A Bibliographical Review for Identifying Research Gap Areas

Keoladeo Ghana National Park, Bharatpur:

A World Heritage Site

V B Mathur
K Sivakumar
Bhumesh Singh
Anoop K R

United Nations Educational, Scientific and Cultural Organization

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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1. Introduction

Keoladeo National Park (KNP) (27º7'6"N – 27º 12'2"N and 77º 29'5" E – 77º 33'9"E) is a 29 km^2 area situated on the extreme western edge of the Gangetic basin that was once confluence of Rivers Gambhir and Banganga in Bharatpur district in the State of Rajasthan (Figure 1). KNP has a unique mosaic of habitats that include wetlands, woodlands, scrub forests, grasslands that supports an amazing diversity of both plant and animal species. Keoladeo National Park's flora consists of over 375 species of angiosperms of which 90 species are wetland species. The fauna includes more than 350 species of birds which include 42 species of raptors and 9 species of owls, 27 species of mammals, 13 species of reptiles, 7 species of amphibians, 58 species of fishes and 71 species of butterflies, more than 30 species of dragonflies and more than 30 species of spiders inhabit the park. Owing to the abundance of the birds, KNP is often referred as 'Birders Paradise'.

The unique mosaic of habitats includes physiognomic types of forest, woodland, scrub woodland, savanna woodland, low grasslands with scattered trees and scrub, plantations and wetland. Forests, mostly in the north-east of the park, are dominated by kadam *Mitragyna parvifolia,* jamun *Syzygium cuminii* and babul *Acacia nilotica*. Rich diversity of habitats supports the highest congregation of waterfowl in the region and is also home to many resident terrestrial and local migratory species. The wetlands of the park are host to the most spectacular heronry of the region. 15 species of birds nest here forming an extensive heronry from the month of July to September.

Major grasses such as *Vetiveria zizanioides* and *Desmostachya bipinnata* mostly in Koladhar area form savanna type of vegetation, which supports several mammalian herbivores such as chital, sambar, nilgai ,and feral as well as domestic cattle. Trees and shrubs usually found in savanna are *Prosopis cineraria*, *Acacia nilotica*, *A. leucophloea*, *Zizyphus maurutiana* and *Salvadora persica*. Certain wetland areas are also bordered with this kind of vegetation. Low grasslands, mainly of *Sporobolus helvolus* and *Cynodon dactylon*, occur in some parts of the Park with a few scattered trees and shrubs such as *Acacia nilotica*, *Prosopis cineraria*, *Salvadora persica* and *Krignelia reticulata*.

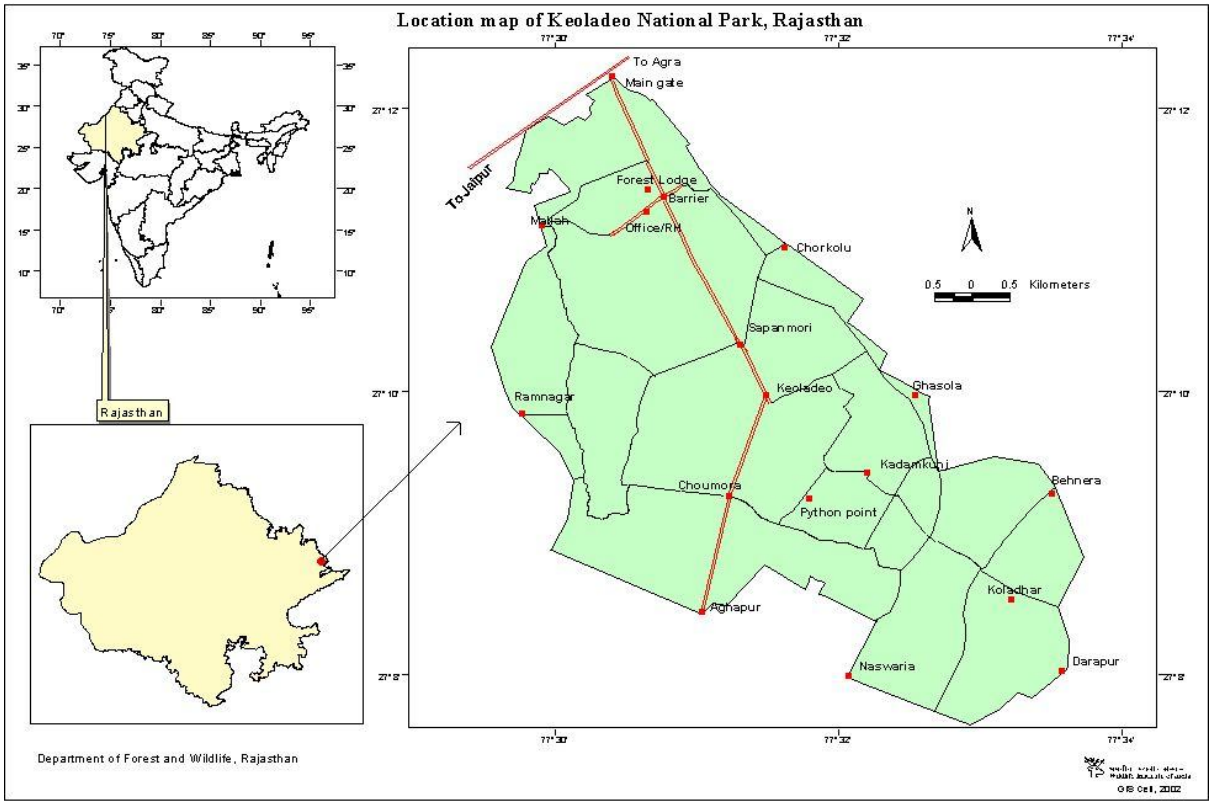
The wetland of Keoladeo National Park has more than 90 species of flowering plants. These are classified as follows: (a) Free floating (*Spirodella polyrhiza, Lemna perpusilla, Eichornia crassipes*), (b) Rooted with floating leaves (*Nymphaea*

pubescens, N. nouchali, Nymphoides cristatum), (c) Un-anchored submerged (*Ceratophyllum demersum, Utricularia aurea, U. stellaris*), (d) Rooted submerged (*Hydrilla verticilata, Najas minor, Potamogeton crispus*), (e) Emergent, amphibious (*Eleocharis dulcis, Scirpus littoralis, Ipomea aquatica*), and (f) Marshland plants (*Caesulia axillaris, Eclipta prostrta, Echinochloa colonum*). Commonly seen weeds in the park are *Prosopis juliflora, Lantana camara* and *Eichornia crassipes*.

As the park lies on the Central Asian Flyway of the Asia Pacific Global Migratory Flyway, it is a staging / wintering ground for a large number of migratory waterfowls that breed in the Palearctic region. KNP had been the only wintering ground for the central population of the endangered Siberian Crane (*Grus leucogeranus*). It has a long and unique history as it was once part of erstwhile state of Bharatpur and had been managed as a duck shooting reserve. Due to its rich avian biodiversity value, the Park has been declared as both a Ramsar site as well as a World Heritage site.

Published research literature available upto June 2009 had been reviewed in this document to identify the gap areas in the research activities in Keoladeo National Park.

Figure 1. Location map of the Keoladeo National Park, a World Heritage site



2. Objectives

1. To prepare a bibliography of existing information on research activities of Keoladeo National Park

2. To summarize all past and ongoing research in the Keoladeo National Park

3. To identify gap areas for research

3. Summary of the research findings

Keoladeo Ghana National Park is considered as a paradise for avian biologists in India. Apart from extensive ornithological studies, studies on reptiles, fishes, vegetation, invasive species, mammals, socio-economic issues, hydrology, impact of grazing, feral cattle, pollution etc have also been carried out. More than 200 research publications are available from this Park. A decade long study conducted by the Bombay Natural History Society and more studies by several other institutions, NGOs, universities etc have provided a lot of insight to the biodiversity of Park and have suggested several conservation measures to manage this Park in a better way so that biodiversity in the Park can be conserved in perpetuity and the 'Outstanding Universal Values' as a World Heritage Site are maintained.

Birds

A decade long study on 'Ecology of Keoladeo National Park was conducted through an integrated and multidisciplinary project during 1980 to 1990 funded by the US Fish & Wildlife Service through BNHS and later it was monitored by Salim Ali Centre for Ornithology and Natural History till 2006. The first decade-long study on bird communities showed that the ecosystem function of KNP depends mainly on the quantum and time of release of water and fish fry every year. Considerable changes have taken place in the Park on account of irregularity in water released and invasion of many exotic species.

Population of the threatened Sarus Crane has declined drastically with 8 pairs in 2003, 7 pairs in 2004 and 8 pairs in 2005 with only 2 nests and one chick compared to 14 nests in 1983 and 8 in 1992 because of mortality due to pesticides, continuous droughts and shrinkage in water spread area. The critically endangered Siberian Crane was only five in 1993, two in 2002 and nil thereafter. The critically endangered raptors recorded were the Long-billed Vulture and White-backed Vulture, very rare and no nests, although food availability was plenty inside the park.

Studies on raptor of KNP observed that due to availability of mosaic of habitats in KNP there is a large raptor congregation. The variety of habitats available i.e. wetland, part grassland, and part semi-arid forested grassland gives an idea of the multitude of niches present within KNP. The park supports resident and both staging and wintering raptors during winters every year. Long term monitoring of this group of birds is needed for designing conservation strategies for the KNP ecosystem.

Since they are ‘umbrella species’, holding large territories their conservation indirectly helps in the conservation of many other micro and macro fauna and flora. Apart from these studies, several studies on selected bird communities or individual species have also been carried out which have provided insight into the ecology of birds of KNP.

Bird ringing

Among all ornithological studies, the most important one was bird ringing in KNP. Between 1965 and 1974, 10,958 common teals *Anas crecca* were trapped and ringed at Keoladeo National Park. Most ringed birds were recovered in the former USSR (485 recoveries), while 85 birds were recovered from the Indian subcontinent. Ringing numbers suggest that males arrive first from their breeding grounds in September, before females arrive. The males subsequently spread out, while the females are more sedentary. Males leave Bharatpur first in the return migration as well. The sex ratio of birds caught showed an overall female bias (male:female 1:1.7). Almost all recoveries in the USSR were made east of 60 degrees longitude, suggesting that the teals had crossed the Himalaya during their outward journey.

Fish

The wetlands in the Keoladeo National Park, receive water from the Ajan Bund that in turn receives water from the Banganga and Gambhir rivers. A total of 58 species of fishes have been recorded in KNP. Of these, seven species are new and reported after 1995. Of the new arrivals, African catfish, is one of the most dangerous invasive aquatic species of the Park. The highest number of fish species was found in open water with sparse vegetation, and the lowest in (*Paspalum*)dominated areas of wetland of KNP. Non-air-breathing fishes preferred least vegetated areas, while air-breathers like (*Channa punctatus, C.striatus, Clarias batrachus)*and (*Heteropneustes fossilis*)were seen in widely differing habitats, with (*Chana punctatus*)frequent even in thick (*Paspalum)*dominated areas. Areas with thick vegetation inhibit movement, and have lowered dissolved oxygen due to the decomposition of plant material. This explains the absence of non-air-breathers from these habitats. Other physicochemical parameters like carbon dioxide and methyl orange alkalinity also differed between vegetated and non-vegetated waters.

Amphibians

A preliminary assessment of the distribution pattern and status of the anurans had reported six species of frogs Ranidae: 4 species, Microhylidae: 2 species and two species of toad. Thus, out of twelve species in Rajasthan, KNP harbours eight

species of anurans. The maximum distribution of the Ornate Narrow-mouthed (*Microhyla ornata*), Indian Skipping (*Euphlyctis cyanophlyctis*) and Cricket (*Fejervarya limnocharis*) frogs was observed in the wetlands. The distribution of Indian Green Frog (*Euphlyctis hexadactylus*) was restricted to few of the core wetland sites whereas Indian Bull Frog (*Hoplobatrachus tigerinus*) had the scattered distribution pattern. Marbled Balloon Frog (*Uperodon systoma*) was found in the N and L blocks. The two toads were mainly cited and recorded during the night time. Marbled Toad (*Bufo stomaticus*) showed its presence all over the marginal areas of blocks with water whereas Common Asian Toad (*Duttaphrynus melanostictus*) was mainly recorded on the terrestrial habitat and was more prone towards the man made sites of the blocks.

Reptiles

The activity pattern of Indian pythons has been studied in detail in this Park. Pythons were found to be active mainly during the day (0600 to 1800 hrs) in both winter and summer. Activity was diurnal in winter, uniform in spring, and bimodal-crepuscular in summer. Activity patterns were not entirely explicable in terms of temperature, humidity or prey activity. Burrow temperatures paralleled ambient temperature during the day, while in the night, burrows were warmer than the ambient temperature. Prey activity was consistently bimodal, with a peak at morning and evening hours throughout the study. The decline in sightings towards the summer may be due to emigration of pythons, or a decrease in conspicuous basking activity.

The aestivation behaviour of the Indian Flapshell turtle *Lissemys punctata* was also studied in KNP. *Lissemys punctata* spent about 160 days in aestivation and the aestivation depth varied from 2 to 10 cm with a mean of 5.2 cm Bushes near drying water bodies had the highest concentration of turtles (166/ha). Overall, the highest density of (*L. punctata*) was observed within 50 m radius of the last drying water bodies. Diurnal substratum temperatures in the aestivating habitats varies from 28' to 48' C. Of the seven species of turtles found in the study area, all except (*L. punctata*)stayed temporarily in the drying mud and either deserted their sites or were found dead within a month. Only (*L. punctata*)stayed in the aestivation site till the monsoon. It was therefore concluded that only (*L. punctata*)can be considered as a truly aestivating species in Bharatpur.

Mammals

Keoladeo Ghana is known as one of the finest waterbird sanctuaries in India. However, it is not generally appreciated that this reserve also harbours/harboured such typically Indian big game species as the blackbuck, nilgai, and chital, in addition to sambar, hog deer, leopard, and others during 1960s. Fishing cat, common palm

civet, stripted hyena, common mongoose, etc are other mammals recorded in this Park. Diet of the smooth Indian otter (*Lutra perspicillata*) was studied here and found that fish were the main prey throughout the year. Other prey items included molluscs, insects and birds. Molluscs were present in the diet only during summer while birds and insects were eaten during the monsoon and winter. A study aimed to investigate the foliage-as-fruit hypothesis which holds that the foliage of small-seeded species has the same co-evolutionary function for megafauna as fleshy fruits have for frugivores. Seeds of (*Paspalum distichum*)were found in the dung of nilghai, feral cattle and wild boar during most of the year, while (*Acacia nilotica*)and (*Prosopis juliflora*)seeds were found during the hot-dry season and (*Echinochloa crusgalli*)seeds during the monsoon. A total of 37 small-seeded species germinated from the dung of the three species.

Invertebrates

Larger varieties of invertebrate species in Keoladeo National Park (KNP), though not well known and appreciated, play a significant role in the ecology of the habitat. More than 100 species of butterflies were recorded from different habitats of Bharatpur, out of which approximately 80 species could be sighted inside the park in different seasons. The odonate group which is one of the bio-indicator of wetland health has a diversity comprising more than 30 species inside the park. Over 30 types of spiders were recorded inside park along with ten types of beetles. Beetle *Cassida circumdata* occur in this Park observed controlling the population of invasive plant *Ipomoea reptans.*

Habitat studies

A study aimed to investigate the effect of ecological changes caused by the excessive growth of wild grasses such as *Paspalum distichum* on the existence of various species in the KNP found that growth rate of several species, such as floating vegetation (*Nymphoides indicum*, *Nymphoides cristatum, Nymphaea nouchali* and *Nymphaea stellata)* fishes, waterfowl etc, and the corresponding carrying capacity of the wetland are assumed to decrease with the increase in biomass density of wild grasses. By analysing a model it was shown that if the wild grasses are not controlled, the existence of various other species will be threatened. It is shown through the model study that if the growth of wild grasses is controlled, either by allowing a managed number of buffaloes to graze them or by using some other mechanism to remove them, then the other species in the wetland will boom. Keeping in view the growth of *Paspalum distichum* and using the corresponding parameters for this wetland in the model, the number of buffaloes to be permitted for grazing has also been calculated for management purposes.

Organochlorines, due to their slow decomposition rate and long half-life, remain in the environment for a protracted period of time and exert deleterious effects on non-target organisms of KNP. Wetland suffer the maximum as the agricultural run off finally finds its way into aquatic systems. A study found that the residue levels of a few organochlorine pesticides, namely BHC and its isomers, DDT and its metabolites, and aldrin were measured during 1989 and 1990 in the waters of Keoladeo National Park. Several alkaline and alkali earth metals were also found in the decomposing macrophytes in the Park.

The Keoladeo National Park, a man made freshwater carved out of a natural depression on the floodplain of two minor tributaries of the Yamuna Gambhir and the Banganga. An attempt has been made to evaluate the habitat of sarus crane in the KNP using satellite data. The sarus crane mainly fed in the wetland on the Rhizome of *Nymphaea sp. Scirpus tubersus* and *Eleocharis plantaginea*. As there were changes in their habitat requirement in different seasons, the sighting of sarus crane in each habitat were recorded using along with the time and activity during observation. The most utilized habitat for the entire period of study was moderately wet grassland followed by pools. The pools were used mainly during the summer. The water depth requirement observed was between 30-40 cm and 20-40 cm. The suitability maps for Sarus crane were then generated using all remote sensing based and conventional information using rule based equation in the GIS within the Keoladeo National park.

People, socio-economic condition and awareness

Although studies on socio-economic issues, people dependency, awareness level etc have been carried out in detail but these studies are not much helpful in the management of the Park in the present contest. Keoladeo-Ghana is well known to the people from the local terrain. This is the general perception of any visitor. Although partially it is agreeable that people of Bharatpur know about the park, its importance and its need. Keeping this general perception in mind, a study assessed the level of knowledge among children from the villages of Bharatpur. The responses showed that students have only very basic information about KNP. Latest initiative by the Wildlife Institute of India under UNESCO-World Heritage Programme and the Rajasthan State Forest Department has generated a lot of awareness among local people. This UNESCO programme has also changed the attitudes of people and made them Pro-Park.

4. Gap Areas of Research

Several studies focusing on birds, reptiles, fishes, insects, vegetation, invasive species, mammals, hydrology, social issues, impact of grazing, feral cattle, pollution etc have been carried in KNP. More than 200 research publications are available from this Park. Findings of these studies have helped the management to take certain important conservation measures, for example, acquiring required water from the Ajan Bund, control of feral cattle, creation of boundary wall around the Park etc.

Nevertheless, there are still several gaps in the research activities of the Keoladeo Ghana National Park, which need to be plugged. For example;

1. Study on seed- bank of the Park. A study aimed to investigate the carrying capacity and minimum ecological requirement of seeds of both plants and fishes of the Park is required to be carried out.
2. Bharatpur is one of the fast developing towns in Rajasthan and drastic changes in the land use pattern have been observed around the Park, which might have an adverse impact on the biodiversity of the Park. There is a need to study the study the landuse changes around the Park with special focus on the intensification of agriculture and use of organic fertilizers.
3. Although, mammals of the Park had been studied in the past. A study aimed to investigate the co-existence and resources partitioning of major herbivores such as nilgai, sambar, chital, and feral cattle needs to be carried out. This would provide the information which could help the management of habitat and population of these species in KNP in the present contest.
4. Though studies on Sarus Crane, Vulture and Python have been carried out, it is necessary to continuously monitor their populations and habitats for their long term conservation inside the Park
5. Several thousands migratory birds visit this Park during the winter and hence this place provides an excellent opportunity for bird ringing and monitoring. This would help to study the impact of global climate change, avian influenza etc on global bird communities and their migration.
6. KNP also provide an opportunity to study the epidemiology of avian influenza in India, which needs to be studied.
7. Continuous monitoring of water quality and pollutants levels inside the Park is to be carried out to monitor the health of aquatic ecosystem.

8. A study of ‘Economic evaluation of KGNP’ and its ecological goods and services needs to be initiated.

9. Creation of research data-base and analysis on research-management interface is required.

10. Aquatic-terrestrial habitat relationship: Due to changing climate and landuse pattern the habitat relationship between aquatic and terrestrial ecosystems of the Park needs to be studied. There is a possibility of encroachment of aquatic ecosystem by the terrestrial ecosystem due to drought or scarcity of water.

11. Impact Assessments studies related to landuse level, hydrology and water regime, impact of infrastructure development, ground water removal, increasing visitors etc are also required.

12. Impact of wild and feral mammalian herbivores on the management of invasive species in the Park needs to be studied. It is expected that introduced animals inside the Park may be dispersing the seeds of invasive species.

13. Identification of indicator species and its ecology needs to be studied for the long term conservation of the Park.

14. Changes in vegetation pattern and soil quality due to ongoing invasive species eradication programme also need to be studied.

15. A study on catchment area evaluation needs to be carried out to understand the landuse pattern and its impact on the Park environment.

16. Assessment and Inventorization of tourism resources for diffusing increasing tourism pressure from KGNP

17. Role of KNGP in carbon sequestration also required to be assessed.

18. A greater emphasis on the Socio-economic studies and economic evaluation which is lacking at present needs to be studied.

19. Continuous monitoring of biodiversity needs to taken up for the long term conservation of Park. This data would help the PA Management to take corrective measures.

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The wetlands in the Keoladeo National Park, Bharatpur, Rajasthan receive water from the Ajan Bund that in turn receives water from the Banganga and Gambhir rivers. This paper presents the results of a survey of the icthyofauna in the Banganga-Gambhir river system conducted during May and June 1989. Fish samples were collected at 27 sites along the two rivers, their tributaries and several dams across the rivers. Samples were also collected from 3 sites on the river Chambal. A description of the two rivers, Gambhir and Banganga, their tributaries and associated dams, bunds and reservoirs is given. During the survey, 46 species were recorded of which 41 were seen in the Banganga-Gambhir river system. (*Aplocheilus panchax*), collected from the Banganga is a new record for Rajasthan. Fish species richness was higher in the Gambhir (38) than in the Banganga (28). The analysis of the distribution of species in the Gambhir showed that approximately half of the species were common and distributed uniformly while the other half were comparatively rare and site specific. Although both rivers are not perennial, a number of perennial pools were recorded along the Gambhir and some of its tributaries. Several dams in the Banganga-Gambhir river system are used as reservoir fisheries. The Natural perennial pools and the reservoirs form the major source of fry to the Park. The conservation of these perennial pools is emphasized.

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This study add 13 new records to the fish fauna of Keoladeo National Park. making the total, including those recorded by earlier workers, to 50. It is also interesting to note that this tiny wetland has, altogether, added 13 species to the fish fauna of Rajasthan, in- creasing it to 88; the former record being 75 species. Of the 40 species recorded during the study, only six breed inside and the rest enter through the canal while the water is Iet in. Among the 10 locally extinct species, it is not clear how many of them were breeding inside. It is likely. two of them *Channa gachua* and *Notopterus chitala* might have been breeding inside as their congeners *Channa punctatus, C. striatus, C. marulius* and *Notopterus notopterus* are the major breeding species of the Park.

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Between 1965 and 1974, 10,958 common teals (*Anas crecca*)were trapped and ringed at Keoladeo National Park, Rajasthan. This paper synthesizes the recoveries of these ringed birds. Most ringed birds were recovered in the former USSR (485 recoveries), while 85 birds were recovered from the Indian subcontinent. Ringing numbers suggest that males arrive first from their breeding grounds in September, before females arrive. The males subsequently spread out, while the females are more sedentary. Males leave Bharatpur first in the return migration as well. The sex ratio of birds caught showed an overall female bias (male:female 1:1.7). Almost all recoveries in the USSR were made east of 60 degrees longitude, suggesting that the teals had crossed the Himalaya during their outward journey.

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The activity pattern of Indian pythons was studied in an intensive study area of 0.5 sq. km at Keoladeo National Park between December 1990 and April 1991. Two permanent transects (2.4 km each) were walked every four hours on a 24 hr basis to record python tracks and sightings. An activity index (tracks encountered divided by the number of replicates in a time class) was calculated for each time class. The microclimate (temperature and humidity)of python burrows was also monitored. Pythons were found to be active mainly during the day (0600 to 1800 hrs)in both winter and summer. Activity was diurnal in winter, uniform in spring, and bimodal-crepuscular in summer. Activity patterns were not entirely explicable in terms of temperature, humidity or prey activity. Burrow temperatures paralleled ambient temperature during the day, while in the night, burrows were warmer than the ambient temperature. Prey activity was consistently bimodal, with a peak at morning and evening hours throughout the study. The decline in sightings towards the summer may be due to emigration of pythons, or a decrease in conspicuous basking activity. The results from this study are compared with findings on other snakes.

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Individual pythons in Keoladeo National Park, Rajasthan, were identified based on the structure and pattern of their blotches. The prominent blotches considered in this study are the head blotch, the eye marking, the dorsal (vertebral) blotches, the dorso-lateral blotches, and the lateral blotches. The size and shape of the dorsal blotches varied considerably. Photographs of individual pythons were taken, and the shape of a few anterior dorsal blotches was drawn. The first four dorsal blotches were sufficiently different among individuals that there was no danger of misidentification. Twenty-four surveys were conducted and a total of 132 sightings obtained during the study period (November 1988 to March 1989). Altogether, 35 pythons were identified using blotch structure, compared with only 24 during an earlier census.

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These turtles fed on fruits of (*Ficus racemosa*)which were dropped by rhesus monkeys into the water. They also accepted cooked food such as chapatis and peanuts. Young turtles fed on swarms of millepedesm, and on fish. Live flapshell turtles (*Lissemys punctata*) and waterfowl were also taken. Besides live food, dead fish and mammals were scavenged by these turtles.

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The aestivation behaviour of the Indian Flapshell turtle was studied in the Keoladeo National Park, Bharatpur, between January and June 1987. Plots of

varying size were laid in dried up marshes and intensely searched for aestivating turtles. For each aestivating turtle located, the species, microhabitat, and aestivation depth were recorded. A digital thermometer was user to record the atmospheric and substratum temperature at the aestivation site. The aestivating turtles were also monitored to record the aestivation duration. (*Lissemys punctata*)spent about 160 days in aestivation and the aestivation depth varied from 2 to 10 cm. with a mean of 5.2 cm. Bushes near drying water bodies had the highest concentration of turtles (166/ha). Overall, the highest density of (*L. punctata*) was observed within 50 m radius of the last drying water bodies. Diurnal substratum temperatures in the aestivating habitats varies from 28' to 48' C. Of the seven species of turtles found in the study area, all except (L. punctata) stayed temporarily in the drying mud and either deserted their sites or were found dead within a month. Only (*L. punctata*) stayed in the aestivation site till the monsoon. It is therefore concluded that only (*L. punctata*) can be considered as a truly aestivating species in Bharatpur.

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Scat analysis was used to study the feeding ecology of the Indian flapshell turtle in Keoladeo National Park, Bharatpur, Rajasthan, between June 1989 and July 1990. Turtles were collected from the wild, measured, observed for 48-72 hours and released after they defecated. The scats were analysed, the contents identified, and the percentage of each food species in the scat estimated visually. Both plant and animal matter were recorded in the scat. Animal matter was recorded in 95 percent of the scats while plant matter in 83 percent. Molluscs constituted 26 percent by volume of the diet, fishes 20 percent, and insects 20 percent. Fish were mostly recorded in the scats in summer. This is a period when a large number of dead and dying fish are available as a result of waterbodies drying up. It is concluded that the Indian flapshell is an opportunistic omnivore with a preference for animal matter.

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Arrival, departure, sex ratio and wetland utilization by migratory waterfowl was studied in Keoladeo National park (KNP), Bharatpur from August through May

between 1987 and 1989. Direct observation method was used for data collection. Waterfowl started arriving in the KNP in the first fortnight of August and were seen till may. They extended their stay in KNP during the year of normal rainfall. Imbalance in sex ratio was observed in pintail, shoveller (Male biased and common teal (female biased). Gadwall, wigeon and mallard showed balanced sex ratio (1:1). Reasons for the disparity in sex ratio are discussed.

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were found during the hot-dry season and (*Echinochloa crusgalli*)seeds during the monsoon. 37 small-seeded species germinated from the dung of the three species. The authors present data that suggest that the minimum conditions for the foliage-as fruit hypothesis have been met with in their study area.

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The Keoladeo National Park Bharatpur a man made freshwater carved out of a Natural depression on the floodplain of two minor tributaries of the Yamuna Gambhir and the Banganga is the country's finest waterfowl habitat. This important wetland was set aside as a bird sanctuary in 1956 and it was elevated to the status of a National park in 1981. It was also designated a Ramsar site a wetland of international importance under the Ramsar convention. This important wetland ha distinction of being the only wetland to be included under the both the ramsar and the world heritage convention. The attempt has been made to evaluate the habitat of sarus crane in the Keoladeo National park using satellite data IRS LISS III and PAN merged product and GIS. Geocoded data of IRS-1C LISS III of 21 March 1999 on 1:50,000 scale and PAN data of March 17 1999 were used to generate the vegetation cover type map and open water. The map showing drainage, human habitation, contours, roads, etc were prepared using the survey of India topographical sheets and contours map of park area. Information regarding habitat parameters was collected from the existing literature and field observation. The sarus crane mainly fed in the wetland on the Rhizome of *Nymphaea sp*. *Scirpus tubersus and Eleocharis plantaginea*. As there were changes in their habitat requirement at different season, the sighting of sarus crane in each habitat were recorded using along with the time and activity during observation. The most utilized habitat for the entire period of study was moderately wet grassland followed by pools. The pools were used mainly during the summer. The water depth requirement observed was between 30-40 cm and 20-40 cm. The suitability maps for Sarus crane were then generated using all remote sensing based and conventional information using rule based equation in the GIS within the Keoladeo National park.

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140 Perennou, C. & B.R. Ramesh 1987. *Explanatory notes on the vegetation map of Keoladeo National Park*. French Institute, Pondicherry & Bombay Natural History Society, Bombay.

141 Peter Scott, 1966. Visit by IUCN delegation to the Keoladeo Ghana Sanctuary, Bharatpur, Rajasthan, India. *Journal of Bombay Natural History Society*, 63(1):206-209.

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143 Prakash, V. 1988. *Status and ecology of the raptors at Keoladeo National Park, Bharatpu*r.Ph. D. thesis, University of Bombay.

144 Prakash, Vibhu. 1999. Status of vultures in Keoladeo National park, Bharatpur, Rajasthan, with special reference to population crash in gyps species. *Journal of Bombay Natural History Society*. 96. (3). 1999. P.365-378.

Seven of the eight species of vultures reported from the Indian subcontinent are recorded from Keoladeo National park, Bharatpur, Rajasthan. The vegetation of the park is described as tropical thorn forest, which is very widespread in the country as it covers the entire semi-arid and parts of the deccan plateau biogeographical zones. The population and distribution, including the nesting distribution, of the vultures was studied between the years 1985-88 1990-92 and 1996-99. A sharp decline in the population of Gyps species was recorded over a decade. A decline of 96 per cent was recorded in the population of white-backed vulture and 97 per cent in long billed vulture. The population od king and egyptian vultures remained stable over the decade as is expected in the population of large and long lived birds. Possible reasons of the decline in vulture populations are discussed. Circumstantial evidences suggest pesticidal contamination and disease as the most like determination of pesticide load in vulture and its food, attempts to detect a possible pathogen and genetic diversity are suggested for conserving the species. Captive breeding is suggested to save the white-baked vulture from imminent extinction.

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146 Prakash, Vibhu. 1988. Lesser Spotted Eagle (*Aquila pomarina hastata*)Nesting In Keoladeo National Park, Bharatpur. *Journal of the Bombay Natural History Society*; 85(2):614-614

147 Prakash, Vibhu; C. Nanjappa.1988. An Instance Of Active Predation By Scavenger Vulture (*Neophron percnopterus ginginianus*) On Checkered Keelback Watersnake (*Xenochrophis piscator*) In Keoladeo National Park, Bhatratpur, Rajasthan. *Journal of the Bombay Natural History Society*; 85(2):419-419.

148 Prakash, G.; Prakash V.2001 Nesting population and breeding success of resident raptors in Keoladeo National park, Bharatpur, India (abstract) *Vulture News*; 45: pp. 63-64, September 2001-64, 2p

149 Prasad, V.P. 1989. Flora of Keoladeo National Park, Bharatpur, Rajasthan. *J.Econ.Tax.Bot*.: 13: 3, 1989. P. 729-750.

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151 Prasad, V.P. 1988. Wetland angiosperms in Keoladeo National Park, Bharatpur. *J. Econ. Tax. Bot*. 12: 457-466.

152 Prasad, V.P.& L. Vijayan 1990. *Centrostachys aquatica* - a rare species in India and its occurrence in Rajasthan. *J. Econ. Tax. Bot*. 14: 612-614.

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154 Prusty A.K. and P. A. Azeez. 2007. Vertical distribution of alkali and alkaline earth metals in the soil profile of a wetland–terrestrial ecosystem complex in India. *Australian Journal of Soil Research,* 45(7):533–542.

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157 Rai, Vikas. 2008. Modeling a wetland system: The case of Keoladeo National Park (KNP), *Ecological Modeling* 210(3):247-252.

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159 Ramachandran, N.K.; Vijayan, V.S. 1995. Breeding ecology of the bronzewinged (*Metopidius indicus*) and pheasant-tailed (*Hydrophasianus chirurgus*) jacanas in Keoladeo National Park, Bharatpur, Rajasthan. *Journal of the Bombay Natural History Society*. 92. (3). 1995. P. 322-334.

The breeding ecology and behaviour of bronze-winged and pheasant-tailed jacanas were studied in the Keoladeo National Park, Bharatpur, Rajasthan, from 1986 to 1988. Spot mapping was used to census and monitor nesting jacanas throughout the breeding season. Whenever nests were found, data on the location of nests, the nesting habitat, nesting material, water depth and clutch size were collected. Macroinvertebrate populations and vegetation were studied in the feeding areas of both species. For the pheasant-tailed jacana, vegetation around nests was quantified. Data on nesting habitat, nests, territory, eggs, clutch size, recruitment of chicks and dispersal are presented for both species. Factors affecting the breeding season of both jacanas are discussed in detail. The major abiotic factors affecting the breeding season in both species seem to be the timing and intensity of the south-west monsoon and the availability of water in the Park in a particular year. The important biotic factors were found to be the availability of food and the presence of suitable habitat.

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161 Ramachandran, N.K.; Vijayan, V.S. 1994. Distribution and general ecology of the sarus crane (*Grus antigone*)in Keoladeo National Park, Bharatpur, Rajasthan. *Journal of the Bombay Natural History Society*. 91. (2). 211.

The ecology of the Sarus crane was studied during 1985 and 1986 in the Keoladeo National Park, Bharatpur, Rajasthan. The breeding population was further monitored till 1988. Total counts of the cranes were made twice a month, covering all the blocks in the Park, and sightings were plotted on a map of the area. Habitat preference was studied through regular surveys of different blocks where the habitat type where the bird was sighted was recorded for each sighting. Food and feeding habits were studied through direct observations, and through food samples and droppings. The distribution, seasonal fluctuation in numbers, breeding seasonality, territoriality, nesting behaviour, breeding success, parent-offspring relations, food and feeding habits, roosting behaviour, movement patterns, and habitat preferences of the sarus crane are discussed. The population of cranes in the park fluctuates from around 250 in summer to around 24 in winter. The possible reasons for this pattern are discussed. Over the last 10 years the number of breeding pairs seem to be declining. Fledgeling success was 20. and 37.5. during 1984 and 1985 respectively. Threats to the sarus crane in the study area and conservation measures to alleviate these threats are discussed.

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164 Rana, Gargi; Prakash, Vibhu. 2004. Unusually high mortality of cranes in areas adjoining Keoladeo National park, Bharatpur, Rajasthan. *Journal of Bombay Natural History Society*. 101. (2):317.

165 Gargi 1999 between Siberian crane Grus leucogeranus and checkered keelback snake Xenochrophis piscator in Keoladeo National Park, Bharatpur Journal *of the Bombay Natural History Society*; 99(1): 114-115;

166 Ranjit Lal, 2004. *The Crow Chronicles*. Penguin, 406p.

167 Ritu Singh, 2007. Assessment of Hydrological Functions and Water Budget of Keoladeo National Park Watershed. Ph.D thesis, Forest Research Deemed university, Dehradun. 114p.

168 Samuel Israel and Toby Sinclair, 1987. *Indian wildlife : Sri Lanka, Nepal*, APA productions, Singapore, 363p.

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171 Sankhala, K.S. 1958. Ghana - Rajasthan's Bird Sanctuary. *Indian Forester* (January): 50-56.

172 Sauey, R.T. 1987. Disturbance factors affecting Siberian crane at Keoladeo National Park, India. Proc. 1983 International Crane Workshop (Ed. G. W. Archibald & R. F. Pasquier). International Crane Foundation, Baraboo, Wisconsin.

173 Sauey, R.T. 1985. The range, status and wintering ecology of the Siberian Crane Grus leucogeranus. Ph. D. thesis, Cornell University.

174 Saxena, V.S. 1993. Wildlife and Its Management in Rajasthan: in Natural & Human Resources of Rajasthan ed. by Chouhan,T.S, P. 211-268.

175 Schaller, B.G. & J.J. Spillet 1966. The status of the big game species in Keoladeo Ghana Sanctuary, Rajasthan. *Cheetal* 8(2): 12-16.

176 Shivrajkumar, Y. 1962. A visit to Bharatpur, Rajasthan. *Newsletter for Birdwatchers* 2(10): 3-6.

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178 Sivasubramanian, C. & S. Bhupathy 1990. Indian flapshell turtle (Lissemys punctata) in the food of the adjutant stork (Leptoptilos dubius) J. Bombay nat. Hist. Soc. 87(3): 460.

179 Sebastian, Sunny, 1993.The Crane saga : experiments with Siberian visitors. *Frontline*: 23, Apr., 1993. P. 78-80.

180 Seshadri, S. 1986. India's Wildlife and Wildlife Reserves, Sterling Publishers, New Delhi. 215p.

181 Sharma, Chhaya; Chatterjee, Shantanu. 2007. The past 26000 years evolutionary History of Keoladeo National park, Rajasthan. *Current science*. 92. (8). P.1161-1165.

182 Sharma, Sunayan. 2007. Community participation in management of Keoladeo National park. *Cheetal.* 46. (1-2). P.34-37.

183 Sharma, V.D.; Sharma, Sunayan. 1991. The vanishing Siberian crane. *Indian forester.* 117. (10). 850-855.

The population of Siberian crane (*Grus leucogeranus*)a winter migrant to India is decreasing day by day. Studies have been conducted in the Keoladeo National Park from 1974 to 1991 about number of their coming, feed habit and breeding etc. Valuable information about their movements have also been recorded to provide authentic information about their speed.

184 Shukla, J.B.; Dubey, B. 1996. Effect of changing habitat on species: application to Keoladeo National park, India. *Ecological modelling*. 86. (1). 1996. P.91-99.

In this paper a mathematical model is proposed to study the effect of ecological changes caused by the excessive growth of wild grasses such as *Papalum distichum* on the exostence of various species in the Keoladeo National wetland park, Bharatpur, Rajashtan, India. In the model the growth rate of several species, such as floating vegetation (*Nymphoides indicum*, *Nymphoides cristatum, Nymphaea nouchali* and *Nymphaea stellata*) fishes, waterfowl etc, and the corresponding carrying capacity of the wetland are assumed to decrease with the increase in biomass density of wild grasses. By analysing the model it is shown that if the wild grasses are not controlled, the existence of various other species will be threatened. It is shown through the model study that if the growth of wild grasses is controlled, either by allowing a managed number of buffaloes to graze them or by using some other mechanism to remove them, then the other species in the wetland will boom.

Keeping in view the growth of *Paspalum distichum* and using the corresponding parameters for this wetland in the model, the number of buffaloes to be permitted for grazing has also been calculated for management purposes.

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187 Sivasubramanian, C. 1992. Indian skimmer (*Rynchops albicollis*)Swainson and black stork (*Ciconia nigra* (Linn.)- new additions to the avifauna of Keoladeo National Park, Bharatpur. *Journal of the Bombay Natural History Society*. 89. (2). 1992. P. 252-253.

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197 Subramanian, K.S. and Vlassoff, Michael, A case study of Keoladeo National Park- population pressure and biodiversity. 30p.

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City of Bharatpur fell enroute to the total solar eclipse on oct. 24 1995, total darkness for more thatn 38 seconds coupled with considerable drop in temperature influenced the activity patterns of many diurnal and nocturnal birds. The present communication deals with some observations on darter (*Anhinga rufa)*commonly called snake birds and night heron, (*Nycticorax nycticorax*)it is inferred that the total solar eclipse has influenced call and communications perch shifting and resting behaviour in night-heron. In case of Darter, no deviations as compared to normal activity were observed.

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208 Vasant K Saberwal and Mahesh Rangarajan, 2003. *Battles Over Nature: Science and the Politics of Conservation* / edited by Vasant K Saberwal and Mahesh Rangarajan. Delhi: Permanent Black, 412p.

209 Vardhan, H. 1976. *Birds of Bharatpur Sanctuary*. Tourism and Wildlife Association, Jaipur.

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211 Venkataraman, K. 1988. Cladocera of Keoladeo National Park, Rajasthan II, New Records. 1. *Moinodaphnia macleayii* and 2. *Bosminopsis deitersi* Richard. *J. Bombay nat. Hist. Soc*. 85: 229-233.

212 Venkataraman, K. 1992. Cladocera of Keoladeo National Park, Bharatpur, and its environs. *Journal of the Bombay Natural History Society*. 89. (1). 16-26.

213 Venkataraman, K.1990. New records of Cladocera of Keoladeo National Park, Bharatpur - III. *Journal of the Bombay Natural History Society*. 87. (1). 1990. P. 167-168.

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216 Verma, Ashok. 2003. Wintering site fidelity in western marsh-harrier *Circus aeruginosus* in Keoladeo National park, Bharatpur, Rajasthan. *Journal of Bombay Natural History Society.* 100. (1). 2003. P.117-118.

217 Verma, Ashok; Prakash, Vibhu. 2007. Winter roost habitat use by Eurasian marsh harriers *Circus aeruginosus* in and around Keoladeo National park, Bharatpur, Rajasthan, India. *Forktail*. 23. 17-21.

Roots of Eurasian marsh harriers *Circus aeruginosus* were studied for four winters between 1996 and 2000 in and around Keoladeo National park (KNP) eastern Rajasthan, India. Fourteen communal roost were found in which harriers gathered in loose aggregations of 11-132 birds. Roosts were situated in tall grasses and wetlands with floating vegetation in KNP and in tall grasses, sedges crops and bare ground in areas adjoining KNP. Birds shifted to roost in wetlands and peripheral sites when grassland roosts in KNP were disturbed during the grass cutting season. A comparison of roost sites with randomly selected non roost sites in grassland indicated that birds preferred sites in tall grasses and further from the nearest trees and road.

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223 Vijayan, V.S. 1987. Keoladeo National Park - Ecology Study: Annual Report 1987.: Ministry of Environment, Government of India and U.S. Fish and Wildlife Servic. BNHS, Mumbai, 32p.

224 Vijayan, V.S. 1988. Keoladeo National Park - Ecology Study: Annual Report 1988. U.S. Fish and Wildlife Service.: Ministry of Environment and Government of India. BNHS, Mumbai. 123p.

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226 Vijayan, V.S., 1986. Summary of Papers Presented at Salim Ali Festschrift Seminar. BNHS, Mumbai, 59p.

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6. Abstracts of Annual Research Seminar 2009

Second Annual Research Seminar on Keoladeo National Park (2nd ARS-KNP), Jointly organized by KNP, Forest Department of State of Rajasthan (India) & WWF, 15th March 2009, Keoladeo National Park, Bharatpur, India

1. ***Lalitha Vijayan, V S Vijayan & R. Venkitachalam, 2009.*** **Wetland Birds at Keoladeo National Park: an overview. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Ecology of Keoladeo National Park (KNP) Bharatpur was studied through an integrated and multidisciplinary project during 1980 to 1990 (Vijayan 1991) funded by the US Fish & Wildlife Service through BNHS and later monitored by SACON during 1992-93 and 2003-06. The first decade-long study showed that the ecosystem function depends mainly on the quantum and time of release of water and fry (fish) every year, and the vegetation. Considerable changes have been taking place in the park. Birds being the best indicator for monitoring the ecosystem are discussed here. Total counts of birds were conducted using the dykes as transects twice every month. Nests of the colonial fish-eating birds were counted separately recording the adults as well as chicks.

Water birds comprising ducks, teals, rallids and piscivores mainly colonial nesting birds, and a few threatened species are considered for comparison. In January 1993, 28269 birds of 57 species were counted while it was only18962 birds of 48 species in December 2003. During 2005-06 maximum number was in November (16106), but much less than in 1992-93. In January 1986 it was 26,320 of 68 species. Migratory waterfowl population had direct relation with water spread area and vegetation. The maximum counts of the dominant waterfowl in January of 2004, 2005 and 2006 showed very low number in 2004 (4359) when water input in the preceding rainy season was only 0.51 MM^3 and better in 2006 (13335) with much higher quantum of water (16.14 MM^3). However, it was less than in 1986 (16342) when water input was (13.73 MM^3). There was considerable change in the composition in different years. Population of some of the migratory birds was high during the beginning and end of the season as they used this site for stopping over.

Seven species of colonial nesting birds with 244 nests were recorded in 2003, five species with 359 nests in 2004 and 15 species with 2325 nests in 2005. Indian Cormorant had the maximum nests. Only two nests of the near threatened Black-necked Stork were found with four chicks in 2005; three other near threatened species Painted Stork, White (Black-headed) Ibis and Darter had more nests. All the

species had fewer nests than in a good rainfall year during 1980s (totally 8468 nests of 15 species with 7222 chicks in 1988).

Population of the threatened Sarus Crane has declined drastically with 8 pairs in 2003, 7 pairs in 2004 and 8 pairs in 2005 with only 2 nests and one chick compared to 14 nests in 1983 and 8 in 1992 because of mortality due to pesticides, continuous droughts and shrinkage in water spread area. The critically endangered Siberian Crane was only five in 1993, two in 2002 and nil thereafter. The critically endangered raptors recorded were the Long-billed Vulture and White-backed Vulture, very rare and no nests, although food availability was plenty inside the park.

Efforts have to be made for an integrated development programme for this region as suggested earlier which should include bringing in enough quantity of water to the park and controlling the weeds. Regular monitoring of the key parameters should be conducted and documented using Remote sensing & GIS techniques.

2. ***Satya Prakash Mehra, Sarita Mehra and Parikshit Gautam.*** **Avifaunal diversity of Keoladeo National Park: A Review. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Keoladeo National Park at Bharatpur, locally known as "Ghana", is acknowledged as one of the most fascinating and outstanding wetland reserves in the world. The wetland ecosystem is a system of small dams, dykes, sluice gates, created to control water level in different sections. This became the hunting preserve of the Bharatpur royalty, and was one of the best duck-shooting wetlands in the world in the 1850's which ended by the 60s. It was designated as a bird sanctuary in 1956 and recognized as a Ramsar site in 1981. In 1982, it was established as a National park and inscribed on the World Heritage List in 1985. The importance of this Park lies in the fact that the 29 sq km mosaic of habitats is formed by more than 375 species of floral species. From these varied habitats approximately 400 species of avifauna have so far been reported by the birders. The checklist has been prepared by reviewing the contributions made by the scientific workers which were published in the leading journals, newsletters and other scientific platform. The paper highlights the historical perspective of ornithology and importance of human involvement for the betterment of this unique ecosystem along with the checklist of avifauna. The paper is an attempt to give an actual number of bird species sighted inside the park since its origin.

3. ***Jatinder Kaur and B.C. Choudhury*** **Suggested conservation strategies for enabling long-term survival of Sarus Crane in the semi-arid landscape of Rajasthan. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

The Sarus Crane (*Grus antigone antigone)* is a globally threatened species found largely in the Indian wetland habitats. Though Natural wetlands are considered to be the most crucial requirement for the survival of the Sarus Cranes in its distribution range, the present distribution of Sarus Cranes are influenced by the changing agricultural patterns and hydrological intervention which affects its biology and therefore its distribution. Sarus Crane appears to have adapted to a somewhat different life cycle in the Semi-arid tract in its distributional range as compared to the water rich zones in the central and eastern Gangetic plains. The study was conducted in the semi-arid landscape of Kota and Bharatpur districts of Rajasthan from February 2000-May 2002.

The results indicate that it is necessary to maintain the periodicity of water, particularly in wetlands of Kota and Keoladeo Ghana National Park and other semi-arid areas where the post-monsoon provisioning of water to wetlands support the wetland avifauna and the Sarus. The involvement of local communities around the wetland plays a vital role in the conservation of Sarus Crane and wetlands.

4. ***Ashok Verma and V B Mathur,*****The significance of Satellite Wetlands of Keoladeo National Park for wintering waterbirds. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

The UNESCO-WII Project '*Enhancing Our Heritage –Monitoring and Managing for Success in Natural World Heritage Sites*' attempted identification, documentation and monitoring of satellite wetlands for water-birds in Keoladeo National Park (KNP) environs since 2005.

Since 2005-2007, a total of 34 satellite wetlands spread over 6 districts i.e. Bharatpur, Dausa, Jaipur, Krauli, Dholpur (Rajasthan), Mathura and Agra (Uttar Pradesh) could be identified within 200 km radius of KNP. Of these, 9 wetlands were large perennial, 4 small perennial, 16 large seasonal and 5 small seasonal. Except Nonera (Bharatpur), Hulwana and Sankhi (Mathura), the brackish wetlands the remaining all were fresh water wetlands. Many of these wetlands hold high conservation value for both migratory and resident water bird species by providing them staging and wintering grounds.

The size of these wetlands ranges from 1 to 100 sq km. Lot of information exists on the avifauna of KNP however little is known about the dynamics of wetlands and water birds around it. The present paper evaluates conservation value of such satellite wetlands for water birds. The study recommends that wetlands should not be protected as isolated spaces but, on the contrary, dynamic, complex habitats with biotic and abiotic connections all around and therefore while declaring Protected Areas in the country wetland protection should take into account water bird movements and bird migration as functional processes.

5. ***Lata Verma and Ashok Verma*** **Population status, structure and habitat use of Peafowl *Pavo cristatus* in and around Keoladeo National Park: implications for management. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

A study on the population status, sex structure and habitat use of Peafowl *Pavo cristatus* was carried out in the Keoladeo National Park and its adjoining 19 villages during 2006-07. A total of 355 individuals were counted at roosts from the KNP during May-June 2007 with 35% males and 65% females while the block-count estimated a total of 345 individuals with 37% males and 63% females. In the adjoining villages during these months there were 127 individuals counted at roosts and the ratio of males to females was found to be 40% to 60%. A year round study (2006/2007) in the adjoining villages estimated a total of 307 individuals, of which males comprised 34% and females 66%. In the park, the pea fowls used 6 species of trees with *Acacia nilotica* being the dominant followed by *Mitragyna parvifolia* whereas around the park they used 13 species of trees with *Ficus religiosa* being the dominant followed by *Azadirachta indica*. Management implications for peafowl are discussed in the paper.

A monitoring program for Peafowls should be continued for ensuring their long term survival in the park and its adjoining areas.

6. ***C. Ramesh & S. Bhupathy.*** **Conservation of the Indian rock python in Keoladeo National park, Bharatpur. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

The Sálim Ali Centre for Ornithology and Natural History, Coimbatore is conducting a study on the ecology of this endangered (Schedule I) snake in Keoladeo National Park (27˚ 7.6' to 27˚ 12.2' N and 77˚ 29.5' to 77˚ 39.9' E), since October 2007. Major objectives of the present study are to (1) Study the population trend in Python in

KNP comparing results from earlier studies (2) Gather data on aspects of ecology of Indian Python such as basking, breeding, ranging, cohabiting species in the burrow and food habits and to (3) Assess the impact of tourists on the basking and movement patterns of Python. In the present paper, we provide preliminary data on the ecology of Indian Python.

Estimated number of Python during 2007-08 is 70-80, which was about 110-120 (during 1986-87 to 1999-2000). The present figure (70-80) could be an underestimate, as *Prosopis* eradication programme was in progress in the Park during 2007-08 and large number of labourers worked including in Python habitats as well. The presence of workers would have forced Pythons to retreat into the burrows resulting in underestimate of its number. The assessment of Python populations in the forthcoming year would provide us the real picture on their status. Basking behaviour of Pythons with limited data set (10 days each in disturbed and undisturbed Python burrows), showed that on an average the basking duration of snakes in the undisturbed area range from 5 to 6 hours/ day, which is only 1-2 hours/ day in snakes inhabiting areas visited/disturbed by tourists. This difference in basking duration may affect the growth and breeding of Pythons in long run. The study is being continued and this result may help the Park authorities in regulating visitors to Python burrows. Thirty eight Pythons have been identified individually based on blotch pattern using photo documentation and their GPS points recorded. Preliminary results show that Pythons may move about 1.2 km (straight-line distance). However, during winter, they mostly restrict their activity near burrows. Among several ground burrows found in the Park during 2007-08, in 29 burrows Pythons were found, in 25 Indian porcupines was found cohabiting with Pythons. Other animals such as Jackal, and Monitor lizard were found each in three burrows.

Further to the suggestions based on the project findings, the Park administration had taken steps to close the disused ground wells (2 nos.) which resulted in death of snakes in the past. The eradication of *Prosopis* is a welcome step for the conservation of Pythons and other flora and fauna in the Park. The impact of eradication of this exotic weed is being studied. The field work of this research project is in progress.

7. ***K. K. Sharma[1], Vivek Sharma[2], Sarita Mehra[3], Satya P. Mehra[4] and Parikshit Gautam[5.]*** **Herpetofaunal composition of Keoladeo National Park with main emphasis on Anurans, Rajasthan, India. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Keoladeo National Park (KNP) has the diversity of habitats. The wetland habitat is one of the most important and ideal habitat for the faunal biodiversity. The aquatic avifaunal were well studied in the wetland habitats of the park. The herpetofaunal composition is very high inside the park owing to its diverse habitat. The reptile class tops the list of the herpetofauna. Detail studies of the Amphibians are lacking in the park. From the preliminary assessment of two years on the distribution pattern and status of the anurans were observed. Earlier studies had recorded seven species of the anurans. Six species of frogs (Family Ranidae: 4 species, Family Microhylidae: 2 species) and one species of toad (Family Bufonidae). In the monsoonal assessment of year 2007 and 2008, the authors recorded one more species from the Park. Thus, out of twelve species of Rajasthan, park harbours eight species of anurans. The sound based taxonomic identification of species was used for the purpose. This is for the first time in Rajasthan to use this technique for the field identification and monitoring.

The maximum distribution of the Ornate Narrow-mouthed (*Microhyla ornata*), Indian Skipping (*Euphlyctis cyanophlyctis*) and Cricket (*Fejervarya limnocharis*) frogs was observed in the wetlands. The distribution of Indian Green Frog (*Euphlyctis hexadactylus*) was restricted to few of the core wetland sites whereas Indian Bull Frog (*Hoplobatrachus tigerinus*) had the scattered distribution pattern. Marbled Balloon Frog (*Uperodon systoma*) was only found its distribution in the N and L blocks. The two toads were mainly cited and recorded during the night time. Marbled Toad (*Bufo stomaticus*) showed its presence all over the marginal areas of blocks with water whereas Common Asian Toad (*Duttaphrynus melanostictus*) was mainly recorded on the terrestrial habitat and was more prone towards the man made sites of the blocks.

The present study had tried to assess the distributional pattern of the species within park. The deaths of the anurans were mainly observed through the trampling on the man made pathways within the park. On comparing the distributional pattern of year 2007 with year 2008, there was major shift in the pattern was recorded. This might be due to the drought conditions in year 2007 along with human interference in the habitats which was not observed in year 2008. Long-term studies are required to asses their association with the vegetation of the park.

8. **Satya Prakash Mehra[1], Sarita Mehra[2], Jaykant Saini[3] and Parikshit Gautam[4]A Preliminary Study of Lower Organisms of Keoladeo National Park. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Larger varieties of invertebrate forms in Keoladeo National Park (KNP), though not well known and appreciated, play a significant role in the ecology of the habitat. KNP has a long History of avifaunal studies but a majority of these are confined to globally important species of higher groups of animals. In late 19th and early 20th centuries, the then British Officers explored and documented lower organisms from their administrative areas. In the late 20th century, Indians started exploring and documenting different groups of invertebrates. Most of such studies focused on the fascinating groups of butterflies, termites heamatophagous insects and the parasitic groups such as Platyhelminthes and Aschelminthes. Lower invertebrates of the park have been neglected from the research point of view. This is substantiated by the fact that no collective and authentic data of all the invertebrate species of the park is available at present, and therefore, this is the first attempt to do so. More than 100 species of butterflies were recorded from different habitats of Bharatpur, out of which approximately 80 species could be sighted inside the park in different seasons. The odonate group which is one of the bio-indicator of wetland health has a diversity comprising of more than 30 species inside the park. Over 30 types of spiders were recorded inside park along with ten types of beetles. The text is supported by the checklists of various invertebrate phyla with main emphasis on the most studied orders of butterflies and odonate. The work is based on the review of literature, sighting and photographic records of the species for a period of two years (Mar 2007 - Feb 2009). The paper also recommends the need of further studies on the lower organisms inside the park. Further, the long-term studies are required for monitoring the impact of climate and habitat change inside the park which could be an effective tool for the managers and policy makers to plan strategies for the conservation and protection the mosaic habitat of the park.

9. **B. Anjan Kumar Prusty, Rachna Chandra and P. A. Azeez. Circadian Variation in Fry Movement to Keoladeo National Park Wetland System. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

The circadian variation in the availability of fry in the feeder Ghana canal of the Keoladeo National Park (KNP) was assessed in September-October 2005. 24 hours sampling with an interval of 3 hours was carried out for the purpose of monitoring throughout the duration of water release into the KNP. A total of 16 species of fish were recorded entering the park with the input water, of which, *Clarias gariepinus*

and *Danio dangila* were new records. Six of the 16 species were diurnal, 6 nocturnal, and the others were abundant during both day and night. Fish drifting was high during the day hours. Except *C. gariepinus, Catla catla, Mastacembelus armatus armatus* and *Chela cachius*, all other species were significantly (χ^2, $P < 0.05$) distinct and independent in their abundance in the incoming water. Temporal movement of fry in the canal entering the park was positively skewed, indicating most of the species to be active during or after 1: 30 AM until the next midday. Of the 16 recorded fish species, 7 were found to have a leptokurtic distribution and the others a platykurtic distribution. The fish arriving through the canal formed 3 clusters. *C. cachius, C. bacaila, Catla catla, Wallago attu, Clarias gariepinus, M. armatus, Cirrhinus reba, C. mrigala, D. dangila, Securicula gora, Mystus vittatus, Chanda nama*, and *Salmostoma bacaila* formed one cluster. *Chanda ranga* and *Puntius sarana* formed another cluster, while *P. sophore* appeared distinct from all the other species. Hierarchical clustering with respect to time showed one distinct cluster consisting of the species that are active during 9: 00 PM to 6: 00 AM.

10. B. Anjan Kumar Prusty[1,2], Rachna Chandra[1], M. Shah Hussain[3] and P. A. Azeez[1] Arrival Pattern of Fishes into Keoladeo National Park Wetland System: A Catchment Driven Process? Annual Research Seminar, Keoladeo National Park, March 15' 2009.

We examined the arrival pattern of fishes into the wetland system of Keoladeo National Park (KNP), from 2003 through 2005 to 1) assess and analyze the variation in the fish recruitment into the KNP and to compare the present scenario with those of the mid eighties and 2) explore the influence of the catchment processes on occurrence and abundance of fishes in the feeder canal. A total of 40,766 individuals belonging to 8 families, 18 genera and 24 species were recorded. The species accumulation curve, however, suggests that there might be 30 species in the catchments of KNP. The present investigation recorded 7 new arrivals to the park, viz. *Brachydanio albolineatus, Cyprinus carpio communis, Clarias gariepinus, Danio dangila, Mystus tengara, Rasbora daniconius* and *Securicula gora*. The highest fish diversity was during 2004 (1.368) and the least in 2003 (0.934). The drift density ranged from 45.57 to 1.01 x 106 (individuals/100 m^3 water) and the drift rate from 0.2 to 93.8 (number/second). Except *B. albolineatus, Catla catla, C. gariepinus* and *Mastacembelus armatus*, all other fish species were distinct and independent with respect to their abundance (χ^2, $P < 0.05$). Of all the recorded species *Puntius sophore* was apparently distinct forming one cluster. *Chanda ranga* and *Puntius sarana* formed another cluster distinct from rest of the species. Reduced availability water, induced by sporadic rainfall, has become a crucial issue for the very sustenance of this wetland system and its ichthyofauna in the recent past.

Nevertheless, overall decline in the fish species recruitment after the monsoonal flood in the catchments in comparison to the previous decades necessitates a review of the ongoing anthropurgic pressures on fishes, and habitat destruction for infrastructure development and urbanization in the catchments.

11. ***Dr. M.M.Trigunayat and Nidhi Johri*** **On the Mud Puddling behaviour of Butterflies in Keoladeo National Park, Bharatpur. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Mud puddling is prominent behaviour among butterflies. Nutrients that hardly become available to the butterflies in their nectivorous and herbivorous diets e.g. sodium are procured either by mud puddling or dung puddling. During summer season the water of the puddles in different blocks of the park start evaporating that expose many minerals and nutrients in wet surroundings. Nymaphalid, Pierid, Lycaenid and Hesperid butterflies have been seen puddling mud and dung in the park. Such observations are common in monsoon season also when the minerals get dissolved in the puddle water. Butterflies visit moist ground in order to replenish essential nutrients of water during gamete formation, mating or general metabolism. Sodium is essential for the female to increase fecundity. It is supplemented through mud puddling. The males of many species suck minerals and nutrients from the damp places. These minerals are not only used as energy source but substantial amount of these nutrients is transferred to the females during mating to improve reproductive success.

Present paper describes physiology and different species puddling in mud and dung.

12. ***Rachna[1] Chandra, B. Anjan Kumar Prusty [2]and P. A. Azeez.*** **Vegetation dynamics and hydroperiod induced changes in Keoladeo National Park. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

We measured the temporal variation in the aboveground biomass and productivity of 37 available macrophytes in the wetland system of Keoladeo National Park (KNP) during July 2005 through April 2006. Net Primary Productivity (NPP) of the macrophytes was 2.71 g m-2 on dry weight basis. The maximum and the minimum average biomass of macrophytes were 92.21 g m-2 and 27.52 g m-2, respectively. Several species accumulation indices showed different levels; the Second order Jackknife showed the lowest species accumulation and Bootstrap the highest with 31.44 and 40.39 species, respectively. Univariate Analysis of Variance showed significant variation in biomass among the months, the blocks and the categories. The hierarchical cluster analysis of plant categories with respect to biomass resulted,

in total 5 clusters. Terrestrial, emergent species, algal species and rooted submerged categories formed one distinct cluster each, and the fifth one was formed by the rest of the categories. As reported in the present study and also earlier studies the vegetation of KNP wetland was largely dominated by emergent macrophytes. Water depth seemed to be significant explanatory variable for macrophytic assemblage, in combination with several other factors. Further, in the case of KNP, a monsoonal wetland, the plant community development is largely the result of germination and establishment from a long-lived, dormant seed and vegetative propagules that survive the drought conditions and such community zonation may differ from year to year and season to season as water levels fluctuate in space and time. The complete absence of some of the species reported during 1980's hint at the anthropogenic alternations in the KNP microenvironment. Development of plant communities under Natural, fluctuating water regime is a consequence of several factors, including livestock grazing and individual plant tolerance and/or response to the stresses of flood and drought, characteristics of the catchment and the nature of the substratum of the wetland.

13. ***Hari Shanker Srivastava[1], Parul Patel[2], K. P. Sharma[1] and Y. V. N. Krishnamurthy[3].*** **Explored and demonstrated potential applications of multi-parametric synthetic aperture radar in wetland studies in context of Keoladeo National park. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Wetland ecosystems have received little recognition on the vital role that they play for human well-being. As a result of this, there is an alarming loss of wetlands. It is required to arrest the losses and to achieve optimal resource use with balanced priorities of biodiversity conservation. This calls for meaningful and timely information and data on wetland habitats, its fauna, flora and socioeconomic variables of relevance. Traditionally, the source of the spatial information that captures dynamics of a wetland ecosystem has been that of optical remote sensing data. Although optical remote sensing data is found to be very useful for wetland monitoring, cloud cover restricts the availability of satellite data during rainy season, which is main source of water for most of the inland wetlands. Moreover, delineation of several classes of importance for wetland ecosystem is also not clearly differentiable on optical remote sensing data. Synthetic Aperture Radar (SAR) can play an important role to achieve the above goals. Due to their unique response to open water and water with varying vegetation coupled with their all weather capability, SAR sensors are the best choice for monitoring of a wetland ecosystem. In this paper, authors address the dynamics of wetland habitat using satellite data from optical (IRS-L-III)

and multi-parametric SAR sensors (ERS-1/2, Multi-incidence angle RADARSAT-1, Multi-incidence & Multi-polarized ENVISAT-1 ASAR, multi-parametric DLR-ESAR) over Keoladeo National Park, Bharatpur, India acquired between 1996 and 2004. Results of the study clearly indicate that use of SAR data can improve quality of information on various components of a wetland ecosystem, which is of great significance in wetland conservation and monitoring.

14. ***B. Anjan Kumar Prusty, Rachna Chandra and P. A. Azeez.*** **Distribution of Carbon, Nitrogen, Phosphorus, and Sulphur in the Soil in the Multiple Habitat System of Keoladeo National Park, Bharatpur. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

We measured the background level and spatial variation of C, N, P and S and associated basic soil parameters along the depth profile for 3 years i.e. from 2003 through 2005, in 3 habitats (woodland, wetland, and grassland), in Keoladeo National Park (KNP). The study examined soils at 5 depths (0, 0.25, 0.50, 0.75, and 1.00 m). Total organic carbon (TOC), total nitrogen (TN), total available phosphorus (TAP), and total available sulphur (TAS), irrespective of the habitat type and year, were found to be highest in the litter layer, gradually declining with depth. Elemental ratios (C: N, C: P and C: S) followed the same declining trend, whereas, the N: P ratio increased down the soil profile. The high C: N and C: S ratios in the litter layer suggest the relatively low mobilization of N and S from the decaying detritus layer.

All the variables studied varied significantly among the soil layers (GLM-ANOVA, $P<0.05$). Principal component analysis (PCA) showed 4 components based on examination of the scree plot. The first component accounted for 27.1% of the total variance in soil characteristics among samples, reflecting the influence of soil variables such as P, TOC and pH. The second component accounted for 23.5% of the total variance, reflecting the influence of total dissolved solids (TDS) and TAS. The influence of carbon on elemental ratio (C: S) was pointed by the third component that accounted for 14.2 % of the total variance. The fourth component accounted for 13.6% of the variance, indicating the influence of soil TN. Thus, the 4 PCA components that accounted for 78.4% of the total variance in the data can be qualified as 'N: P/soil P/C', 'TDS/TAS', 'C: S ratio', and 'soil TN' respectively.

15. ***Satya Prakash Mehra[1], Sarita Mehra[2], Aditi Raina[3] and Parikshit Gautam[4.]*** **Post *Prosopis juliflora* Eradication Scenario of KNP. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Non-native species are a major cause of the loss of biodiversity globally. *Prosopis juliflora* is in IUCN's new list of 100 world's worst invasive alien species. *P. juliflora* is an evergreen fast-growing, drought resistant, Natural fuelwood with remarkable coppicing power tree species native to Central America. It is highly tolerant to water stress, soil salinity and sodicity. It is known to flower about four times a year in the region, and during the period large amounts of pollen debris are deposited underneath trees. These are easily distributed by human and animal activities which inducts its fast spreading.

Keoladeo National Park (KNP) has faced severe drought conditions in the last decade. *P. juliflora* was planted in small patches in the 1970s, gradually it got spread over the entire park and become a serious threat to the bio diversity of the park. This enhanced the spreading of this noxious weed invading terrestrial and wetland habitats within the park. Furthermore, absence of Natural enemies like insects and diseases are responsible for its spread. Ecologically it has range from Tropical Thorn to Dry through Subtropical Thorn to Dry Forest Life Zones (with little frost). This species provides >90% of the fuelwood in some Indian villages. In the years 2007 and 2008, an effort was made by the Forest Department to eradicate this exotic species totally by root through people's participation within the park.

The observations were commissioned to investigate, through desk study, the occurrence of non-native species in the Keoladeo National Park, Bharatpur (Rajasthan, India). The short assessment on the distribution of exotic species with main emphasis on *P. juliflora* was carried out from February 2007 to December 2008 to find out its impact after its removal from the park. 15 quadrates of 100 x 100 m (1 Ha) were laid randomly in the different habitats of the park. Monthly observations of the vegetation were collected along with the vegetative characteristics of the species. The main objective of the study was to assess the intensity of the regeneration of the indigenous species after removal of the *P. juliflora*.

The main conclusions include *Prosopis juliflora* is showing negligible (nil presence of saplings) growth in blocks B, C, G2, G3 & J2. Heavy growth was observed in blocks F1, F4 & I which needs immediate attention to check its further spreading in nearby blocks. Growth of *P. juliflora* is in the pockets in blocks D, E, F2, F3, K, L1, L2, M1, M2, N & O whereas the scattered pattern of the saplings of *P. juliflora* was observed in blocks F1, F4 & I. Blocks A, G1, G4, H & J1 were having both scattered and

pocket distribution of the *P. juliflora*. Best regeneration of *Acacia nilotica* was seen in blocks B & C. Distribution of the *Calotropis procera* was observed for the first time up to such a great extent. The northern periphery and the northern blocks A, B & C were heavily invaded by this species. *Salvadora* sp. is flourishing well in blocks F1, F2 & J1. Similar pattern was seen to lesser extent in blocks A, B, N & O. *Mitragyna parviflora* saplings were found regenerating to lesser extent in blocks B & C.

Immediate attention and management strategies are recommended to check the growth in few blocks of southern (block I, J1, H etc.) and central parts of southern region (F3, F4 etc.) whereas uprooting of the saplings are required at higher rates in all over the park.

16. **Emera Bridger. LIVELIHOODS IN MOTION: THE RICKSHAW PULLERS OF KEOLADEO NATIONAL PARK. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Tourism has been identified as an emerging industry which can be used to generate employment and reduce poverty, particularly in rural and semi-rural areas. Keoladeo National Park, Bharatpur provides an interesting case study in the articulation of tourism and livelihood generation due to the fact that it has had an on-going program of recruiting economically disadvantaged men to ply rickshaw within the park. Compared with other employment prospects in the Bharatpur region, working at the park provides the rickshaw pullers with substantial economic opportunities. However, due to the seasonality of tourism at the park and issues of water shortage, the rickshaw pullers are unable to rely solely on tourism to maintain their livelihood. This paper examines the strategies that rickshaw pullers use to mitigate the risks of working in the tourism industry as well as to provide some suggestions to improve the existing program.

17. ***Satya Prakash Mehra[1], Sarita Mehra[2], Jaykant Saini[3], Aditi Raina[4] and Parikshit Gautam[5]*** **Awareness and Knowledge of Keoladeo National Park (KNP) among Children of the Local Terrain - A Sample Study. Annual Research Seminar, Keoladeo National Park, March 15' 2009.**

Keoladeo-Ghana is well known to the people from the local terrain. This is the general perception of any visitor. Although partially it is agreeable that people of Bharatpur know about the park, its importance and its need. Keeping this general perception in mind, we assessed the level of knowledge among children from the villages of Bharatpur. The sample area selected comprised of the villages downstream of River Gambhiri, adjoining KNP till Sheola Head. The age group

targeted was 10-14 years or children studying in standard 6, 7 and 8. The methodology used was a questionnaire- based random survey. The twenty questions asked in the questionnaire aimed to get information on the children's level of awareness about water, such as the water cycle, water related issues, such as water pollution and water conservation as well as about the Keoladeo National Park.

Out of 1,000 respondents from 50 villages, 112 were directly rejected due to several reasons (such as blank sheets, unclear, etc.). Three main populous villages Uchchain, Pichoona and Kurka contributed to approx. 57% of the responses. Most interestingly only 3 children of the target age group were found not taking formal education, so the section on 'children with no formal education' was left in analysis. Male proportion was 58.33% in the selected response. Class 6^{th} standard students contributed 36.37% whereas class 7^{th} contributed highest with 42.23% and class 8^{th} contributed lowest 3.15% out of the total correct responses. 56.64% respondents were classified in Category II, *i.e.*, children with average awareness whereas 37.17% respondents were classified in Category III (unaware). Only 4.50% respondents were categorized in I Category. The responses showed that students have only the basic information but lack the knowledge about KNP.

Thus, this led to the conclusion that there should be a program for children around KNP to provide the information on the major aspects of water pollution, water cycle, water conservation and the KNP.