JOURNAL
OF THE
BOMBAY NATURAL HISTORY SOCIETY

December 1999 Vol. 96 No. 3

STATUS OF VULTURES IN KEOLADEO NATIONAL PARK, BHARATPUR, RAJASTHAN, WITH SPECIAL REFERENCE TO POPULATION CRASH IN *GYPS* SPECIES[1]

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(*With six text-figures*)

Key words: white-backed vulture, long-billed vulture, king vulture, population crash, stable population, pesticide contamination, captive breeding

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 bigeographical 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% was recorded in the population of white-backed vulture and 97 % in long-billed vulture. The population of 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 likely causes of population decline. Detailed investigation for the cause of population decline, 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-backed vulture from imminent extinction.

INTRODUCTION

Eight species of vultures are reported from the Indian subcontinent (Ali and Ripley 1983) of which seven species are recorded from Keoladeo National Park, Bharatpur, Rajasthan (Samant *et al.* 1995). Only the bearded vulture *Gypaetus barbatus*, which is a typical mountain species, is not recorded from the Park. Four species are residents and three altitudinal migrants in the Park. The residents are the white-backed vulture *Gyps bengalensis*, long-billed vulture *G. indicus*, Egyptian vulture *Neophron percnopterus*, and king vulture *Sarcogyps calvus*. The Indian griffon *Gyps fulvus*, Himalayan griffon *G. himalayensis*, and cinereous vulture *Aegypius monachus* are altitudinal migrants.

The white-backed, king and Egyptian vultures regularly nest in the Park, whereas the long-billed nests at the nearest cliffs about 50 km

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southwest of the Park. The Indian and Himalayan griffons are uncommon winter visitors, seen in the Park from November to March. The cinereous vulture is seen occasionally, in winter.

All the species are scavengers and feed on the carcasses of large mammals, both domestic and wild. All the griffon vultures (*Gyps* species) are communal feeders and are seen in huge numbers on large animal carcasses (Ali and Ripley 1983). They are known to occur and breed in very high density near cities: a breeding density of 2.7 pairs per sq. km was recorded for the white-backed vulture in New Delhi (Galushin 1971). Prakash (1989) recorded a breeding density of 17 pairs per sq. km in Keoladeo National Park. The Egyptian and king vultures are usually solitary feeders, and feed on carcasses of smaller mammals, reptiles and fish.

The population of vultures was very high in India because of the unnatural food supply created largely by primitive methods of carcass and slaughterhouse waste disposal (Grubh 1989).

The Park falls in the semi-arid biogeographical zone (Rodgers and Panwar 1988). The vegetation of the area is a mixture of xerophytic and semi-xerophytic species consisting predominantly of *Acacia nilotica, Prosopis cinerea, Salvadora oleoides, Capparis decidua* and *C. sepiaria* (Prasad *et al.* 1996). According to Champion (1968) the vegetation of the Park can be described as Tropical Thorn Forest. This type of forest occupies a large part of western India which is not actual desert, western Punjab, Rajasthan, Kutch and Saurashtra, and a strip in southwest Madhya Pradesh running south to Bombay and east to Khandesh; Aurangabad south to northern Mysore and east to Guntur dist. in Andhra . This region has some of India's most productive agricultural areas, and a large proportion of the total livestock population. High concentrations of white-backed and long-billed vultures were seen in this area.

The land use pattern around the Park and the general landscape including vegetation type and structure represents the typical semi-arid agrarian ecosystem of the country. The Park could be considered broadly representative of semi-arid region. Hence, we could expect population trend of the white-backed vulture and long-billed vulture to be similar in most parts of the country to that of the Park.

Study Area

The Keoladeo National Park is situated at 27° 7.6'-27° 12.2' N lat. and 77° 29.5'-77° 33.9' E long., 2 km southeast of Bharatpur city and 180 km south of Delhi. It covers about 29 sq. km of flattish terrain sloping to a slight depression of about 8.5 sq. km in the centre. This forms the main submersible area of the Park and has been divided into several unequal compartments by dykes (Ali and Vijayan 1986). The Park gets water from an inundation reservoir situated about 500 m from the Park during June-July. Most of the waterspread areas dry up by March-April and the water remains in a few perennial water bodies. The inundation reservoir turns into an agricultural field after the water is released in the Park and for irrigation.

The average elevation of the area is 174 m. Extremes of climate are experienced with temperature varying between 1°C and 50°C. Apart from the wetland, the Park has *ca* 20 sq. km of woodlands, savanna-type grasslands and savanna with thickets. In some of the compartments, the marshes have scattered mounds planted with *Acacia nilotica*, and are also bordered with the same species, other tree species are *Mitragyna parvifolia*, *Sizygium cumini* and *Prosopis spicigera*. Agricultural fields of about 14 villages surround the Park. The major crops are mustard *Brassica campestris* and wheat *Triticum aestivum*. Pesticides are extensively used in the fields northeast of the Park in the water scarcity areas as they can become infested with white ants.

Study Period

The work was carried out as part of a Ph. D. programme during 1985-88, part of the project Ecology and Status of Resident Raptors in India, during 1990-92 and as a part of the ongoing project on the Effect of Environmental Contamination on Raptors during 1996-99.

Method

Population and Distribution of Vultures

The following standard methods (Fuller and Mosher 1981) were followed for estimating the population of vultures in the Park.

1. Road Transect Method

Roads and bunds were taken as transects and the birds were counted by driving slowly along the transect in the Park. An absolute count was attempted for all the species except for the white-backed and long-billed vultures. Their population was estimated during 1985-86 and 1986-87 as their number was very large and it was difficult to actually count all the birds. However, during rest of the years, the actual number was counted. All the sighting locations were marked on a map.

2. Nest Census

Nest searches were conducted once in a month throughout the Park for various species of vultures. The total count of the nests of white-backed vultures was carried out during February and March, when maximum nests are encountered.

3. Count at Carcasses

The number of vultures at large mammal carcasses was estimated whenever a carcass was observed.

Results and Discussion

1. **White-backed Vulture *Gyps bengalensis*:**
Population and Distribution

The white-backed vulture is a resident of the Park and is sighted throughout the year. The population is usually low from June to September when most of the Park gets flooded, and there is hardly any habitat left for foraging. Its population gradually builds up, with the initiation of the breeding season in September when the pairs start occupying their old nests, and reaches a peak during March and April when the nestlings fledge and there is also an influx of birds from outside the Park. Food is available in abundance during this period as apart from the usual mortality of frail and old cows abandoned in the Park by villagers, a number of domestic cows perish on getting caught in the wet mud of the drying marshes, when they come to drink water.

A 96% decline in the maximum population was observed over the last one decade. During 1985-86 the highest population of 1800 vultures (density=62/sq. km) was recorded, whereas maximum of only 86 vultures were recorded during 1998-99 (density=3/sq. km) (Fig. 1).

The nesting population of the white-backed vulture also crashed by 95% over a decade. For instance, 353 pairs (nest density=12.17 nest / sq. km) were recorded nesting during 1987-88 but only 150 nests were recorded during 1996-97, 25 nests during 1997-98 and just twenty 20 (nest density= 0.68 nest/ sq. km) in 1998-99 (Fig 2).

During 1987-88, these vultures were observed throughout the Park, but they were seen only on the trees near the wetland in 1998-99.

Nesting Success

A sharp decline in the nesting success of the vulture was recorded over a decade. The nesting success was recorded as 82% (n=244) in 1985-86, but it was nil during 1997-98 (n=25) and 1998-99 (n=20).

During 1997-98, 60% of the nests were lost during nestling period (n=15), 20% were lost during incubation and in 20% nests (n=5) the birds failed to lay. During 1998-99, the birds did not lay in 60% (n=12) nests, nestlings died in 30% nests (n=6), and there was incubation failure in 10% (n=2) nests.

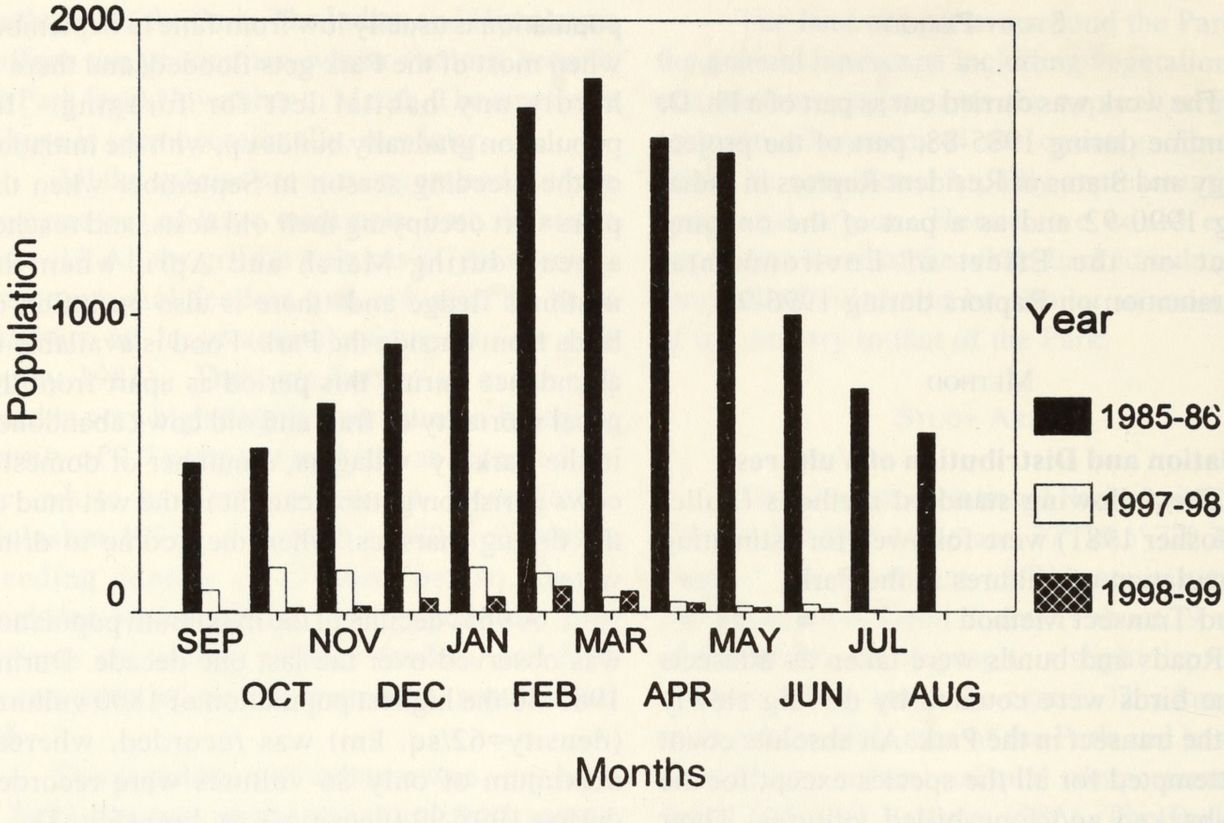

Fig. 1: Population of White-backed Vulture in KNP during various years

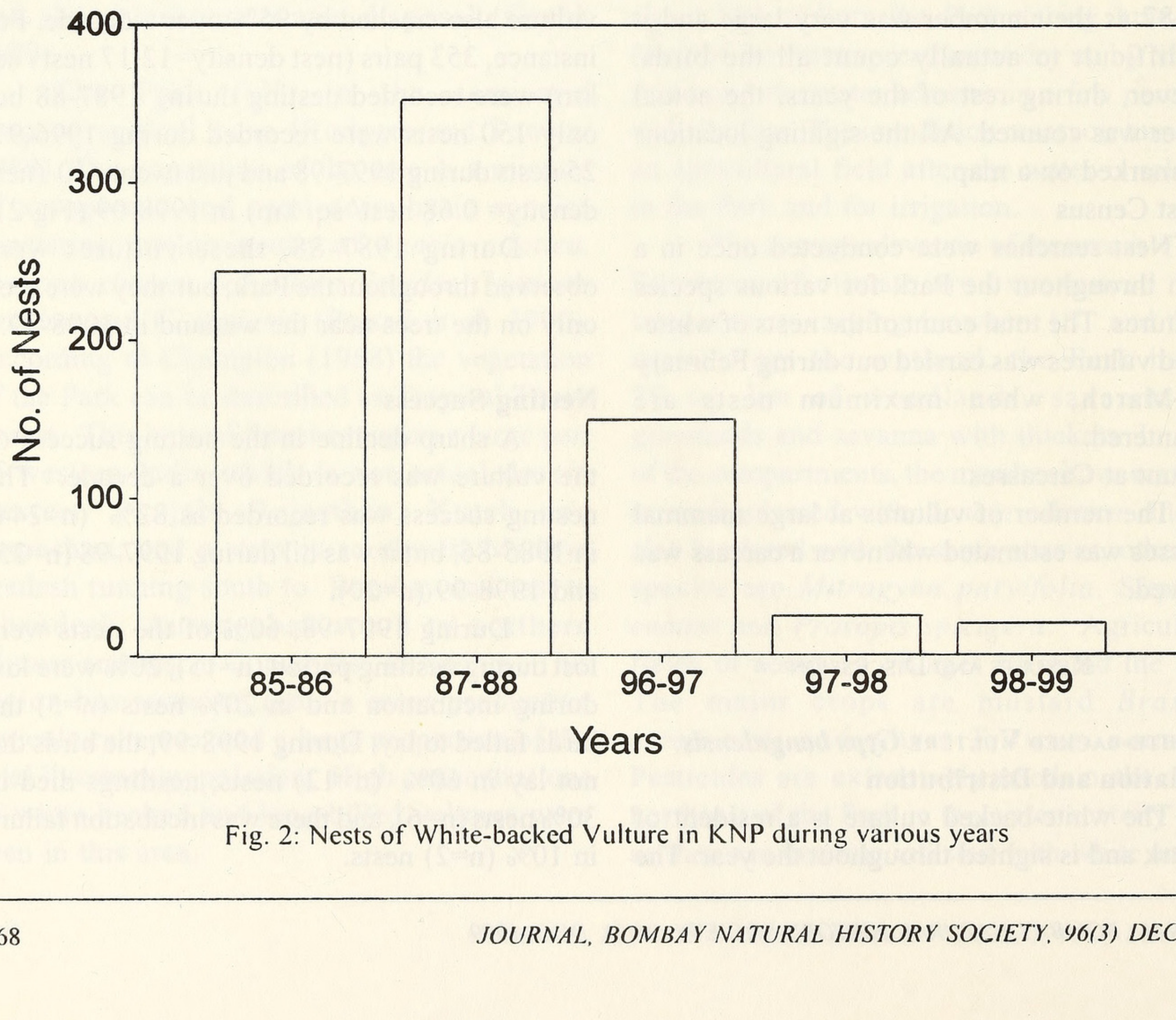

Fig. 2: Nests of White-backed Vulture in KNP during various years

Mortality

It is usually difficult to locate dead vultures, as they often die on large trees and quite often in secluded areas. Their carcasses are frequently seen entangled in the branches of trees or in thickets below the trees. Jackals also feed on the vulture carcasses. So, though vultures are big birds, their carcasses largely go unnoticed.

The birds were usually found dead on the nest, on trees or on the ground below the trees. Sporadic deaths were observed. Prior to death, individual vultures were seen perched on trees, dozing, with the neck slowly slumping down. They would wake up with a start, when the beak hit the branch. The bird usually remained in this condition for more than 30 days (n=5) and then would fall off the branch, sometimes getting caught in the branches of the trees and at times falling on the ground. The birds would die within minutes of falling down. The number of dead vultures must be far more than were recorded, due to various constraints.

High adult as well as juvenile mortality was recorded during 1997-98 and 1998-99, compared to 1985-86. Only 0.4 % mortality of total adult population (n=1800) was recorded during 1985-86, whereas it was as high as 1.5% of the total adult population (n=86) during 1998-99.

TABLE 1
MORTALITY IN WHITE-BACKED VULTURE RECORDED IN DIFFERENT YEARS

Year	Adult	Juvenile	Total No. of Nesting Pairs Recorded
1985-86	7	7	244
1987-88	10	1	353
1997-98	73	10	25
1998-99	9	6	20

2. LONG-BILLED VULTURE ***Gyps indicus***:

It is a resident and nests about 50 km southwest of the Park. It does not breed in the Park due to paucity of its nesting habitat, i.e. cliffs (Ali and Ripley 1983). The birds are,

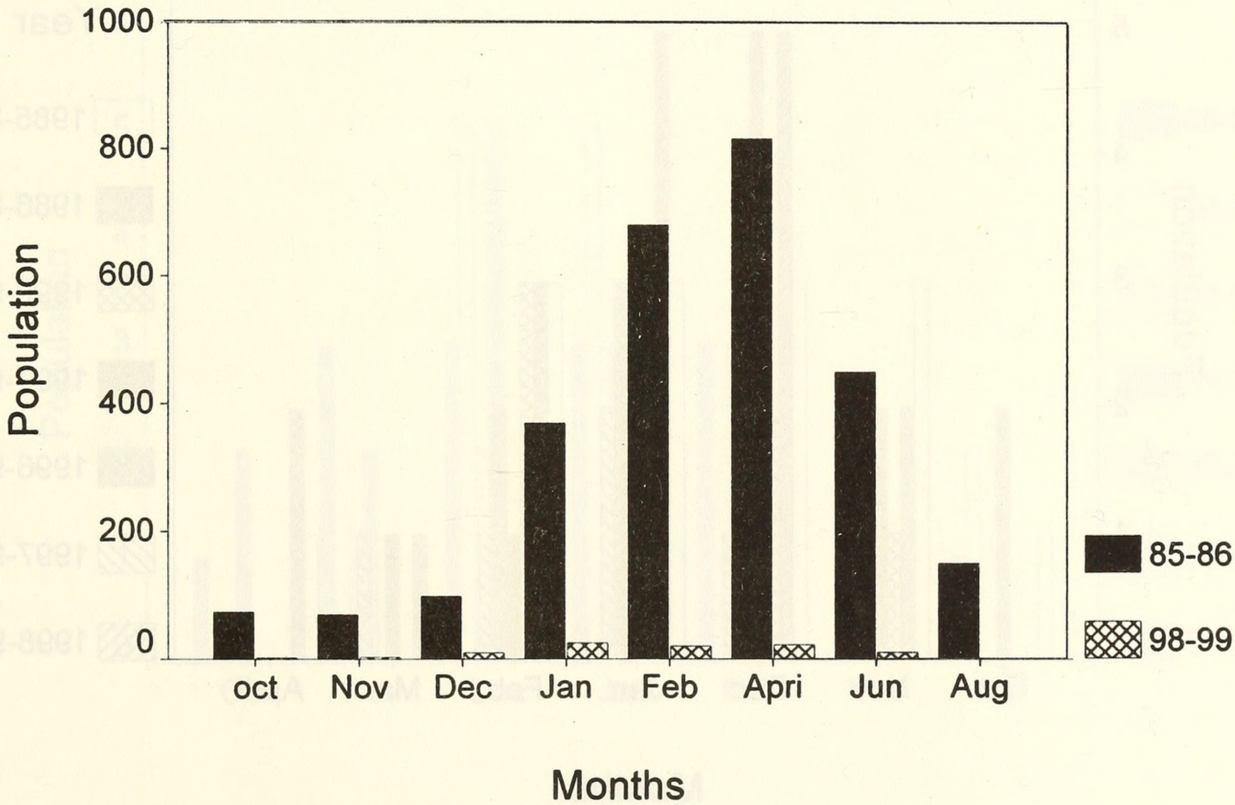

Fig. 3: Population of Long-billed Vulture in KNP during various years

however, seen in the Park throughout the year. Their number starts building up from November and the population reaches a peak in March-April.

The population of the long-billed declined by over 97% over a decade. A maximum of 816 birds (density=28 birds/sq. km) were recorded during 1985-86 but only 25 birds (0.86 birds/sq. km) were recorded in 1998-99 (Fig. 3).

During 1985-86, on an average 80 vultures were sighted on a cattle carcass (n=13) of which 69% (n=79) were white-backed and 31% were long-billed. None of the carcasses were observed without vultures. However, during 1998-99, a total of 100 carcasses were sighted from November till May, but 92% were without any vulture and only eight (8%) had vultures feeding on them. On an average, 19 vultures were sighted on a carcass (n=8), of which 63% (n=12) were white-backed vultures and 37% (n=7) were long-billed vultures.

It appears that both the species have shown a drastic decline, but it is more pronounced in the white-backed vulture.

3. Indian Griffon ***Gyps fulvus***:

It is a winter migrant to the Park. 25-30 birds were observed wintering in the Park every year (Fig. 4). The population has shown a downward trend over the last decade. Only two birds were observed during 1997-98 and none during 1998-99. Despite the availability of food and much reduced competition from congenerics, the population of this species did not increase, but showed a drastic decline. Although the griffon is known to winter at a number of places in the Indian subcontinent, the drastic decline in population when food and habitat is available in abundance, could indicate a decline in its overall population.

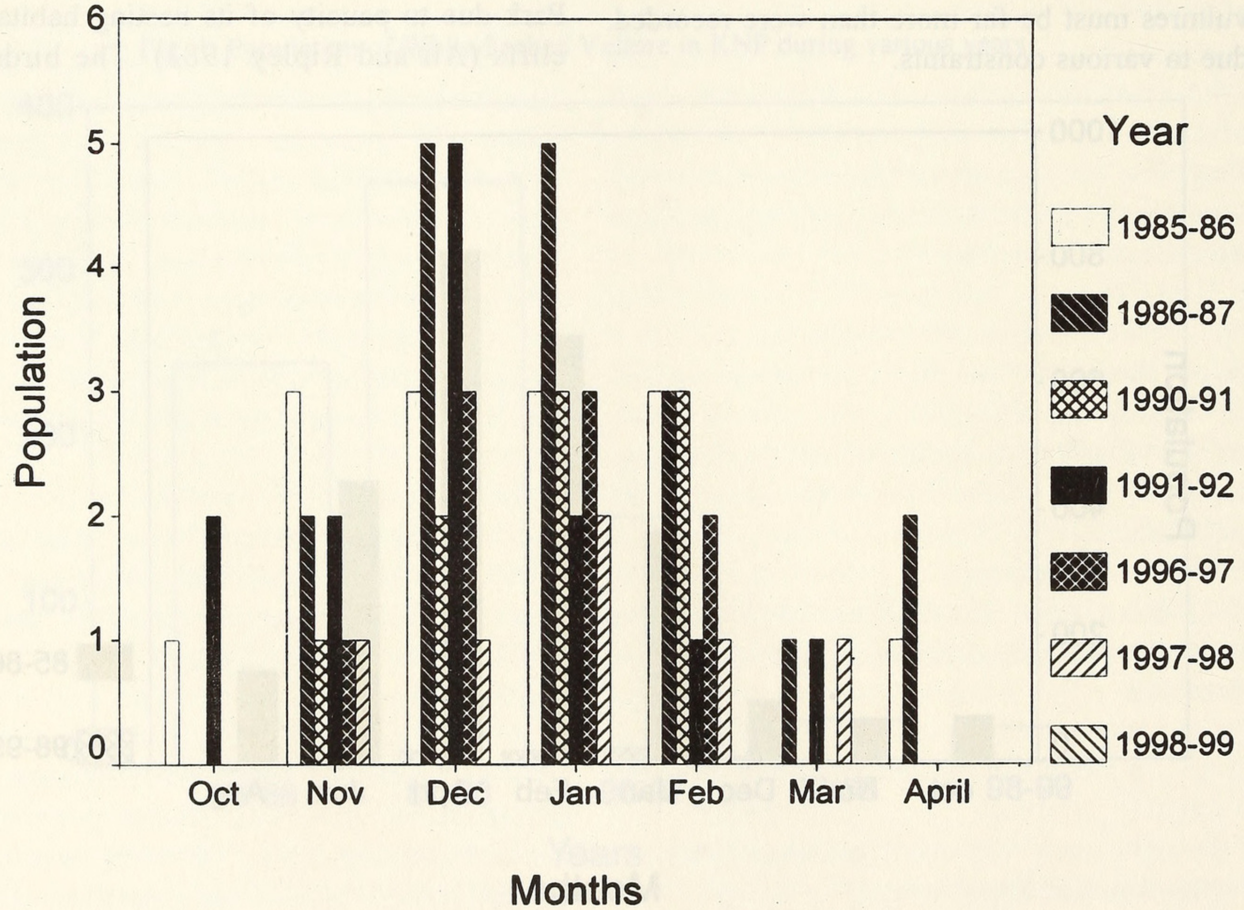

Fig. 4: Population of Indian Griffon in KNP

4. Himalayan Griffon *Gyps himalayensis*:

It is an uncommon winter migrant to the Park. A few juveniles regularly wintered in the Park since 1985-86 (Fig. 5). No bird has been seen since 1996-97. The absence of the species from the Park, despite availability of food and habitat and near absence of competition for food from the congenerics, possibly indicates decline in the population of the species. A survey of the species in its known range will give a better overall picture.

5. Egyptian Vulture *Neophron percnopterus*:

The population of Egyptian vultures fluctuated throughout the year in the Park. The highest population of vultures was seen during the months of April and May, when the water dried up and the birds came to feed on dying fish and turtle.

The breeding population of these birds has remained stable in the Park over the last ten years. Up to five pairs were recorded nesting during 1987-88, 90-91, 96-97 and 98-99. The vulture is largely a cliff nester and occasionally nests on trees. Absence of its preferred nesting habitat could be a limiting factor for its nesting population in the Park.

The population of the Egyptian vulture has also shown a decline, although there is very limited data on the population. Between 350 to 400 vultures were estimated during April 1986, whereas only 100-120 vultures were recorded during April 1998 and 25 vultures during April 1999. Their fall in number could be largely because of difference in food availability. Their number increases due to the drying up of water, as they come to feed on dead fish. However, the low breeding success of the bird is a cause of concern. Breeding has been nil during 1996-97 and 1997-98, while 50% success was recorded between 1985 and 1988. However, during 1998-99, 70% success was recorded.

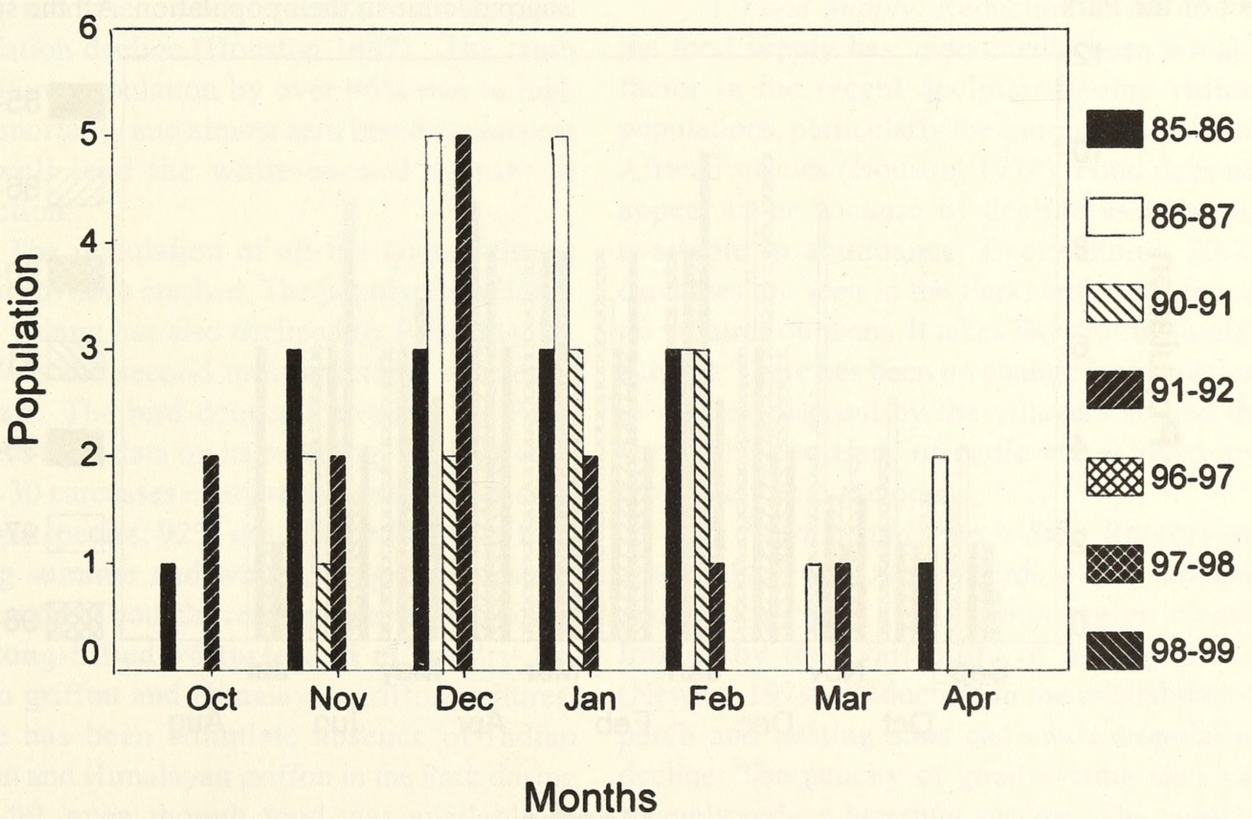

Fig. 5: Population of Himalayan Griffon in KNP in various years

TABLE 2
NESTING PAIRS OF EGYPTIAN VULTURE IN KEOLADEO NATIONAL PARK DURING VARIOUS YEARS

Year	No. of Nests	Nesting Success
1985-86	5	50 %
1986-87	5	50 %
1987-88	5	50 %
1990-91	2	No data
1996-97	3	0
1997-98	3	0
1998-99	3	70%

6. **King Vulture *Sarcogyps calvus*:**

This is a resident species, seen in the Park throughout the year. Most of the adults and the fledged birds move out of the Park during the monsoon (July to September). The population starts building up and becomes highest in December-January. A fairly stable population of this species is seen in the Park. Over the last decade 4-5 pairs were observed (Fig. 6), and 3-4 pairs nest regularly (Table 3). Very few first year birds are sighted: perhaps all the young disperse out of the Park.

The nesting success has been erratic, but has been recorded low since 1991.

TABLE 3
NESTING PAIRS OF KING VULTURE IN KEOLADEO NATIONAL PARK

Year	No. of Nests	Ave. Clutch size	Nesting success
1985-86	3	1.33	0
1986-87	2	1	100 %
1987-88	3	1	100 %
1990-91	3	1	33.33 %
1996-97	4	1	Nil
1997-98	5	1	40 %
1998-99	3	1	100 %

7. **Cinereous Vulture *Aegypius calvus*:**

It is a rare winter visitor to the Park. Three birds were recorded during 1991-92 and were seen throughout the winter. The bird is a common visitor to western Rajasthan in the desert areas.

Observations and Discussion

Population Crash in *Gyps* species

All species of *Gyps* vultures have shown a sharp decline in their population. All the species

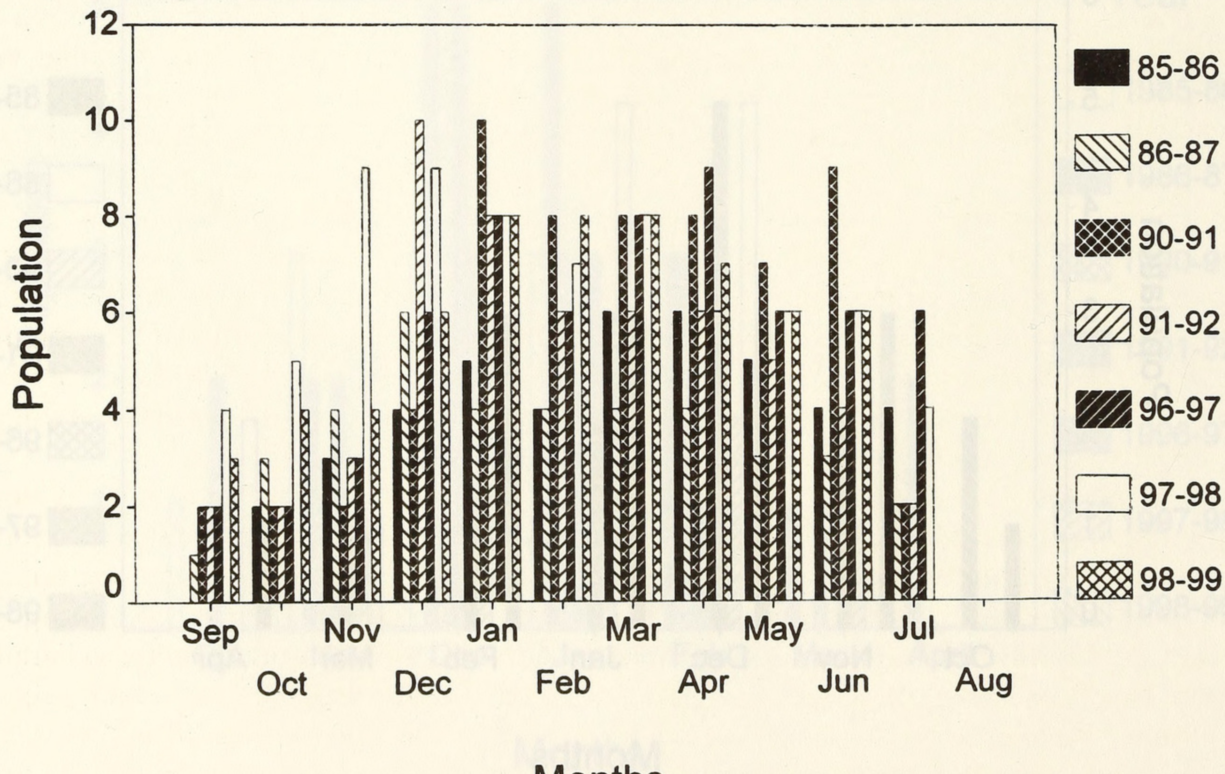

Fig. 6: Population of King Vulture in KNP during various years

are communal feeders and are known to feed on the carcasses of the larger mammals.

There has been a very steep decline in the population of white-backed and long-billed vultures. The population of white-backed has declined by 96% and that of long-billed vulture by 97% over a decade in the Park. (Figs. 1 & 3). High adult mortality (Table 1) and total breeding failure have caused the population decline.

Vultures are long-lived birds and together with the albatross have the lowest reproductive rate of any bird species in the world (Lack 1968). It follows that their mortality rates must be among the lowest of any bird species. The studies on large tropical seabirds suggest that the adult survival rates of 95 to 97% may not be uncommon (Houston 1979). If adult mortality becomes heavier the birds cannot compensate by increasing their rate of reproduction, and the species slowly declines to extinction. Computer models show that for vulture populations it takes only a relatively small annual increase in adult mortality to lead to rapid population decline (Houston 1987). The crash in vulture population by over 96% due to high adult mortality and almost zero breeding success can well lead the white-backed vulture to extinction.

The population of all the *Gyps* vultures appears to have crashed. The population of long-billed vulture has also declined by 97% (Fig. 3). This was the second most abundant species in the Park. The bird does not breed in the Park, so there is no data on its breeding. The presence of 25-30 carcasses every month and the absence of *Gyps* species, 92% of the time (n=100), both during summer and winter, suggest a crash in population of both the residents i.e. white-backed and long-billed vultures and migratory i.e. Indian griffon and Himalayan griffon vultures. There has been complete absence of Indian griffon and Himalayan griffon in the Park during 1998-99, even though food was available in abundance. The Himalayan griffon was also not seen during 1997-98.

The breeding population of the king and Egyptian vultures has remained fairly stable over the years. This appears to be the normal situation elsewhere, with the population of large and long lived raptors (Newton 1979). Large birds, especially raptors, have greater immunity from predation and an increased ability to survive temporary food shortages. The larger the bird, the more consistently is its population likely to remain close to the level that the environment will support (Newton 1979). The stability of the population does indicate stable ecological conditions for the species. Incidentally, both the king and Egyptian vultures feed more on smaller carcasses and occasionally on large mammal carcasses. They usually remain either solitary or in pairs. They are seldom seen feeding in flocks.

To investigate the major causes of decline in the population of *Gyps* vultures, the ecological factors, which could have caused major changes in the population, were examined:

1. *Food Supply*: Reduction in the size of the food supply has undoubtedly been a major factor in the recent decline of some vulture populations, particularly the European and South African species (Houston 1974). Food does not appear to be a cause of decline as it is still available in abundance. Every month 20-25 carcasses are seen in the Park, with very few or no vultures on them. It takes days to finish off a carcass. There has been no change in the method of carcass disposal by the villagers around the Park. The carcasses of cattle are skinned and thrown out into the open.

2. *Nesting and Perch Site*: Raptors are among the few groups of birds whose numbers and nest success are in some region clearly limited by the availability of nesting places (Newton 1979). Reduction in the availability of perch and nesting sites can cause population decline. The paucity of good nesting sites can severely reduce breeding success. The vultures are big birds, which weigh about 4-5 kg and hence need big and strong trees for nesting. There

has been a general decline in the number of old and mature trees, but not so severe as to cause a crash in vulture population. Although we do not have hard data on the nesting tree availability, there has been no marked decline in number of big trees for nesting. Anyway, it cannot lead to the steep decline seen in white-backed vultures.

3. *Effect of Pesticides and Insecticides*: The sharp fall in raptor population with the increase in the use of pesticide is well known (Ratcliff 1967, Hickey and Anderson 1968, Hickey 1969). Persistent, high fat solubility and sub lethal effects are the main qualities, which lead organochlorine pesticides to cause decline in bird population. Predators and scavengers at the top of the food chain are among the most affected species (Newton 1984) as they are especially liable to accumulate organochlorines in large amounts. At sublethal levels of only a few ppm in tissues, organochlorines can disrupt the breeding of certain birds (Newton 1984).

In India, organochlorine pesticides are extensively used in agriculture. This group includes DDT and cyclodienes such as aldrin, dieldrin, endrin and endosulphan. A survey of pesticide use around the Keoladeo National Park revealed extensive use of organochlorine compounds including aldrin, dieldrin, endosulfan and heptachlor. The use of aldrin has become very restricted as it is banned and is not available in the market. DDT, which has been banned for use in agriculture, is still extensively applied after being diverted from the National Malaria Control Programme. Lethal levels of DDE, aldrin and dieldrin were detected in the tissues of sarus crane *Grus antigone* and ring dove *Streptopelia decaocto*, but negligible levels were found in greylag geese *Anser anser* in Keoladeo National Park (Vijayan 1991). DDE, the main metabolite of DDT, causes shell thinning and egg breakage as well as embryo death in intact eggs. Different species of raptors show little variation in their response to DDE, but raptors in general are more sensitive to a given level of DDE than birds in other families. Aldrin and dieldrin are more toxic than DDT, and cause mortality of both adults and embryo. Increased mortality led to very rapid population declines of sparrowhawk *Accipiter nisus* and peregrines *Falco peregrinus* in Britain (Newton 1979).

Circumstantial evidence suggests that the population decline in vultures could have been caused by the lethal and sublethal intake of pesticide through food. The vulture population has shown symptoms of pesticide contamination like breeding failure due to non-hatching, breaking of eggs in the nest, failure to lay and death of nestlings. High adult mortality is also recorded.

It is, however, not clear how vultures ingest such a high dose of pesticide, which causes direct mortality and total breeding failure. The white-backed and long-billed vultures feed mainly on the carcasses of large mammals. Among the raptors in any given area, mammal eaters invariably contained lower organochlorine levels than bird eaters or fish eaters (Conrd 1977, Henry 1977, Newton 1979). In addition, mammals in general are better able to metabolise organochlorines than are birds. Birds and fish have higher levels of contamination than herbivorous mammals (Cooke 1973, Stickel 1975). There was less concern for raptors or avian scavengers which feed mainly on mammals, since it was presumed that they would not accumulate as high a body burden of organochlorine (Lockie *et al.* 1969).

There has been no noticeable decline in the breeding success of fish eating birds or their population in the Park. The population of other raptors including vultures other than *Gyps* species, which largely feed on fish, amphibians and reptiles, has also not shown any drastic decline. As should be expected, based on the studies carried out elsewhere (e.g. Cooke 1973, Conrd 1977), fish eaters and bird eaters should get affected earlier than the raptors feeding on mammals. It may be that vultures metabolise pesticides differently than other groups of birds, resulting in greater concentration. The Andean condors *Vultur gryphus* collected in Peru had much higher concentration of chlorinated hydrocarbons than other local species including the brown pelican *Pelecanus occidentalis*, which is known to concentrate pesticide. In contrast, golden eagles, with a food source similar to condors, have shown no significant eggshell thinning (Hickey and Anderson 1968) or bodily concentration of pesticides (Reichel *et al.* 1969). Due to a different metabolism, the vulture accumulates pesticides faster than other species (Snyder 1986). *Gyps* vultures could also have accumulated pesticide faster than other bird species in a similar process. High residual level of DDE was detected in the eggs of California condor *Gymnogyps californianus* (Jarman and Risebrough 1986), Eurasian griffon (Mendelssohn 1972), and cape vulture *Gyps coprotheres* (Wyk *et al.* 1993) but the source of DDT is still not confirmed (Kiff 1989). All three species also scavenge mammalian carcasses like the white-backed vulture. The few vulture tissue samples from the Park analysed so far have, however, not shown any significant load of pesticide. (Bhagwat, A.M., C. B. Patel Institute, Vile Parle, Mumbai, pers. comm. 1999).

Breeding failure could be due to organochlorine contamination in the tissue, but the cause of adult mortality is still not clear. There have been no observations of large-scale deaths of vultures after feeding on a carcass. Mortality has been sporadic and widespread.

4. *Poisoning*: Vultures are far more susceptible to poisoning than any other bird of prey, for the obvious reason that they may not be able to distinguish a dead animal that contains poison (Houston 1987).

Carcass poisoning in and around the Park was not observed. No large-scale mortality has been observed in vultures after consuming meat from the carcass. There have been instances of village cows dying after deliberately being fed on rodenticide zinc phosphide by hide collectors. No mortality was seen after vultures fed on the poisoned carcasses. Thus poisoning does not seem to be a major cause of decline in vulture population. Strychnine poisoning of carcasses by farmers was identified as a major cause of population decline of Cape vulture (Dobbs and Benson 1984). There have been reports of deliberate poisoning of carcasses to kill wild animals such as jackal *Canis aureus*, wolf *Canis lupus*, leopard *Panthera pardus*, tiger *Panthera tigris* and lion *Panthera leo*, whenever these animals are suspected to have attacked the cattle and sheep in different parts of the country. Mortality of vultures after feeding on poisoned carcasses has been reported (Grubh 1974). Such incidents are few and far between and cannot be the cause of population crash in vultures.

5. *Changes in Genetic Diversity of the Population*: All biologically important characteristics of populations including their size and reproductive efficiency are determined by historically established gene pool (Wyk *et al.* 1993). Depression of fitness traits, such as survival and fecundity, which are components determining breeding success may be associated with low levels of heterozygosity (Leberg 1990). Fluctuation in the size of breeding populations can be accompanied by a reduction in the genetic variability (Eitniear 1989) which in turn reduces the ability of a species to adapt to environmental changes (Meffe 1990). In the current situation, the lack of genetic heterozygosity could be indicative of the abovementioned negative factors for white-backed vulture. Low levels of genetic variability were reported in *Gyps coprotheres* in South Africa and this was considered to be a major reason for the drastic population decline in the once abundant *G. coprotheres* in South Africa (e.g. Wyk *et. al.* 1993). No studies have been carried out on the *Gyps* species on genetic variability in India. Low level of genetic variability, coupled with some other factors, could be a cause of population decline.

6. *Outbreak of Disease*: According to Newton (1979) disease plays an insignificant role in the control of raptor populations, and accounts for only a small part of the total mortality. However, disease is not rare in raptors and has caused mortality. The typical symptoms displayed by birds suffering from pesticide contamination like increased aggression, reduced discriminatory behaviour and alertness, poor incubation and reduced territorial activity were not evident in the sick vultures in the Park. Vultures also have unusual resistance against disease (Kalmbach 1939, Singh, R. B. pers. comm.) There is still a possibility of a viral disease, which has probably caused the widespread mortality in the adults and juveniles. The birds appear sick before they die. They perch on a branch, appear drowsy and frequently doze off with the neck limp and hanging. The vulture wakes up with a start and pulls up the neck. After a while, the neck becomes limp again, and the same sequence is repeated. The bird remains at the same place for about 32 days (n=5) and then falls on the ground and dies. They can fly short distances while they are sick.

7. *Calcium Deficiency*: Calcium deficiency is thought to cause problem in the chick skeleton development and causes chick mortality. Evans and Piper (1981) estimated that approximately 20 % of all cape vulture chicks were affected by nutritional bone disease. The authors postulated that the necessary calcium for chick development was inadequate and directly related to the declining population of bone crunching hyenas (Mundy and Piper 979). The population of hyenas has also declined with the spread of human population in India. Some chick mortality in the country could be due to calcium deficiency. But this needs to be investigated further. Dobbs and Benson (1984), however, found that bone abnormalities in growing cape vulture were not caused by inadequate calcium intake and the vulture gets adequate calcium from the food. So calcium may not be a cause of decline in vulture population.

Conclusions

There has been a crash in population of *Gyps* vultures in Keoladeo National Park over a decade. The white-backed vulture has suffered large-scale adult mortality and total breeding failure. The long-billed vulture has also suffered a population decline of over 97%. The Indian griffon and Himalayan griffon have also experienced drastic fall in numbers. The non-*Gyps* species of vultures have maintained fairly stable population over the years.

The exact cause of the population crash is not clear. Circumstantial evidence suggests pesticide contamination to be the major cause of decline. However, the high adult mortality could not be explained by pesticidal contamination alone. The decline in genetic variability could have made the vulture population susceptible to disease, which caused high adult mortality and breeding failure. Intensive efforts are required to determine the cause of decline in vulture and effective conservation measures should be taken to save the species from extinction.

Recommendations for saving *Gyps* species from imminent extinction

The population of white-backed vulture has declined because of adult mortality and almost total breeding failure. The population of other *Gyps* species vultures is feared to be facing a similar fate. There is no definite clue to the causes of adult mortality and total breeding failure. The following steps should be taken to save these vultures from imminent extinction:

i. Pilot survey of vulture populations all over the country especially in areas where data on vulture populations exists, to find out the extent of population decline.

ii. Tissue samples of vultures and their food should be analysed on a large scale in different parts of the country to estimate the load of organic pesticides, specially organochlorines in the tissues.

iii. Genetic studies should be initiated to see if there is decline in genetic diversity.

iv. Pathological studies should be initiated immediately to find out if any disease is responsible for the crash in vulture population.

v. Captive breeding programme should immediately be taken up to save the species from extinction. A 96% decline in population and total breeding failure can certainly cause extinction.

ACKNOWLEDGEMENTS

I thank the U. S. Fish and Wildlife Service for funding, Ministry of Environment and Forests, Govt. of India, for sponsoring the study and the Rajasthan forest department for permission to work in the Park. I am thankful to David Ferguson, SFC coordinator, U. S. Fish and Wildlife Service, William Clark, U. S. advisor to the projects, and Dr. V. S. Vijayan, Director, SACON, for help and guidance during the study. I thank Mr. J. C. Daniel, Honorary Secretary and Dr. A. R. Rahmani, Director, BNHS for encouragement and critical assessment of the paper. I thank Ms. Gargi, Research Fellow, BNHS for help in field and referencing. I had the excellent field assistance of Mr. Brijendra Singh, local assistant, BNHS.

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