expanse of grasslands used by group no. 3 (Block K) area, it prevented people to approach closer to the cranes and hence they used this grassland extensively during summer. Among the pair, the female was more the wary and cautious while using these water patches. Solitary sarus cranes preferred foraging in grasslands. In summer, water spread became small and narrow and sarus cranes spent more time in grasslands (winter 5% & summer 12%). Sarus crane did not use dry wetlands in summer due to lack of moisture in this area which, hinders growth of grasses and other aquatic flora and also insects in such dry wetlands were less. Generally, sarus crane used agriculture land more for foraging at the time of sowing and harvesting of cereal and pulses.

The encounter rates (sightings/ hour) of sarus crane correlated with water level. During large water spread times, more cranes were encountered. Water depth was correlated with mean encounter rates ($r = 0.77$, $N=12$), similarly water spread also had a significant positive correlation ($r=0.64$, $N=12$). As expected water depth and water spread had a strong positive correlation ($r=0.95$, $N=12$).

At the beginning of the study in November the juveniles were estimated to be three months old, and when the study was concluded in May, the juveniles were nine months old and they continued to remain in the vicinity of the parents. Although the distance increased with time it is speculated that the quantum of time spent by the adults parenting the juvenile would diminish with time and also the distance between parents and juveniles.

The major interaction between parent and juvenile during the observation period was "nursing" behaviour, where the parent fed the juvenile directly into its mouth. Subsequently, the parent "induced the juvenile to forage" by leading the juvenile to some areas in the wetland where food was abundant and the disturbance from tourists was low. From the last week of February juvenile started to move farther away from the parents and maintained an average distance of about 65 m. During this time the parents started courtship behaviour and paid less attention to the juveniles, even though the juveniles showed interest on their parents. In reciprocation of the lack of attention from the parents the juveniles continued to forage away from the parents. Till the end of the study period in May the juvenile still continued to tag along with the parents.

To summarize, seasonal shift in sarus crane social structure was observed in the study area. Following factors appear to affect the sarus crane group structure and behaviour:

(a) Availability and limitation of food.

(b) Changes and availability of water in wetland.

(c) Age of juveniles appears to be a factor for their attachment to parents.

(d) The diurnal weather appears to be relative to sarus crane behaviour and social structure, which change on cloudy, sunny and rainy days.

# CHAPTER 1 : INTRODUCTION

## 1.1 General Introduction

Fossils of cranes have been found as early as some "forty to sixty" million years ago during the Eocene period. The members of the crane family are also widespread, existing on five of the seven continents. Only Antarctica and South America do not have cranes. Preserving cranes and their habitat requires a careful, disciplined, and holistic approach to their conservation (Website, savingcranes.org).

There are four existing genera of cranes namely *Grus*, *Bugeranus*, *Enthropoides* and *Balearica* of which the genus *Grus*, consist of ten species. The Indian sarus crane (*Grus antigone)* has two races in the Indian sub-continent. There are *Grus antigone antigone* and *Grus antigone sharpii* (Gole, 1986). The present study deals with the Indian sarus crane (*Grus antigone antigone*), which is the most common species of this crane in country.

The sarus crane (*Grus antigone antigone*) is one of the resident species of the cranes in the Subcontinent. The Indian sarus crane (*Grus antigone antigone*) has the maximum height of (160-165) cm and weight of 6.8 - 8 kg. The world population of this crane has been estimated at 8000-10,000 individuals (Meine and Archibald, 1996). All the previous natural historians have mentioned that in the sarus crane both the sexes look alike except that the male is slightly larger than the female (*Ali, 1977 and *Walkinshaw, 1973). However, detailed observations revealed that in the male the lower border of the dark red band around the neck is oblique and extends ventrally downward in the front region, whereas in the female it is a horizontal line around the lower part of the band. The general plumage colour throughout the body is darker in male hatchlings than in the female ones. Secondly, the bald cap is larger in the male than in the female and in the former the posterior border extends up to the supercilium. Unlike the male in the female the posterior border of the featherless cap does not extend up to the supercilium (Desai, 1980).

Presently the population of the sarus crane in India is concentrated in Uttar Pradesh, Gujarat, East Rajasthan and in parts of Haryana and Madhya Pradesh. It also occurs in North Haryana, West Rajasthan, Saurashtra, East Uttar Pradesh, North Mahratra, North Bihar and Northeast India but in less number (Choudhury *et al., 2000*). This species is protected under Schedule IV of the Indian Wildlife (P) Act 1972 and is placed in Appendix II of the CITES convention and recommended to be moved to Appendix I (Meine and Archibald, 1996).

The Rajasthan State is one of the stronghold states as far as the sarus crane population is concerned. The areas in and around Keoladeo Ghana National Park are strongholds of sarus within the Rajasthan State.

## 1.2 Review of literature

The fifteen species of cranes constitute one of the most endangered families of birds in the world. Most of the cranes are migratory species. Although, some species and their sub species congregate during the non-breeding season the birds flock, and may then gather at favorable locations well away from nesting areas (such as *Grus antigone antigone, Balearica pavonia, Grus japonensis*) (Johnsgard, 1983).

Some species consist of two major migrations units such as winter migration and spring migration (*Anthropoides virgo*). Incase of some species very little is known of their migration. These may be opportunistic ones, depending on local water conditions, extreme drought, seasonal temperature variations and food availability (*Bugeranus carunculatus, Grus rubicundus*). Although it is apparent that migration does occur in following species (*Anthropoides paradisea, Grus vipio, Grus canadensis, Grus monacha, Grus nigricollus, Grus americana, Grus grus* and *Grus leucogeranus* (Johnsgard. 1983).

There are few, if any, seasonal movements of sarus cranes in India, where the birds are forced to migrate only in times of extreme drought (*Walkinshaw, 1973). However, in Thailand there are apparently some seasonal movements, at Chiang Mai, the birds appear only during the colder nonbreeding period between December and March (*Delgnan, 1945). Certainly there must be occasional movements of vagrant birds; otherwise one could not explain the development of an isolated population on Luzon Island, at least 11200 km from the nearest possible mainland range (*Madsen, 1979). More surprising is the recent establishment of a population in northern Australia, at least 4828.032 km from the probable present range limits of the species in southeastern Asia. In spite of their large size and relatively heavy weight, the cranes are fully capable of extended soaring (*Ali and Ripley, 1969), so such occasional long-distance movements are certainly within the limits of possibility. According to *Ali and Ripley 1969, short "commuting" flights are normally made each day between foraging areas and midday roosting places at edges of rivers or jheels, with the birds flying only at about treetop height (Johnsgard, 1983).

*Walkinshaw, 1973, reported that there are daily flights to and from roosting sites every morning and evening at Keoladeo National Park. During the nonbreeding season some birds remained on the roosting ponds all days, while others flew out to nearby meadows, fields, and grain fields, although *Walkinshaw, 1973 did not estimate the flight distance involved. Cranes typically run into the wind to achieve the lift necessary for flight, but if alarmed a crane can spring directly into flight.

Pre and post breeding social groups structure in crane population play an important role in their biology. Solitary, pair, family, group and non-breeding congregation from to migratory movements have been recorded for various crane species. However the factors that influence such social grouping have not been well documented nor the linkages between social groups and migration. As far as sarus crane is concerned the social structure has not been well studied. Whatever studies have been done are mostly population studies either during the immediate breeding season or during summer congregations. To understand the social structure of sarus cranes this study was designed with the following objectives.

## 1.3 Objectives

The present work studied the change in social group structure during the post-breeding season (November) to almost onset of breeding season (April-May). Following are the objectives of this study.

(a) To evaluate the population and social group inside and outside of Keoladeo Ghana National Park

(b) To investigate the habitat use by sarus cranes in and around the Keoladeo Ghana National Park, Bharatpur

(c) To establish relationship between habitat and sarus crane abundance

(d) To document Natural history of weaning.

## 1.4 Hypotheses

Sarus crane being a non-migratory resident species changes in social group structure is expected to be influenced by number of factors, which could be availability of habitat, food, or other factors like intrinsic factors. Following are the major hypothesis of this study:

(a) Availability and limitation of food is an important factor that determines social structures of sarus crane

(b) Changes and availability of habitat has an impact on the social structure

(c) Intrinsic factors, breeding seasons, inter and inter specific interaction influence social grouping in sarus crane

# CHAPTER 2 : STUDY AREA

The duck shooting forests was declared as Keoladeo Ghana Bird Sanctuary in March 1956. Subsequently in August 1981 under section 35 of the Wildlife (Protection) Act, 1972, it was declared a National Park. The Keoladeo National Park is a magnificent marsh, heaven for the birds. It is named "Keoladeo" after the name of a temple of lord Shiva in the heart of the park. UNESCO declared it "World Heritage Site" in 1985. The estimated number of visitors to this park has reached over 100,000 annually.

Bharatpur, the nearest town and the headquarters of the district, is 5,084 $km^2$ in area with a population of 16,46,501 the number of villages around the park has increased over the years. The most populated with 2200 persons is Mallah village. Agriculture is the major source of income, with livestock raising in some villages. Frequent droughts have affected the groundwater table considerably leading to changes in the cropping pattern from food crops towards cash crops (Vijayan, 1994).

The present studies were conducted in Keoladeo National Park as well as in the radius of 60 km outside of the park (Figure 1). This National Park is one of the few remaining wintering ground of western population of endangered siberian crane and other variety of birds. The physical and floristic feature of the park is discussed below.

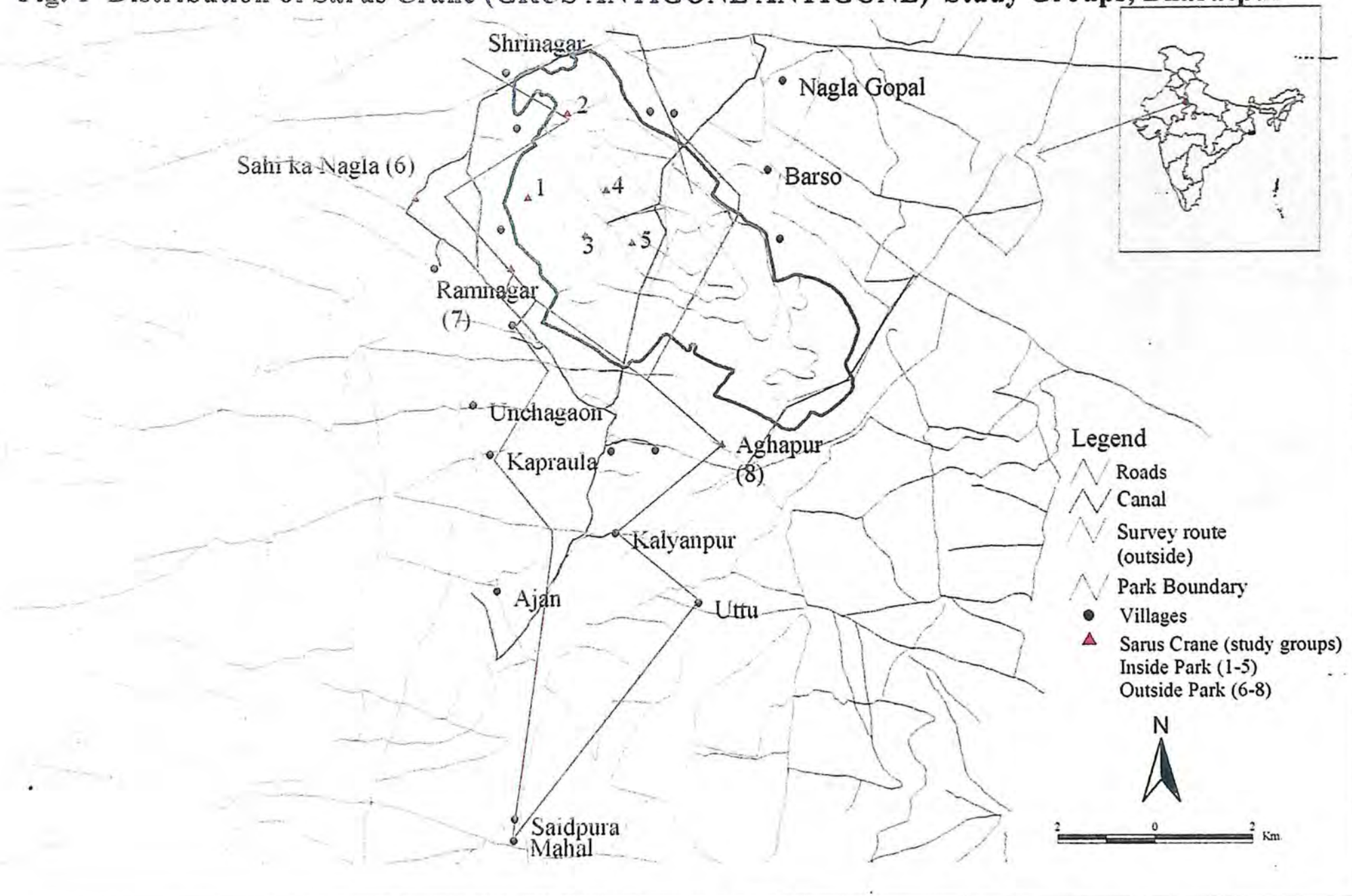
## 2.1 Location

The study area, Keoladeo National Park situated between 17°7'6" to 27° 12'2" N and 77°29'5" to 77°33'9"E, is 2 km southeast of Bharatpur city, 38 km South–west of Mathura and 50 km west of Agra. It is midway between New Delhi and Jaipur some 180 km from each (Vijayan, 1994).

## 2.2 Boundary

A masonry wall around the border separates 29 $km^2$ park from surrounding agriculture fields. There are 18 villages around the park.

Fig. 1 Distribution of Sarus Crane (GRUS ANTIGONE ANTIGONE) Study Groups, Bharatpur



## 2.3 Landmarks

A unique feature of the wetland ecosystem of the Keoladeo Ghana National Park is its origin from a natural depression, which was an evanescent rainfed wetland. The Ajan bund, a temporary reservoir, about a kilometer from the present border of the park, constructed some 150 years ago and the subsequent, several earthen bunds and sluice gates were constructed to contain and regulate the water level.

Two major canals pass through the park, Chiksana canal and Ghana canal which are the major source of water in the park drawn through a canal from Ajan bund during monsoon. However the water gradually recedes and the park dries up between February to May, leaving only some pools in the deeper areas. These pools, which teem with fish, attract flock of fish-eating birds of different species. Despite this a large number of fish die in the drying pool and scavengers King Vulture (*Sarcogyps calvus*) and Long billed Vulture (*Gyps indicus*) have a feast. During this season the park is supplied with water with 3 water pumps, so some resident creatures are able survive and use the park for roosting as sarus crane (*Grus antigone antigone*) and Black- necked stock (*Ephippiorhynchus asiaticus*).

### 2.3.1 Water management

Water, no doubt, is the key factor of any wetland system. The quantity, quality. and time of supply along with the duration of the dry period determine the biological cycles and the functioning of the wetland system (Vijayan, 1991), as has been observed in the case of many wetlands and marshes (*Weller,1978). The optimum amount of water required for Keoladeo Ghana National Park is recommended at 14 million $m^3$ and it should be released between the first and third weeks of July. Although this area has a history of floods and droughts, the frequency of these has changed over the decades during this century, with a decrease in floods but increase in droughts during 1980s (Vijayan, 1991).

The water holding capacity of the wetland extending over $12km^2$ area is 11 to 14 million cu. m. With the onset of monsoon sufficient quantity of water is released into the park in order to coordinate with the breeding activity in the heronry (Ali and Vijayan, 1986).

By August- September the park is filled up to its maximum water holding capacity. Water depth in each block is kept at different levels so that habitat diversity providing the specific water depth requirement of each bird species is maintained (Ali and Vijayan, 1986).

(Vijayan, 1991) recommended bringing in water from the river Chambal, although it is more expensive than from river Yamuna, as the latter is highly polluted. Water from river Chambal could be utilized for irrigation as well, as the park requires it only when water is not available from river Gambhir, the present source. Therefore the project to bring water from Chambal is proposed to a part of an integrated development programme for the whole area. This will not only enable the conservation of the wetland, but also keep a long-term perspective of gaining goodwill of the local communities living around without which the conservation of this tiny but important wetland is impossible. Tapping ground water is not considered as an alternative, since it is devoid of any life forms. The multitudes of plankton, other lower organisms and fish that enter the park through the water from rivers have a major role in maintaining the biodiversity and ecology of the park (Vijayan, 1991).

### 2.3.2 Hydrometeorology

The average relative humidity from 1984 -1990 was 62.5+- 10.5% (Ali and Vijayan, 1986). The impact of rainfall on water storage is negligible because of high evaporation. Annual water loss through evapo-transpiration during 1983 to 1988 varied from the minimum of 167 to the maximum of 238cm.The average rate of infiltration for the aquatic blocks was 44.64 mm per month. The average rainfall in the area for the last 100 years was 655 mm and for the last 10 years 496 mm. It fluctuated between 356.6 mm and 889.4 mm during the last decade. Drought condition was experienced in two consecutive years, 1986 and 1987 when the rainfall was 425 mm and 423 mm respectively. Precipitation was largely from the southwest monsoon (Ali and Vijayan, 1986).

During my study, the lowest temperature was about 4°C at 06:00 hours in winter and 15°C at 06:00 hours in summer. The highest temperature was 30°C at noon time in winter and 50°C at noon time in summer.

## 2.4 Topography

The total area of the park is about 29 $km^2$. It is flat with a gentle slope towards the center forming a depression, which constitutes the wetland, the total area of which is about 8.5 $km^2$ The average elevation of the park is 174m from mean sea level. The bottom of the compartments is generally flat except a narrow stretch a long side each dyke, and a still

narrower stretch around each mound which is deeper owing to the removal of mud for constructing dykes and mounds. Occasionally some ditches of varying sizes occur in the rest of area. The submersible area of about 900 ha is divided into various compartments by earthen dykes in which sluice gates are built at strategic locations to regulate the water supply. These wetland compartments are surrounded by terrestrial habitat of about 2000ha except in a small area on the northwest, which is continuous with the agricultural fields of nearby villages (Ali, 1953).

## 2.5 Soil

The soil is alluvial and at many places the saline patches can be seen. In fact Bharatpur was salt producing town and the salt production was banned in 1885 A.D. through a pact between Bharatpur State and the British Government (Website keoladeonationalpark.com).

## 2.6 Climate

The climate of the area is sub-humid to semi-arid, but has remained mostly semi- arid during the 1981-91 decade. Bharatpur experiences climatic extremes from a hot, dry summer (April to June) to a cold winter (November to January) and short monsoon (July to September) and post- monsoon (September to October) seasons. Spring, although not conspicuous, is experienced in February- March. The temperature ranges from a minimum of $0^0$C to $20^0$C in winter to a maximum of $48^0$C to $50^0$C in summer (Vijayan, 1991).

The southwest monsoon, which sets in towards the end of June, extends up to September with occasional slight showers in October. The mean annual rainfall is about 650 mm, but averaged only 500 mm in the 1980s with more frequent droughts than in other decades of the second half of this century (Vijayan, 1991). Humidity increases with the beginning of the monsoon making the climate muggy (Vijayan, 1994).

## 2.7 Vegetation

The Forest is of the dry mixed deciduous types. The general habitat of the park can be broadly divided into the following types (Vijayan, 1991).

(1) Wetland

(2) Woodland and scrub Jungle

(3) Grassland

(4) Saline and Sandy Soil Patches

Around 282 species of plants have been identified in the park, consisting 41 species of trees, 32 of shrubs 156 of herbs 24 of climber and 39 of grass among these grass which is *Paspalum distichum*, a perennial grass, is the most dominant species (Prasad, 1988). Keoladeo National Park has about 6 $km^2$ of grassland consisting of perennials such as *Cynodon dactylon*, *Vetiveria zizanioides* and *Desmostachya bipinnata* annual such as *Dicanthium annulatum*, *Paspalidium punctatum*, *Sporobolus helvolus*, *Echinochloa colonum*, *Panicum antidotale*, *Paspalum* species, *Cyperus rotundus* and *scirpus tuberosus* (Nanjappa, 1986).

## 2.8 Fauna

50 species of fish, 5 species of amphibians, 8 species of lizards, 13 species of snakes, 7 species of turtles, 375 species of birds and 27 species of mammals have been reported from the park (Vijayan, 1991) A total of 35 species belonging to 19 genera of 7 families of butterflies have been reported from the park (Website.keoladeonationalpark.com).

Around 115 species of birds including common crane (*Grus grus*) and siberian crane (*Grus leucogeranus*) were seen during my study.

## 2.9 The Intensive study area

The intensive study was conducted in and around the park covering at least 10 km radius outside the park. Eight places were chosen out of which 5 were inside the park and 3 outside the park. I started the study on 22 November, and finished work on 3 May 2001. The study lasted a total of 161 study days, out of these 97 days were spent outside the park as well as inside the park.

Based on groups studied inside and outside the park (figure 1), sites were renamed as:

a) Inside the park

group no.1 (27°10'82" N- 077°30'98"E) in block L

group no.2 (27°11'24"N - 077°30'21"E ) in block N

group no.3 (27°09'84"N- 077°31'89"E) in block K

group no.4 (27°10'15"N- 077°31'87"E) in block D and

group no.5 (27°09'91"N- 077°31'54"E) in block E

b) Out side the park

group no.6 Sahika Nagla (27°10'51"N- 077°29'12"E)

group no.7 Ramnagar (27°09'13"N- 077° 29'58"E)

and group no.8 Aghapur (27°07'74"N, 077°30'78"E ) (Figure .1).

# CHAPTER 3 : METHODOLOGY

## 3.1 Population and social group assessment

For understanding the population structure as well as the distribution pattern and social grouping of sarus crane inside and outside KGNP a transect (Figure. 2) was laid within KGNP and a survey route was prefixed (Figure. 1) which were mentioned as detailed below. For examining population status and social structure of sarus crane, sampling has been done in many ways.

1) Two kinds of population census (about 40 $km^2$ and 60 $km^2$ distance) have been done both outside and inside the park respectively. Total 11 days were spent on this throughout the research time. It was done at the same time each day from 07:00 hours to 13:00 hours.

2) The same kind of method was used inside (29 $km^2$) and outside the park (within 11 $km^2$), total 40 $km^2$, for 7 days during the survey period.

3) Another method was used in 29 $km^2$ inside the park and in 31 $km^2$ outside the park. Total area covered was 60 $km^2$, and total 4 days in survey period were spent on this.

4) 3 times a day inside the park, regular population counts were carried out throughout the research period. Data before sun rise to 08:30 hours, 11:00 hours to 12:00 noon and 16:00 hours to just half an hour after sun set were collected.

5) For 4 days continuous observation from 07:00 hours to 19:00 hours were carried out for group no.4 on 30 March, 31 March, 7 April and 11 April 2001.

## 3.2 Intensive study groups and sites

### A. Inside - Keoladeo Ghana National Park (Figure 3)

**Group. 1 (Block L)** (27°10'82"N- 077°30'98"E)

The area covered by this group is about 5.6$km^2$ in block L which was larger than other (Figure 2). The group 1 remained in water through out my observation period. One of the pumps had been providing water supply in this place throughout my study period. Water level was between 0.61 m to 0.91m. Water spread in November was 3.04 $km^2$ and 0.8 $km^2$ in May (Table 1).

Mound numbers 262 are within this area (Table 2). The site had sarus groups, among which three individuals to 22 individuals were in foraging ground. Roosting ground had 10 sarus in last week of November and 3 sarus in first week of May (Table 3).

Fig.2 - Transects laid for Sarus Crane study in the Keoladeo Ghana National Park (Dec 2000 - Apr 2001)

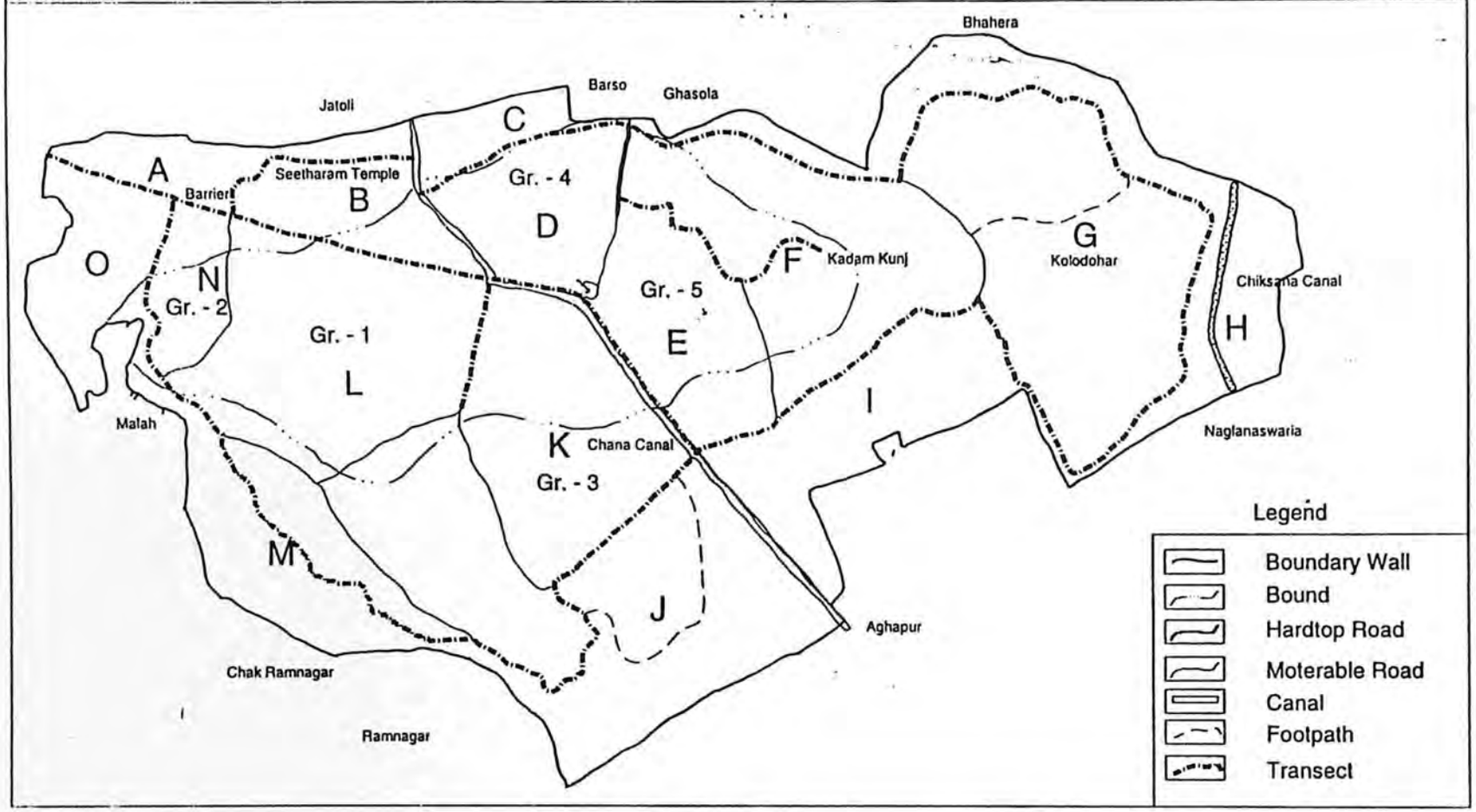


Fig. 3 - Distribution of Sarus Crane in Keoladeo Ghana National Park (Nov 2000 - May 2001)

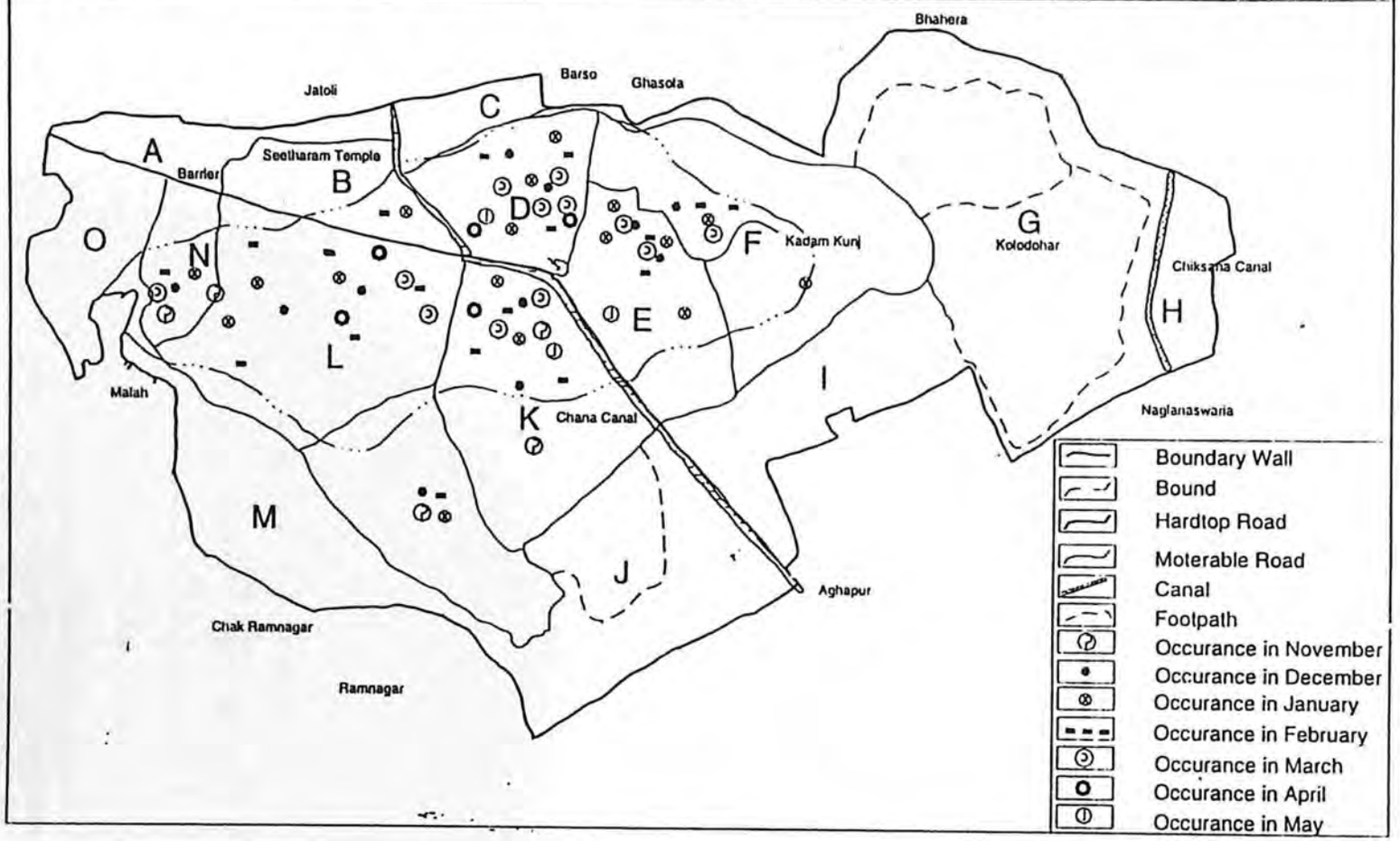


**Table - 1 : Area covered by Water Spread in Intensive study site/ group inside the Keoladeo Ghana National Park during the study period**

| Study/ groups and Block | Area Covered ($km^2$) | Water Spread in November ($km^2$) | Water Spread in May ($km^2$) |
|---|---|---|---|
| 1 - L | 5.6 | 3.04 | 0.8 |
| 2 - N | 0.96 | 0.16 | 0 |
| 3 - K | 2.56 | 1.44 | 0.16 |
| 4 - D | 1.44 | 1.12 | 0.48 |
| 5 - E | 1.76 | 1.28 | 0.48 |

**Table - 2 : Habitat Features at each Intensive study site/ group**

| Study/ Groups and Block | Mound | Area ($km^2$) | Group Type (Dominant) |
|---|---|---|---|
| 1 - L | 262 | 5.6 | Family |
| 2 - N | 87 | 0.96 | Family |
| 3 - K | 106 | 2.56 | Pair |
| 4 - D | 457 | 1.44 | Pair, Solitary, Group and Congregation |
| 5 - E | 150 | 1.76 | Family, Pair, Solitary and Congregation |

**Table - 3 : Sarus Group Sizes in roosts across months (1st week - 4th week) inside the park**

| Study/ Groups and Block | Nov | Dec | Jan | Feb | Mar | Apr | May |
|---|---|---|---|---|---|---|---|
| 1 - L | - 10 | 4 - 6 | 3- 17 | 3- 3 | 3- 5 | 3- 3 | 3- |
| 2 - N | - 4 | 4 - 4 | 3- 3 | 3- * | * | * | *- |
| 3 - K | - 3 | 2 - 4 | 2- 4 | 23- 2 | 3- 2 | 2- 1 | *- |
| 4 - D | - 32 | 23- 32 | 25- 28 | 28- 5 | 4- 27 | 28- 3 | 2- |
| 5 - E | - 7 | 7- 7 | 7- 7 | 43- 48 | 57- 5 | 6- 2 | 2- |

***= not using the study area**

**Table - 4 : Number of sarus pairs sighted month wise in and around Keoladeo Ghana National Park**

| Month | Maximum | Minimum |
|---|---|---|
| November | 3 | 1 |
| December | 4 | 2 |
| January | 5 | 1 |
| February | 8 | 2 |
| March | 14 | 3 |
| April | 10 | 2 |
| May | 2 | 2 |

**Table - 5 : Number of solitary sarus sighted month wise in an around keoladeo Ghana National Park.**

| Month | Maximum | Minimum |
|---|---|---|
| November | 2 | 1 |
| December | 2 | 1 |
| January | 2 | 1 |
| February | 2 | 1 |
| March | 2 | 1 |
| April | 4 | 2 |
| May | 0 | 0 |

**Table - 6 : Number of sarus groups sighted month wise in and around Keoladeo Ghana National Park**

| Month | Maximum | Minimum |
|---|---|---|
| November | 3 | 2 |
| December | 3 | 1 |
| January | 2 | 1 |
| February | 4 | 1 |
| March | 5 | 2 |
| April | 2 | 1 |
| May | 0 | 0 |

**Table - 7 : Number of sarus congregations sighted month wise in around Keoladeo Ghana National Park**

| Month | Maximum | Minimum |
|---|---|---|
| November | 1 | 1 |
| December | 2 | 1 |
| January | 2 | 1 |
| February | 2 | 1 |
| March | 2 | 1 |
| April | 1 | 1 |
| May | 0 | 0 |

**Group. 2 (Block N)** (27°11'24" N- 077°30'21" E)

The area covered by this group is 0.96 $km^2$. Wetland vegetation type was dominant and water became scarce in late winter and summer. It was a dry wetland area. *Typha angustifolia* covers an area of 0.003 $km^2$ with a maximum height of 3.63m and a minimum height of 0.97m, root height at 0.30m. During winter and in the beginning of summer, the juveniles did not fly, so parents and juveniles stayed among the *Typha angustifolia* for foraging. Water spread was 0.16 $km^2$ in November and there was no water at this site in March (Table 1).

In the 2nd week of April all *Typha angustifolia* were dead. Sarus crane family (parent and juvenile) was not using the area after March 2, 2001. However, a sarus pair was using the area on 18 March 2001 at 08:40 hours to 10:15 hours displaying courtship behaviour. Mound numbers 87 are located within the areas of this group (Table. 2).

The site had sarus groups, among which three individuals to 7 individuals were in foraging ground. Roosting ground had 4 sarus in last week of November and no sarus in first week of May (Table 3).

**Group. 3 (Block K)** (27°09'84"N- 077°31'89"E)

The area covered by this group is 2.56 $km^2$. Water spread was 1.44 $km^2$ in November and 0.16 $km^2$ in May. Water depth was 0.61 m in November and less than 0.30 m in May (Table 1).

Grassland habitat was dominant. Mound number 106 are located within the areas of this group (Table 2).

The site had sarus groups, among which one individual to 25 individuals were in foraging ground. Roosting ground had 3 sarus in last week of November and no sarus in first week of May (Table 3).

**Group. 4 (Block D)** ( 27°10'15"N- 077°31'87"E)

The area covered by this group is about 1.44 $km^2$. Water spread in November was 1.12 $km^2$ and 0.48 $km^2$ in May. During November to January water depth was 1.12 $km^2$. In May, water spread was 0.48 $km^2$ (Table 1).

This area was used by congregation group for roosting from Nov 22nd to 14 February 2001. On 15 February that congregation group started to spread and some groups shifted to area of group 5 for roosting.

This area is quite different than others places it has about 457 mounds (Table 2) some of them are 1.2m in height, and then around them there is *Typha angustifolia* 0.001km$^2$ cover. Around the mounds water level was about 0.60m. So it was possible for the sarus to use escape cover also. While water spread and water depth were suitable for sarus roosting as well as feeding ground.

The site had sarus groups, among which one individual to 28 individuals were in foraging ground. Roosting ground had 32 sarus in last week of November and 2 sarus in first week of May (Table 3).

**Group. 5 (Block E)** (27°09'91"N-077°31'54"E)

Area covered by this group was 1.76 km$^2$. Normally, 2 pairs and one family were using this area from 22 November, to 12 February. Initially I observed a congregation using this place as roosting and feeding ground during 15 February to 24 February. On 25 March 2001, only one family was using at this place as roosting site.

On March 31, that family shifted to somewhere else and did not come back till May 3rd. Only one pair used the area for roosting during April to May. In first week of February water spread was 1.28km$^2$ and water depth was 0.61 m and by the last week of April water spread was 0.48km$^2$ and water depth was 0.30m (Table 1). Mound number 150 are located within the areas of this group (Table 2).

The site had sarus groups, among which two individuals to 35 individuals were in foraging ground. Roosting ground had seven sarus in last week of November and 2 sarus in first week of May (Table 3).

**B. Outside - Keoladeo Ghana National Park**

**Group No. 6** (27° 10'51"N-077° 29'12"E)

This group was located 2 km west of the KGNP boundary. The area covered is 2 km$^2$, the field used by the cranes was 1km far from the village (figure 1). Farmers grew following species: *Triticum aestivum* (*Wheat*), *Pisum sativum* (*Muttor*), *Bronica campestris* (*Mustard*),

*Lens culinaris* (*Masoor*), *Chenopodium album* (*Bethur*), *Cicer auretinum* (*Gram*). Group no.1 family used this area for foraging during February to April. The site had sarus groups, among which two individuals to 22 individuals were in foraging ground.

**Group No. 7** (27°09'13"N- 077° 29'58"E)

This groups was within a distance of 0.5 km from the western boundary of the park and used and area of $2km^2$ (figure 1).

The site had sarus groups, among which one individual to 2 individuals were in foraging ground. Both group 6 and group 8 had the same agricultural crops, however the topography was different. High way road was higher than agriculture fields by 6 m and the distance between the car road and the agriculture field was 3 m. So the large number of sarus were not using this area. Group no.8 also car road is 10m higher than agriculture fields but distance between the car road and the agriculture field was 60m.

**Group No. 8** (27°07'74"N- 077°30'78"E)

This group was within a distance of 1km from the southern boundary of the park and used area of studied covering within $2km^2$ (figure 1).

Pair, family and congregation were using this area for foraging ground. Congregation starts using the area in November until 2nd week of March while family (Group 5) used it throughout February to March. Pair was using it till April 10. Sarus cranes were not using this area after April 10, 2001. The site had sarus groups, among which two individuals to 24 individuals were in foraging ground.

## 3.3 Behavioural observations

Ethology can be briefly defined as the application of orthodox biological methods to the problems of behaviour (*Lorenz, 1960).

Behavioural units can be classified in several ways (*Rekoff, 1979). Ethnologists' personal perception constructs and methods of categorization all affect their separation and recombination of behaviour units from a stream of behavior (*Fentress, 1990).

The behavioral repertoire for the world's 15 species of cranes includes over 100 behavioral acts with social significance. Each species performs at least 60 discrete social postures, vocalizations, displays, and activities. Because all but a handful of the stereotyped social displays are common to all species, the presence or absence of social displays was useful only to a limited degree in comparing the relatedness of established crane taxonomic group. (*Eliss *et al.*, 1977).

The social ethogram: it consists of two parts. First is the sociogram (*Wilson, 1975), a description of all social displays, together with higher-level behaviour sequences, (e.g., dance or attack). The second part is a tabulation of the presence and importance of each social ethon (a non- restrictive term for behavioural acts as simple as a reflex or as complex as an activity: (*Ellis, 1979) for each species. Observing cranes in the same context and at the same time each day reveals seasonal changes in social patterns and abnormalities suggesting health problems. Data collection can be as simple as merely noting abnormalities or social problems, or as complex as a bird-by-bird tabulation of behaviour details on form sheets. Daily observations are essential in monitoring the pairing and social interaction of cranes in the same pen or adjacent pens (www.pwrc.usgs.gov/pubdata/htm). For the present study, observation on following six behaviour types were made:

### 3.3.1 Behaviour types

Alert

This is often used when a bird is standing and doing nothing else that the observer can identify other than being vigilant. In cranes, this behavioral category can often be broken down by the posture of the head or body. For example, Head Extreme Up is a high level of alertness compared to Head Up or Head Low (Barzen, pers.comm).

Comfort

In cranes, this refers primarily to bathing, preening and body shakes. Within these sub-headings, further layers of descriptions can be identified (Preening head, Preening body, etc.) (Barzen, pers.comm).

Preening by cranes is a time-consuming activity that begins shortly after hatching and continues throughout life, especially during moulting periods. Typically cranes preen a single region for up to about 20 seconds, and then move to another area. Frequently the feather is nibbled at its base initially, and then feather is gently drawn through the beak between the upper and lower mandibles. This is especially true of the longer body and wing feathers, the vanes of which must be kept in fine repair if they are to provide a suitable airfoil. Bathing is performed by initially crouching in the water and flapping the wings and is often accompanied with a bobbing movement of the body, which tends to spread water up and over the breast and back. Bathing periods may last for several minutes, and are followed by prolonged preening. Newly hatched cranes are able to swim surprisingly well, considering their absence of webbed feet, and even juveniles as old as three months have been observed swimming fairly easily (*Walkinshaw, 1949).

Social Interaction

For cranes, this can refer to aggressive behaviors, courtship, reproductive behaviors (such as copulation) and vocalizations. The third level of description for aggression can be Crouch Threat, Ruffle Threat, etc. (Barzen, pers.comm).

Cranes are aggressive birds. When fighting, they leap into the air to take their opponents with their sharp claws or stab at them with their bill. This continues until one bird runs or flies away, sometimes closely pursued by the victorious bird. Aggression display often occurs immediately after a crane lands near a flock of cranes, while chasing another crane, or immediately after copulation, it may be performed while running, walking or standing still. The crown is expanded, the neck and head are pointed directly downward, and the feathers at the base of the neck and back are strongly raised. This distinctive posture may be held for as much as 10 seconds, and jabbing at the ground or vegetation sometimes accompanies it.

Fighting is dangerous to both participants, however, so cranes use a complex system of threat behaviors allowing rivals to avoid fighting. Communication includes both physical postures and vocalizations. Ruffle, drop-wing, and crouch threats indicate low-, mid-, and high-intensity aggression levels respectively, so many aggressive encounters are resolved

before fighting becomes necessary. Most crane species also will flash the bright red patch on top of their heads to an opponent or predator to indicate growing excitement.

The unison call is a dramatic duet between the male and female of a mated crane pair. It is used as a territorial threat to neighbouring pairs and is most frequently given at the onset of the breeding season when wetland real estate is being divided and defended. During this display, the calls of the male are completely different from, although synchronised with, the call of the female. While male and female cranes are identical in external features, gender is readily told by the unison call. (Website, savingcranes.org)

During courtship the male and female display spectacular dancing, bowing mutually and leaping round each other with outspread wings Courtship behaviour in sarus crane is very spectacular and is so often displayed during the breeding season. Clearly and ancient type of behaviour (Desai, 1980). Indeed, very similar behaviour occurs in trumpeters during apparent courtship. The dancing display of cranes is common to all species. Although crane dancing is also generally believed to be associated with courtship. Flightless chicks dance by alternate wing flapping, jumping or bouncing, and running movements. As the birds grow older, "bowing" and "stick-tossing" also become a part of the activity.

Precopulatory behavior may be initiated by either sex, but usually seems to be started simultaneously. The male may be up to 50meters from the female, and begins to walk toward her in parade march, either tertials raised, crown expanded, bill pointed upward, and neck stretched nearly vertically. The female holds her body in much the same position, and as the male approaches her closely she extends her wings horizontally outward, drooping at the wrists. As the male comes nearer he lowers his bill until it is pointing slightly downward, and then flaps his wings once or twice as he leaps on her back. His toes are hooked over her forewings and his tarsi rest on her rump, as the female bands forward into a nearly horizontal position, with her head slightly raised. The male remains on the females back for up to 5 seconds, while flapping his wings to maintain his balance. He dismounts by stepping off backward or hopping for ward over her head.

Following a successful copulation there is a post-copulatory display that may last up to 20 seconds. The birds typically stand side by side with their crowns expanded and their necks stretched vertically upward. They typically simultaneously perform a charge display, and then stand with their beak horizontal and their crowns expanded for several seconds. Finally, a ruffle-threat or a ruffle-leg-threat may be performed. Foraging, Preening or dancing may follow later (Johnsgard, 1983).

Foraging

Foraging behavior in cranes can be broken down by the types of foraging observed: Pecking, Probing, Gleaning, etc. These behaviors can be broken down based on the habitat in which the bird is observed. (Barzen, pers.comm).

Cranes pursue small prey, and sometimes each other, by running. A running crane takes one to three steps per second and may use its wings for balance and to gain speed. While a running crane looks awkward, they can easily outrun humans. Cranes do not have webbed feet, but they can swim, although adult birds usually avoid deeper water unless necessary. Chicks are good swimmers and may leave the nest to follow the parents through the wetlands, sometimes within a few hours of hatching. Feeding is one of a cranes' most time-consuming activities. Cranes spend most of the daylight hours in areas where food is most abundant. Cranes forage for roots and the starchy swellings found on the roots of certain plants called tubers. They also eat seeds, small mammals and reptiles, eggs of other birds, and invertebrates, such as worms, clams, insects, and crayfish (Website, savingcranes.org).

During the present study, data were obtained of sarus crane feeding on leaves of *Masoor* (*lens culinaris)* and *Masoor* fruit, gram seed and fruit, *Muttor* (*Pisum sativum)* leaves and fruits and wheat seeds and earthworm. These data were obtained by time activity budget and habitat study. Ingestion of solid food is performed by pecking movements or by digging in the ground with the beak. Scratching with the feet is evidently rarely if ever used. Drinking is performed by dipping the bill in the water and quickly raising it upward and forward. A single drinking sequence requires about five seconds, and it may be repeated up to seven times in succession.

Locomotion

Flying or walking is the two most frequent sub-headings with cranes. (Barzen, pers.comm).

Walking and running are performed with a human-like movement, at rates of from less than one to more than three steps per second. When running fast, cranes achieve a bouncing gait, and occasionally a running crane will extend it wings and flap them to some extent, apparently to gain additional speed and maintain balance. In flight, the legs typically are held back in direct line with the body, but it is not uncommon to see cranes flying in cold weather with one or both legs tucked invisibly forward in the flank feathers, producing a goose-like flight profile.

Resting

When birds are sleeping or otherwise not vigilant and not exhibiting. (Barzen, pers.comm).

Resting on a single leg is frequent in adults, with one leg locked in a vertical position and the other lifted and hidden in the flank and belly feathers. Resting or sleeping on two legs is similar, but both legs bear the body's weight. In either case the head and neck may be held fairly erect, may be nearly resting on the breast or may be drawn to the side and rear, with the bill tucked into the scapular feathers. (Johnsgard, 1983).

Other behaviors.

The specific behaviors assigned to each category depend upon the objectives of the study, since these categories can overlap. For example, the behavior of a crane that is walking and pecking at grasshoppers in a field simultaneously might be listed under Locomotion or Foraging. If the study is focused on foraging ecology, it may be listed as Foraging. If the study examines the energetic of behavior, it may be listed it under Locomotion (Barzen, pers.comm).

### 3.3.2 Group types

In the present study group types were described as:

(1) Pair with juveniles (Family)
(2) Pair
(3) Solitary
(4) Group
(5) Congregation.

Time Budget Sampling has already carried out both inside and outside the park at least once a day but different time sequence has been adopted each day.

**Pair with juvenile (Family)**

In the present study one adult male and one adult female with juveniles were indentified. A total of three families were recorded, two families were inside the park and one outside. In side the park, among those two families found in through November to March. In April to May one family it was from inside park shifted to outside my study area.

**Pair.**

In the present study defined as one adult male and one adult female in one area (Table 4).

**Solitary**

In the present study defined as one sarus crane in one area from others sarus crane (Table 5).

**Group**

In the present study defined more than two and less than 10 individuals of sarus cranes within one area (Table 6).

**Congregation**

In the present study defined 10 individuals and more of sarus crane within one area (Table 7).

### 3.4 Habitat use by sarus crane

To determine various kinds of habitat used by sarus crane during the study, all sightings of sarus crane were placed into

a) sightings in wetlands
b) sightings in dry wetlands
c) sightings in grasslands
d) sightings in agricultural lands

Habitat was considered a wetland, dry wetland, grassland or agricultural land based on characteristics as detailed below. Previous researchers have already classified the habitat types inside the park (Vijayan, 1991). In the present study, similar method was followed with modification for habitat availability and utilization. Plant specimens were collected from 58 number of 1.5 $m^2$ quadrates to determine their habitat categories on plants species.

Three major habitat types occur in the Keoladeo National Park:

(1) Wetland: Ecotone formed by the dykes in the wetland area along the blocks D and N covers about 8.5 $km^2$. Trees (*Acacia*) and bushes (*Capparis*, *Salvadora*, *Lawsonia*) with some climbers are abundant along the sides of the dykes (Ali and Vijayan, 1986).

(2) Dry wetland: The habitat within wetland areas that had wetland flora *typha angustifolia*, *Scirpus tuberosus*, *Cyperus rotundus*, *Cyperus alopecuroides* and *Ipomoea aquatica* with no standing water were classified as dry wetland.

(3) Grassland: Keoladeo National Park has about 6 $km^2$ of grassland consisting of perennials such as *Cynodon dactylon*, *Vetiveria zizanioides* and *Desmostachya bipinnata* annual such as *Dicanthium annulatum*, *Paspalidium punctatum*, *Sporobolus helvolus*, *Echinochloa colonum*, *Panicum antidotale*, *Paspalum* species, *Cyperus rotundus* and *scirpus tuberosus* (Nanjappa, 1986).

(4) Agricultural Land: This is one of the major habitat types outside the park. The study listed 12 flora species (both cultivated and natural) in study sites such as *Triticum aestivum*, *Pisum sativum*, *Lens culinaris* and *Bronica campestris*.

Total of 58 quadrats were laid in different habitats and sites covering in throughout the February because February is the start of summer season and all the plants began to dry, while the harvesting of agricultural crops was initiated. Vegetation studies were carried out from November to April. Following parameters were recorded for each day of observation:

Habitat types, water spread and water depth, number of animal sharing the same area when the sarus crane groups was observed. As most sarus cranes were counted in wetland situation it was covered the most throughout my surveys.

### 3.5 Seasonal Changes during the study period

There are three major seasons in the study area, namely, June, July, August and September are the rainy season, October, November, December and January are the winter season and February, March, April and May are summer season. The present study period was two months in winter and three months in summer. Temperature was recorded at noon time while observing time budget during the survey using a mercury thermometer. Weather was recorded using direct measurements during the study period.

### 3.6 Juvenile weaning process

Since the study was conducted during the post- breeding season from November till the onset of a breeding season. An attempt was made to document the process of weaning of juveniles from the parents. To evaluate this average minimum and maximum distance between juvenile and adult were recorded. However, visitors inside the park and unanticipated human disturbances interfered with this heavily.

# CHAPTER 4 : RESULTS

## 4.1 Sarus crane population in the study area

The mean encounter rate of sarus crane outside the KGNP was greater than that of inside the park. Though the data were not tested due to lack of uniform effort in the two areas the difference is likely to be statistically significant (Figure 4). The overall group composition during the study period differed inside and outside park (Figure 5). The agricultural areas outside had greater number of social family groups sighted during the study period than within the park. The mean encounter rates had greater standard errors associated with them outside the park than inside the park. During the present study (November 2000 to May 2001) the overall encounter rate (sighting/ hour) of sarus crane was higher outside of the park than inside the park. Most of the Social family pairs, congregation, and solitary cranes were outside of the park respectively except that of pairs with juveniles.

The season's winter and summer had an influence on the sarus crane group composition apart from the fact that the groups were either seen within the protected area or outside. With the data from the present study it is not possible to tease apart the effects of these two variables on the sarus group composition. However, in winter sarus cranes were seen in social families and pairs with juvenile more often inside the park than outside the park (Figure 6). The other forms of groups of sarus such as social group, pairs and solitary members were not very different inside and outside the park. In winter season, juvenile could not able to fly more than 0.61m height and 61m distances restricting their movements within the park. During summer the chick could fly outside of the park in the Ist week of February onwards and were seen frequently outside of the park. Sarus cranes spent more time outside the park than inside, except pair with juveniles. Inside the park the safety, food and space supported small groups and pairs all through the year.

The group composition showed a dramatic change in summer where greater number of social families and pairs with juveniles were observed outside the park than inside (Figure 7), while other forms of groups did not vary much in the two areas.

**Figure 4. Encounter rate (S.E) of sarus crane Inside and Outside KGNP.**

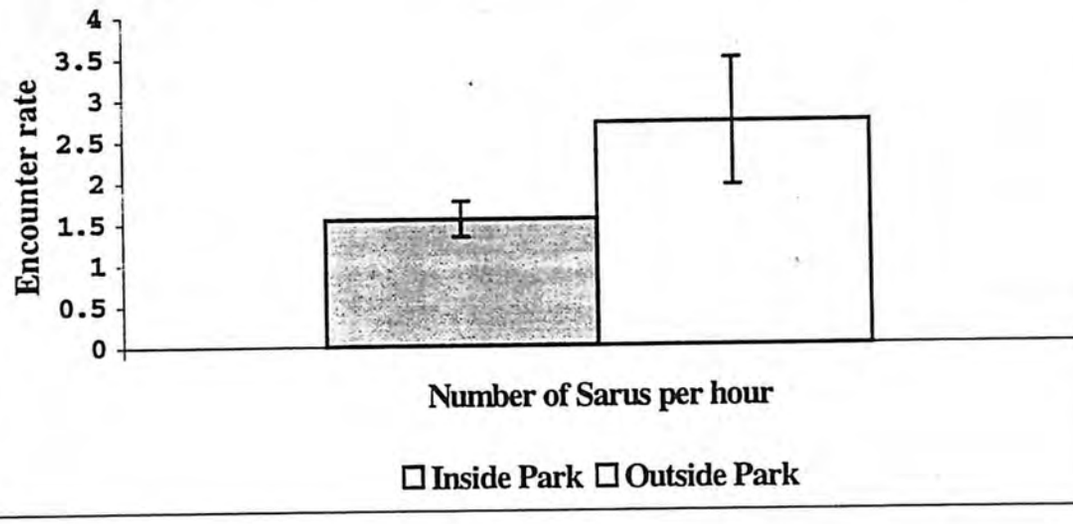


**Figure 5. Group composition (with S.E.M.) of sarus crane inside and outside of Keoladeo Ghana National Park**

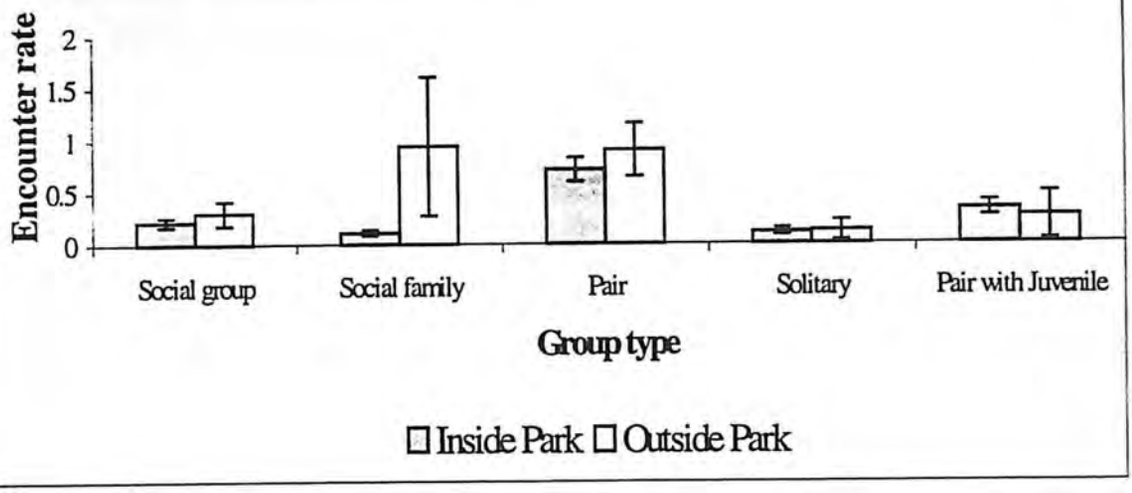


**Figure 6. Group composition of (with S.E.M.) sarus crane inside and outside of Keoladeo Ghana National Park during winter 2001**

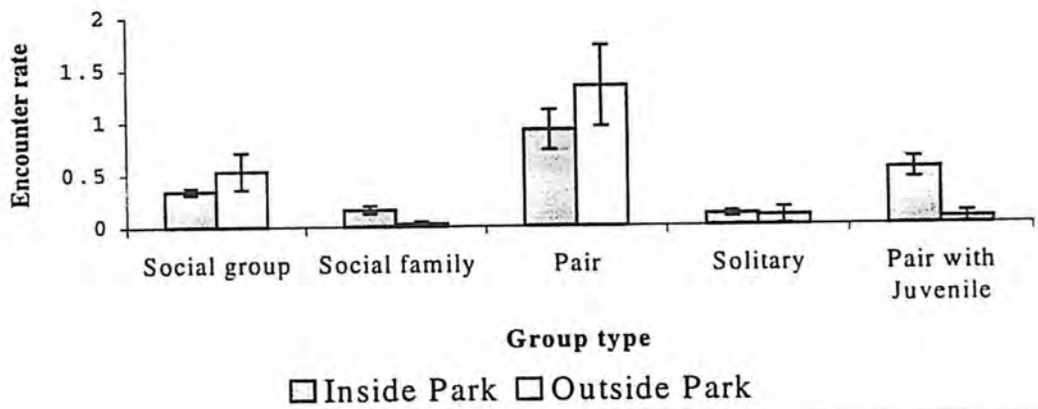
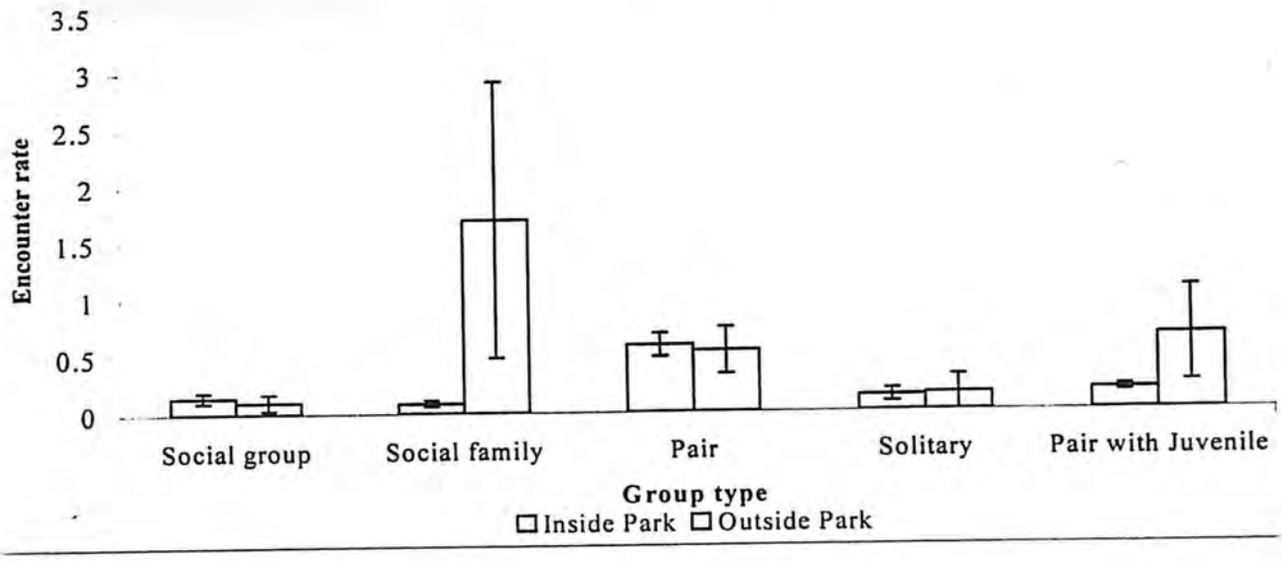


**Figure 7. Group composition of (with S.E.M.) sarus crane inside and outside of Keoladeo Ghana National Park during summer 2001**



During the study period a maximum of 67 sarus cranes were recorded inside the park in roosting areas. Of these eight groups were selected for monitoring. During the present study, sarus crane group used in group no. 1 1.92 $km^2$, 0.64 $km^2$ in-group no.2, 1.28 $km^2$ in group no.3, 1.28 $km^2$ in-group no.4, 1.28 $km^2$ in-group no.5, and 0.64 $km^2$ in others places in inside the park. Total covers were in 7.04 $km^2$ in inside the park (Figure 3). A maximum of 17 sarus cranes were seen in Group no.1 in the 4$^{th}$ week of January, but no sarus crane were seen in group no.2 on 4$^{th}$ week of January 2001. On February 1- 23 sarus cranes in group no. 3 had been seen latter these congregation flew to Group no. 4. However, families (pairs with juveniles) were used in inside the park (group no.1, 2 and group no.5) during November to last week of January for foraging and roosting.

During the present study sarus crane used seven areas inside the park. Roosting for four areas namely, Group no.1, Group no.3, Group no.4 and Group no.5. Foraging for three areas in outside the park, there are group no.6, group no.7 and group no.8. Sarus cranes did not use outside of the park for roosting.

## 4.2 Habitat use

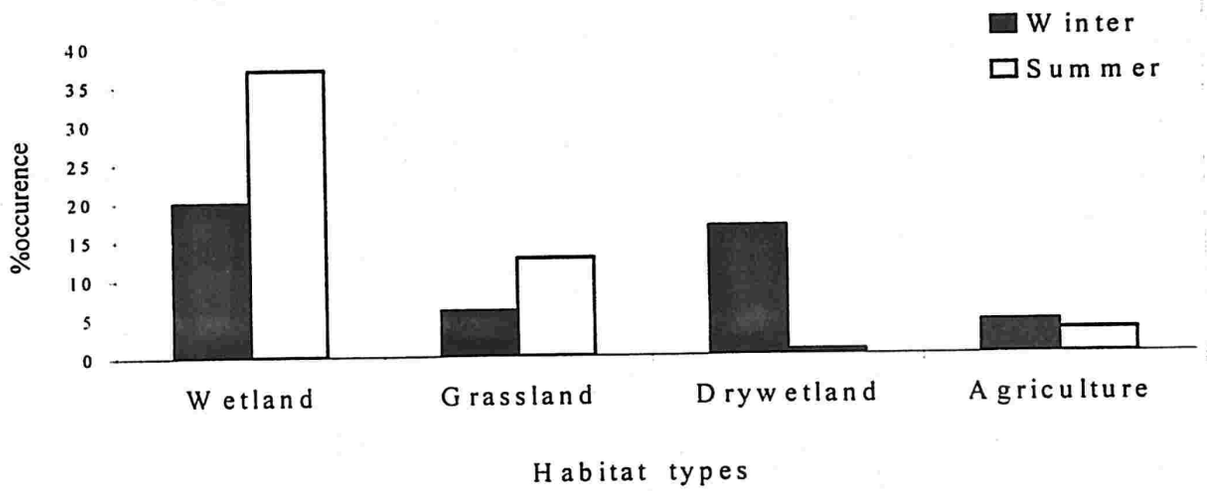
Wetlands were the most used habitat during the study period by sarus cranes than any other habitat type. Grasslands and dry wetlands were used almost uniformly by sarus next to the wetlands, and the agricultural land has the least utilization but with equal proportion in winter and summer. The later could be because of biases in sampling more inside the park than in the agricultural fields outside the park. During summer the sarus cranes occurred more often in wetland and grasslands than in dry wetland or agricultural fields (Figure 8).

During winter and summer sarus cranes mostly used wetland habitat (winter 20.5 % and summer 35%). In summer, as all agriculture fields were harvested and there was no water patch outside the park, most of the sarus cranes used wetland inside the park. The forest department pumped in water throughout the summer in the area of group no.1, group no.4 and group no.5. and sarus crane used this shallow water area extensively.

The area of Group no.3 had very large grasslands. Within this area the wetland area during summer was closer to road so the sarus felt stressed while foraging in this wetland.. Because of large expanse of grasslands in group no. 3 area it was difficult for the visitors to approach to sarus crane. Hence they used this grassland extensively during summer. Among the pair, the female was more wary while using these water patches.

Solitary sarus cranes preferred foraging in grasslands more than the other group types, for example in pairs while female is foraging males remained alert for their safety. However solitary individual can not forage all the time in wetland area in summer time. In summer period. Keoladeo National Park water patches are near the road site only caused disturbance to cranes. In summer water spread becomes narrow so, sarus crane spent more time in grasslands (winter 5% & summer 12%). However throughout my study period sarus cranes were using wetland habitat more than other. Habitat and water is essential for their roosting grounds.

**Figure 8. Percentages of various habitat types used by sarus crane in Keoladeo Ghana National Park during 2000-2001**



Sarus cranes were not found to use dry wetlands in summer due to lack of moisture in this area which hinders growth of grasses and other aquatic flora and also insects in such dry wetlands. Sarus cranes were observed to use agriculture land more during 2nd week of December, 1st week of March and 4th week of April, as farmers sowed wheat during December in the agricultural lands and harvested *mustard* and *masoor* in the 1st week of March and wheat in 1st week of April. During these periods sarus mostly used agricultural fields.

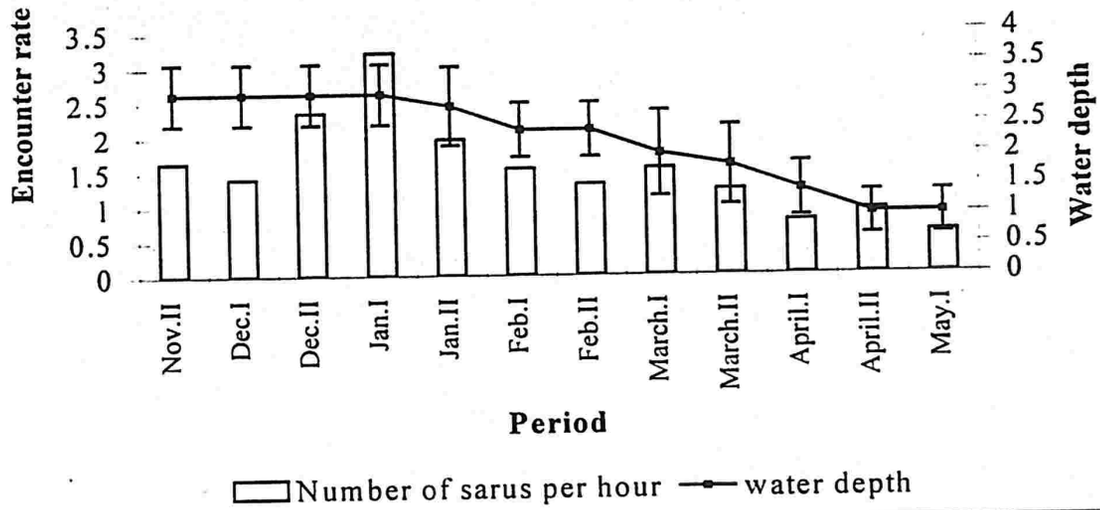
The encounter rates (sightings/ hour) of sarus crane correlated with water level (Figure 9) During higher large water spread more cranes were encountered. Water depth was correlated with mean encounter rates (r= 0.77, N=12), similarly water spread also had a significant positive correlation (r=0.64, N=12). As expected water depth and water spread had a strong positive correlation (r=0.95, N=12).

## 4.3 Parent and juvenile relationship

At the beginning of the study in November the juveniles were apparently three months old, and when the study was concluded in May. The juveniles were nine months old and they continued to remain in the vicinity of the parents. However, it is speculated that the quantum of time spent by the parents parenting the juvenile could have diminished with time. The major interaction between parent and juvenile during the observation period was "nursing" behaviour, where the parent fed the juvenile directly into its mouth.

Subsequently, the parent "induced the juvenile to forage" by leading the juvenile to some areas in the wetland where food was abundant and the disturbance from tourists was low. From the last week of February juvenile started to move far away from the parents and maintained an average distance of about 65 m. During this time the parents start courtship behaviour and paid less attention to the juveniles, even though the juveniles showed interest on its parents. In reciprocation of the lack of attention from the parents the juvenile continues to forage away from the parents. Till the end of the study period in May the juvenile continued to tag along with the parents.

**Figure 9. Relationship between encounter rate of sarus crane and water depth inside Keoladeo Ghana National Park during winter and Summer 2001.**




| | | |
|---|---|---|
| **Water Depth** | **0** | **WATER ABSENT** |
| | **1** | **WATER PRESENT = < 0.3048m** |
| | **2** | **WATER PRESENT = 0.3048m to 0.6096m** |
| | **3** | **WATER PRESENT = 0.6096m to 0.9144m** |
| | **4** | **WATER PRESENT = 0.9144m to 1.2192m** |

## 4.4 Daily Activities

The study was carried out in two seasons, winter and summer. Sun rise in winter was at 06:10 hours. Temperature was 4° C at 06: 00 hours and noon temperature was 25° C. Mostly, the weather condition was thick misty in winter. If weather is not clear till 10:00 hours sarus started to fly from roosting area to agriculture field after at 10: 00 hours and returned to park at 16:00 hours. Sun set at 18:00 hours.

The congregations use Intensive Study Area (I.S.A) group no.4 for roosting. One breeding pair used (I.S.A) group no. 3 through out winter and beginning of summer for roosting, one family used the same group for roosting at 3 different places because of water occurrence which were two places in group no.1 and one place in group no.2. Group no. 1 (27° 11'15"N - 077° 30' 14"E) was used as a roosting place but during the end of winter, as there was no water in this location, sarus family used another place of group no.1 which had water (27° 10'82"N -77° 30'98"E).

Generally, during winter, sarus cranes stayed in the agriculture fields from approximately 10:00 hours to 17:00 hours.

In summer, sun rise time was at 05:40 hours. Temperature was 15° C at 05: 30 hours. Sun set was about at 19:00 hours. In beginning of summer, the sarus flew from park at 06:30 hours and returned to park at around 18:40 hours. But during mid-summer they flew at 05:45 hours and come back before noon when the temperature was about 50° C in noon time. And also no water patch in outside the park. The escape cover of *mustard* plant was harvested in summer time (March) in outside the park.

In 1st week of April a maximum of 28 sarus cranes were seen in group no.4. On April 4 at 11:00 hours to 13:20 hours, 27 sarus cranes are together at 13:35 hours while cow boys beat and keep their 500 cattle to group no.4 for grazing. So sarus cranes were disturbed and they flew away, however 23 sarus returned at 19:15 hours to the same place (group no.4) for roosting. The sarus congregation could not use others place for roosting because group no. 4 was suitable for their roosting place in that time. A similar behaviour was observed on April 7 at 13:30 hours. During February to April, the water becomes a scarcity in the park. When sarus congregation come back from outside the park they could not get a chance near the water for foraging because all other species diversity occupied with influence these water area where sarus crane roosting areas. So sarus crane were moved 2 or 3 area before roosting.

Generally, during summer, sarus cranes stayed in the agriculture fields from approximately 05:30 hours to 12:00 hours.

# CHAPTER. 5 DISCUSSION

## 5.1 Sarus crane population in the study area

The sarus crane has two breeding seasons, a major one in during July to August and a minor in during February to March. The latter depends on the quantum of water remaining inside the park from the previous year's supply (Ali and Vijayan, 1986). During the study, maximum of 4 pairs and minimum of 2 pairs of cranes were seen during December 15 and 31 December 31. On 1st of May, two pairs were seen in roosting ground. Two kinds of pairs were observed during November to April. One kind of pair stay separated and defend their territory during November to May, they did not accept any neighbor and they defend their territory. They also attacked solitary sarus cranes and common crane (*Grus grus*) which were observed in Group no. 2 and group no. 5. Another kind of pairs that stayed with other pairs, as groups, and also seen with solitary and congregated cranes.

The difference that was observed in sarus encounter rates within the park and outside could have resulted due to greater visibility outside the park than within the park. However, it could have also come about because of greater food availability in the agricultural fields due to grains that are grown there. It would be futile to interpret the data on the value of the park for sarus because they do use the park intensively to roost. Since the observations were made during the day, there is no estimate of abundance of sarus in its roosting sites inside and outside the park in the present study. The group composition change inside and outside leading to the formation of more "social families" was probably because of the greater risk of predation and disturbance outside the park than inside. The response of the group composition to seasons could have come about mainly due to the cropping pattern in the agricultural area.

### 5.1.1 Factors that affect social grouping in sarus crane

Birds distribution often is discussed and compared from a geographic perspective (zoogeography). At one time, emphasis was mostly on a scale of continents and hemispheres rather than regional habitat, but the importance of vegetation zonation and climate has now become a regular factor in descriptions of groups and subgroups of species. A more

functional descriptor is home range, which denotes an area and habitat features that delimit the living space of an individual, pair, or other specified group (Weller, 1999).

The sarus crane seems to be relatively nonsocial. Although large flocks have on rare occasions been mentioned, such as groups of as many as 200 birds, this appears to be distinctly unusual (*Walkinshaw, 1973). Rather, families and pairs seem to make up the social groupings of sarus cranes, even during the winter period. (*Walkingshaw, 1973) reported on group sizes moving to and from roosting areas at the Keoladeo Sanctuary in September, just about at start of nesting. Of 503 total groups, the most prevalent group size was of 2 birds (87 percent), while the next most common unit was single birds (8.5%). The largest group he observed was of 9 birds and the average group size was 2.02 birds. Only 13 of the groups (2 percent) were of 3 or 4 birds, suggesting that by this time of the year nearly all of the family groups had already broken up. (*Walkinshaw, 1973) stated that the young birds remain with their parents for at least ten months, but after the breeding season begins they begin to assemble and roam the vicinity in groups.

In this study, during first week of January, one congregation group of 11 birds were seen in agriculture field till at 16:00 hours and in the 1st week and 2nd week of March, two such congregations were observed. The farmers started harvesting mustard in March and Wheat in 2nd week of April and the congregation may be a result of it.

## 5.2 Habitat use

Habitat needs for all birds including similar resources: water for drinking and bathing, food, cover for protection from the elements and potential predators, and undisturbed space for meeting social and other life functions. But each group of birds adapts to general features of their typical habitat and exploits its particular resources (Weller, 1999).

Cranes, being long necked and long legged wading birds, are adapted to life in wetlands. Their future depends on availability of wetland habitats. As wetlands disappear and crane population dwindles, hunting becomes a serious threat to surviving cranes. (Harris, 1992). The chief conservation need is to preserve the wetland (and grassland) habitats on which cranes depend. Wetland ecosystems, with and abundance of nutrients and water, are among the most productive places on earth. Accordingly, they have been centers for human populations for thousands of years. Today, people around the world visit wetlands to harvest

their plants and fish, to utilize the water, or to convert the rich soils of wetlands into rice paddy and other agricultural areas. (Harris, 1992).

Cranes depend on large wetland areas for nesting and rearing their young. Protection of crane on substantial wetland areas, with benefits to a host of other plants and animals. (Harris, 1992). Gole has indicated that wetlands and fields of good grains are the most favored habitats of the cranes. Data collected by him, through surveys have revealed that sarus pairs use agricultural, semi-wet and dry land more than wet areas like marsh, ponds and river. On the contrary, sarus families (pairs with juveniles) use wet areas more than dry and semi-wet areas (Gole, 1986).

### 5.2.1 Changes and availability of wetland habitat

The source of water, its quantity and quality are major factors affecting the Keoladeo wetland. The Gambhir and Banganga river systems, at the confluence of which the National Park is located, bring in water to it. Water from the Gambhir is brought into the Ajan Bund through Pichuna canal. Water from the latter has become rare and from the former, less in quantity. The watershed of Gambhir River is in Karoli Hills of Sawai Madhorpur district (Rajasthan), running through Tahsils of Bayana and Rupbas and other parts of Uttar Pradesh to re-enter Rajakhara Tahsil, Bharatpur district (Rajasthan) before flowing into the river Yamuna. The Banganga river originating at Manoharpur in Jaipur district (Rajasthan) runs through Jamuna Ramgarh and Mekhpur settlements from where water is taken to Ajan bund through the Uchain canal. Water brought into the Ajan bund is retained there for a few days for the silt to deposit and then released into the Park and the surrounding villages in July-August. The bund is emptied in October and the area is put under cultivation of Kharif crops utilization.

Traditionally, both Banganga and Gambhir rivers were sources of water for the Ajan bund, but during the 1980s the Gambhir remained the only source. Due to the construction of a dam and utilization of water for various other purposes along the course of the river, the quantum of water received by the park has been going down steadily. Water from the Ajan bund is supplied by the Public Works Department to the park and to nearby agricultural fields. It is usually released after being retained in the bund for a few days to facilitate inundation irrigation. Through this process the particulate organic matter settles, which is highly nutritious for the crops and, at same time, reduces salutation in the wetland. Water is supplied in July- August for about a month, but very rarely during August- September. The time of release of water to the park is vital to growth of aquatic plants, breeding of the

heronry species and the overall seasonality of ecological events. The quantum of water received is no doubt the most important factor in the survival of the wetland, and to some extent, that of the upland forests.

The quantum of water let into the Park during the seventies and eighties varied strikingly from a minimum of 0.017 million $m^3$ in 1985. In most years it was above 14 million $m^3$ (Vijayan, 1991). Although a minimal quantity was supplied in 1986, the drought was not felt severely in the park during that year because of the availability of surplus water from the previous year's supply. However in 1987- 88, the effect of drought was obvious when the wetland dried out completely and dead and dying animals were observed even during the end of the winter season. Ground water had to be pumped out into the central, deeper areas to sustain some aquatic life and for providing drinking water to animals during the spring and summer.

Once water is let into the Ghana canal within the park, it is taken to different compartments or blocks of the wetland at the desired level through sluice gates. At times, when water is abundantly available, the terrestrial areas are also flooded for a short duration after which, the water is flushed out to the villages. The maximum water spread area was during September- October (Vijayan, 1994). Although water loss through infiltration is minimal, most is lost by evapo-transpiration, which is very high during the hot and dry summers, leaving only a few pools in the central, deeper portions of the park (Vijayan, 1991). Ground water levels within the park and in the low- lying areas nearby are relatively higher. According to local people the frequent occurrences of droughts has probably lowered ground-water levels in recent years, resulting in shift of the cropping pattern towards cash crops, which require less water (Johnsgard, 1983).

At the onset of my research the juveniles were found with their parents. When this study was concluded the pair with Juvenile was still attached to parents. Local people mentioned that during November (at the beginning of this research) the juveniles could be around 3 months old, but there are no sufficient evidences to confirm this. This study reveled that at around 8 to 9 months of age both the parents and the juveniles had strong bond among themselves.

Throughout the study period a maximum 67 sarus cranes were counted in their roosting ground inside the park. Local farmers grow *mustard* (maximum plant height 1.99832m), *gram* (maximum plant height 0.6096m), *masoor* (maximum plant height 0.6096m) and *wheat* (maximum plant height 0.61m) around the park. These cultivated areas provide excellent foraging ground and escape cover for safety for sarus cranes. If the plant

heights in the agricultural fields was higher than road sarus crane feel less stress. Pairs with juveniles used agricultural field during February onwards. Thus agriculture field was important to sarus crane. During the present study it was observed that *wheat* (*Triticum aestivum)* was a staple food of sarus crane in the in study area. Basically, 2 kinds of wheat were being cultivated (local name *Ganhu* and *Jaw*). Sarus crane preferred *Ganhu*. Local people said that *Ganhu* was better quality.

The domesticated animals such as buffaloes, cattle and dogs were increasing the contamination of the water supply by transmitting various diseases. They also interfere with the breeding cycle of sarus cranes by trampling and predating their eggs, chicks and juveniles. Domesticated dogs kill others birds also like purple heron (*Ardea purpuea*) and water coot *Fulica atra* ) (local field assistance pers. comm and personal observation). During December and January, were highest rates tourists visited into the park (*data from park authorities).

### 5.2.1 Affect of pesticides

Throughout the studied period, 16 dead sarus cranes were found in both outside and inside the park which are believed to have been caused by pesticides.

The water passes through various agricultural fields before it finally enters the Park and there are ample chances of pesticides and fertilizers entering the wetland system. Studies conducted on the water from Ajan bund during 1989 and 1990 showed the presence of residues of aldrin, DDT and BHC, but the levels were lower than that in some other rivers such as the Chambal, Khan and Kshipra (Vijayan, 1991). Pesticide residues might be accumulated year after year with increasing concentrations at various tropic levels. Some of the water bodies near Keoladeo National Park are reported to have higher concentrations of certain contaminates (Vijayan, 1987a). Birds, being highly mobile, at times forage outside the park where the environs are more polluted and hence are more liable to be affected by these contaminants (Vijayan, 1987a).

Birds such as the sarus crane, ring dove and blue rock pigeon have been found dead because of aldrin poisoning due to foraging on treated grain in nearby agricultural fields.

Eggs of the colonial breeders also showed residues of DDT, BHC, endosulphan and others, which may affect the breeding colonies of fish-eating birds (Muralidharan. *et al.* 1992). This might result in breeding failure and eggshell thinning.

### 5.3 Parent and juvenile relationships

Sarus crane breeding season is July- December, varying locally (Grimmett *et al.*, 1998). The sarus crane has two breeding seasons, a major one during July-August and a minor one during February- March (*Ramachandran, 1986). Well-paired cranes perform synchronous activities and stay near one another most of the time. If a male is excessively dominant or if the female is dominant over the male, the pair may never breed. Several circumstances can result in weak pair bonds. If one member of a pair is excessively submissive to the other or if one mate prefers a neigh boring unstable pair bond can be weakened. An unstable pair bond can result in one crane injuring or killing its mate. An excellent example of monogamy in this bird, that a sarus stayed at a place where its partner died and did not leave the place (Desai, 1980). Sarus is supposed to be monogamous and therefore breeding pairs will leave the gregarious groups during post-breeding summer congregations.

In Keoladeo Ghana National Park nesting may begin within a week after the start of the rainy season. Territory is well defined. The pairs remained in the same area throughout the year, except in summer. However, during non- breeding season they cover larger areas for foraging. The breeding territory ranges from 0.068 $km^2$ to 1 $km^2$. Usually the nest is built on one corner of the territory. Of the eight nests studied, only one was near the center. Most of the territories had two zones, a shallow area where the parent bird bed and a deeper zone in the immediate vicinity of the nest where the adult never went for feeding during incubation (Ali and Vijayan, 1986).

All cranes exhibit a prolonged period of parental care toward their young, sometimes lasting well beyond the period required for fledging. From the time of hatching the chicks are fed by both parents, which carry food to them by holding it in the tip of the bill. Then, with lowered head, they offer it to the chick or drop it in front of the chick. Gradually the adult begins to lead the young to the food sources, although for a considerable period the adults continue to carry some food to the chick (Johnsgards, 1983).

Brooding of the young is performed in a posture similar to normal sitting. The female usually performs this if the pair has only one chick. When adults are leading young, the male typically takes the lead, followed by the female, and finally the young. From shortly after

hatching, bill touching is fairly frequently performed between chicks and parents. This behaviour, which may be associated with food begging and direct feeding, sometimes occurs as late as the spring following hatching. It is normally initiated by the chick rather than the parents (*Masatomi and Kitagawa, 1975).

Sarus cranes are characteristically seen in pairs at any time of the year. Congregations and groups are rare, and a few families can be observed, though mostly in winter. This behaviour is markedly differently from the common crane, demoiselle crane (*Anthropoides virgo*) and the Blue crane (*Anthropoides paradiseus*), which are mostly seen in groups, often numbering tens of thousands, both in their wintering and breeding grounds (Johnsgard, 1983 and *Allan 1995).

When breeding cranes encounter enemies, either or both two defensive behaviour may result. Animals such as feral cats, dogs, foxes, or deer may be "mobbed" a maneuver during which the adult cranes approach the intruder while uttering an alarm call and move around it at a safe distance until it retreats. When humans, dogs, or other animals approach a nest is having eggs or young chicks, the parents may perform a diversionary display, moving away from the nest, with or without wing spreading, and assuming a posture associated with intense aggressive threat. Sometimes one of the birds will fly away without making diversionary displays, and the other may run around the enemy while uttering alarm calls (*Masatomi and Kitagawa, 1975).

### 5.3.1 Juvenile weaning process

The juveniles, which hatch out during the rainy season and by winter, would be almost four months old and would be in the process of weaning away from the parents. In sarus cranes while rearing the young, attention was focused on the sleep, type and amount of food consumed, voice, trachea and their change with age, first flight beginning with small leaps accompanied by flapping, then gliding to a distance of about 25 to 60 meters, long sustained flight, eye colour and change in plumage (Desai, 1980).

There are two reasons to explain the weaning process, (1) Juveniles moved away from parents for foraging but not more than 30 mins, meanwhile the parents followed them. (2) Adults courtship with other sarus cranes and meanwhile juveniles follow up them (Table.8).

Juveniles have entirely feathered heads and necks, which are buff in color. The feathers of juveniles are edged with brownish gray, and those of the upper parts are cinnamon

brown, often with downy tips adhering. (Johnsgard, 1983). For adult body color cover are darker than others pairs when pair with juveniles are joining to neighbors' pairs distinct dated on throughout my survey. One Family (Group no.1) was seen throughout survey period both inside and outside the park. Another family (Group no. 5 family) shifted to some where else on March 31. One new family (without colour band on juvenile legs) twice visited group no.4 and group no.5 on 25 March 2001 and 17 April 2001. In group no.5 juvenile became distinctly white coloured on his tail on 22 February 2001. On 23 February group no.1 family started to use agriculture field (group no.6) until on April 16. Group no.1 juvenile started to attack Red- wattled Lapwing (*Vanellus cinereas*) on April 25.

### 5.4 Daily activities

Sarus cranes leave their nocturnal roosts shortly after daylight. *Walkinshaw, 1973 noted that the birds left their roosts earlier than did the siberian cranes and also began to call at a much earlier hour. However, when flying from the roost the birds tend to be silent. In the evening, after returning to the roost, sarus cranes once again become very noisy, as they also are in early morning hours (*Walkinshaw, 1973).

During initial phases of roosting, pairs or individuals typically are dispersed from 3 to 100 meters away from other birds, but as darkness increases, they tend to move together toward an area of shallow water. After their early morning flights out for foraging, many of the birds return to the roosting area after about 10:00hours for drinking. They then later returned again to their foraging areas (*Walkinshaw, 1973). The present study conforms to the findings of the earlier study.

In the present study, daily activities of sarus crane depended mainly on the weather conditions. Mist was thick till 10:00 hours in winter, so sarus moved to agriculture after 10:00 hours. Through out the observation, the sarus did not show any activities during sunny days, windy days and rainy days. Especially during the sunny days (noon time) sarus preferred to stay under shady and drink a lot of water. When the wind was strong and during heavy rains, the sarus did kneel and sit in ground. Generally, sarus avoided flying during the dark hours.

# REFERENCES

ALI, S. 1953. The Keoladeo Ghana of Bharatpur, Rajasthan. *J.Bombay Nat. Hist.Soc. Vol. 51 No. 3: 531-536.*

ALI, S. 1986. Summary of paper presented at Salim Ali Festschrift Seminar, November 1986, Bombay Natural History Society, 59 pp.

ALI, S and VIJAYAN, V. S. 1986. Keoladeo National Park Ecology Study- *summary report* 1980-85. Bombay Natural History Society, 185 pp

DESAI, R. M. 1980. Studies in the Biology of the Indian sarus crane (*Grus antigone antigone*) (Linnaeus). (Master of Philosophy in Biosciences to the South Gujarat University, Surat). *Dissertation unpublished paper.*

*ELLIS, D. H, SWENGEL, S. R, ARCHIBALD, G. W and KEPLER, C. B. 1987. Compendium of Crane Behaviour Part.1 Individual (Nonsocial).

*ELLIS, D. H, SWENGEL, S. R, ARCHIBALD, G. W and KEPLER, C. B. 1997. A Sociogram for the cranes of the world.

GOLE. P. 1986. The status and ecological requirements of sarus crane phase I. Ecological Society of India , Pune, India, 45pp.

GRIMMETT, R, INSKIPP.C AND INSKIPP, T. 1988. Birds of the Indian Subcontinent. Oxford University Press, 889pp.

HARRIS, J. 1992. Cranes Around the World. People Water and Wildlife: Human population Impacts of Cranes. National Audubon Society, 75pp

JOHNSGARD, P. A, 1983. Cranes of the World. London, Croom, 257pp.

LEHNER, P. N. 1979. Handbook of ethological methods. New York, Garland Press, 403pp.

MEINE, C and ARCHIBALD, G. 1996. The Cranes: Status Survey and Conservation Action Plan by IUCN/SSC Crane Specialist Group. Switzerland and Cambridge, U. K, 249pp.

MURALIDHARAN, S, REGUPATHY, A and SUNDARAMOORTHY, T. 1992. Organochlorine residues in the eggs of selected colonial water birds breeding at Keoladeo National Park, Bharatpur, India, pp 189-195. In: *Aquatic Ecosystems in Semi- arid regions: Implications for Resource management.* R. D. Roberts and M.L. Bothwell (ed) NHRI Symposium series 7, Environment Canada, Saskatoon.

NANJAPPA, C. 1986. Phenology of terrestrial plants in Keoladeo National Park. *Summary report* 1980-85. Bombay Natural History Society.

PRASAD, V. P, MASON, D, MARBURGER, J, E and AJITHKUMAR, C. R 1996. Illustrated flora of Keoladeo National Park, Bharapur, Rajasthan. Bombay Natural History Society.

SIVASUBRAMANIAN, C. 1986. Freshwater turtle capturing aquatic birds. *J. Bombay Nat. Hist. Soc.* 83 (3): 671-672.

SUNDER, S, KAUR , J. and. CHOUDHURY, B . 2000. *Sarus crane count- 2000* . Wildlife Institute of India, Dehra Dun.

VIJAYAN, L 1994. Ramsar sites of India Keoladeo National Park (World Wide Fund for Nature, India).

VIJAYAN, V. S. 1987a. The proposed Galvalume Plant of General Engineering works and Keoladeo National Park – an impact assessment. Bombay Natural History Society.

VIJAYAN, V.S. 1991. Keoladeo National Park Ecology Study. *Summary Report* 1980-1990.

*WALKINSHAW, L. H. 1973. Cranes of the World. Winchester Press, New York.

WELLER. M. 1999. Wetland Birds: Habitat Resources and conservation Implications. Cambridge University Press, 266pp.

WEB SITE, savingcranes.org.

WEB SITE, keoladeonationalpark.com.

WEB SITE, www.pwrc.usgs.gov/pubdata/htm.

*** not referred in original**