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Population Collapses of Three Species of *Gyps* Vultures in the Indian Subcontinent: an overview

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ABSTRACT

The announcement at this conference by Lindsay Oaks and his colleagues that the non-steroidal anti-inflammatory drug diclofenac had been detected in tissues of White-backed Vultures *Gyps bengalensis* that had died with visceral gout in Pakistan has provided an explanation for the impending extinction in the wild of this and of two other species of vultures, the Long-billed Vulture *Gyps indicus* and the Slender-billed Vulture *Gyps tenuirostris*, over their respective ranges in the Indian Subcontinent. Only a decade ago they were among the most abundant bird species. Experimental demonstration that doses of diclofenac recommended for domestic livestock would induce visceral gout and rapid death of captive vultures, with histological lesions identical to those observed in birds that had died with visceral gout in the wild, further support the conclusion that the use in veterinary medicine of diclofenac, and probably also of related drugs, has caused the high rate of mortalities that has produced the population collapses of these species. Carcasses of domestic animals have traditionally been left to vultures for disposal; those of diseased animals that had been treated with diclofenac provide the route to vultures. Until now, only the appearance of a new disease factor could provide a plausible explanation for the mortalities that have been decimating the populations. Discovery of the cause, or of the principal cause, of the mortalities will not, however, assure the survival of any or all of the affected species. Populations continue to decline, but relatively few White-backed Vultures, very few Long-billed Vultures, and no Slender-billed Vultures are in captivity to ensure their long-term survival. Like diclofenac, related drugs that are possible substitutes for diclofenac cause kidney damage in mammals and are therefore likely also to cause kidney damage in vultures. A conservation effort must be anticipated of a magnitude even greater than that required to rescue Peregrine Falcons *Falco peregrinus*

from extinction in North America as a consequence of DDT use and of a magnitude approaching that required to rescue California Condors *Gyps californianus* from extinction as a consequence of lead poisoning.

THE BACKGROUND

Jerdon (1862) in *The Birds of India Being A Natural History of All The Birds Known to Inhabit Continental India* noted that the Asiatic White-backed Vulture or White-rumped Vulture *Gyps bengalensis* "is the most common vulture of India, and is found in immense numbers all over the country, extending into Assam and Burmha". Throughout the century that followed and continuing after Independence, the construction of slaughter houses and tanning factories and the expansion of carcass disposal areas provided additional sources of food; populations increased accordingly (Grubh & Vijayan 1999). Previously rare or absent in desert areas, their numbers increased when the construction of dams and canals in Rajasthan and Gujarat created populous villages with livestock and provided trees for nesting (Ali & Ripley 1978; Rahmani 1994, 1996). In neighbouring Pakistan, recent plantations of Sheesham *Dalbergia sissoo* and Kapok *Bombax ceiba* in irrigated areas provide nesting sites previously not available (A.A. Khan, pers. comm.). By the 1970s the total number of White-backed Vultures throughout the Subcontinent was therefore very likely substantially higher than the already "immense numbers" recorded a century earlier by Jerdon (1862); large flocks of vultures in the sky numbered into the thousands of birds. Today the White-backed Vultures are approaching extinction in the Indian Subcontinent, along with two other related species, the Long-billed Vulture *Gyps indicus* and the Slender-billed Vulture *Gyps tenuirostris*, unanticipated victims of a technology developed for the benefit of humans and their domestic livestock.

TWO CONFERENCES: MADISON, 1965, AND MUMBAI, 1999

In 1965, Professor Joseph Hickey of the University of Wisconsin convened a conference in Madison to examine the reasons for the disappearance of Peregrine Falcons *Falco peregrinus* as a breeding species in eastern North America (Hickey 1969). The previous year he had sent Daniel Berger and Charles Sindelar to survey 133 sites known to have had active peregrine eyries in the recent past in a total of 14 states and one Canadian province; all were deserted (Berger *et al.* 1969). Peregrine Falcons had become extinct as a breeding species in eastern North America without anyone knowing that such a process was underway.

Thirty-four years later, on 6 August 1999, Dr Asad Rahmani, Director of the Bombay Natural History Society (BNHS), convened a Vultures Conservation Strategy Planning Meeting in Mumbai, India, to address the population declines of White-backed and Long-billed Vultures. Beginning studies of the effects of contaminants on raptors in 1996 with the US Fish & Wildlife Service, Prakash (1999) had recorded 150 nests of White-backed Vultures in Keoladeo National Park, a reduction of 39% and 58% from 244 and 353 nests recorded in 1985-86 and in 1987-88 (Prakash 1988; Vijayan 1991). During the following 1997-98 season the number of active nests dropped to 25, with no

young produced. The population decline was associated with an unusual pattern of mortalities. Birds dropped dead from their roosts, frequently remaining suspended in the branches, or died on their perches or on their nests; fledglings also were found dead in the nests (Prakash 1999). Anecdotal reports of local disappearances of vultures began to circulate throughout India; in November 1998 Dr Rahmani issued a "Vulture Alert" and distributed questionnaires; among more than 50 responses from all over India, many documented the increasing scarcity of *Gyps* vultures in areas where they had been common only a few years earlier (A. Rahmani *in litt.* 1999). As earlier in Madison, the participants in the 1999 meeting in Mumbai discussed a broad range of possible causes of the catastrophe.

At both conferences 'pesticides' were proposed as causes of the respective population declines, without, however, speculating which pesticides or combinations of pesticides might be responsible, or whether the primary effect might be poisoning or a depression of reproduction. To explain the disappearance of peregrines, egg-collecting, the taking of birds for falconry, disturbance and several other possible factors were also proposed, but none of these could plausibly explain the disappearance of the entire population. The linking of reproductive failures of Peregrine Falcons with the DDT derivative DDE (dichlorodiphenyldichloroethylene) was to take four years of intensive research undertaken by numerous investigators at many institutions (Ratcliffe 1967; Hickey & Anderson 1968; Heath *et al.* 1969; Cade *et al.* 1971; Hickey 1988, and many others). In Mumbai, shortages of food and of nesting sites, the appearance of a new disease factor, the poisoning of carcasses to kill predators or scavengers, and programmes to reduce vulture numbers in the vicinity of airports were proposed as possible explanations for the decline of vulture populations. It also took four years of intensive efforts to determine the true cause of a novel process of extinction.

In this overview, prepared a full ten months after the conference, I review the sequence of principal events leading up to the WWGBP conference in Budapest and discuss the causes that were proposed at the Mumbai workshop to explain them. Later developments are not reviewed, except those that confirm the validity of what is referred to as the NSAID (non-steroidal anti-inflammatory drug) hypothesis rather than the 'diclofenac hypothesis', for reasons to be presented.

TAXONOMY

The Long-billed Vulture *Gyps indicus* was treated as a single species throughout the twentieth century. Previously, however, it had been considered to be two species. Murray (1888) in *The Avifauna of British India and Its Dependencies* listed the range of *Gyps indicus*, the Long-billed Vulture, as the "Indian Peninsula, Burmha, Nepal, Siam and the Malayan Peninsula" and the range of *G. pallescens*, the Long-billed Pale Brown Vulture, as Central India, westwards to Sind in present-day Pakistan.

In this paper, the Long-billed Vultures are considered as two separate species, *Gyps indicus* and *Gyps tenuirostris*, on the basis of recent studies by Rasmussen & Parry (2001), who documented over 50 consistent character-state

differences between them. The species referred to here as the Long-billed Vulture *Gyps indicus* occurs in Peninsular India and south-eastern Pakistan, nesting primarily on cliffs (Ali & Ripley 1978; Roberts 1991); the Slender-billed Vulture *Gyps tenuirostris* occurs in northern India on the "Gangetic Plain north to and along the lower Himalayas from Kashmir through Nepal, Bengal and Assam to Burma, Malay Peninsula and Indochinese countries", and nests primarily in trees (Ali & Ripley 1978; Birdlife International 2001). The name *Gyps indicus* has therefore been used for both species. Pending a definitive taxonomic study, the use of these names in this paper is conditional, particularly since the name *Vultur indicus* Scopoli 1786 is a *nomen dubium* (Rasmussen & Parry 2001).

TIMING AND PATTERNS OF THE POPULATION DECLINES

The disappearance of a local population of White-backed Vultures was first documented by Davidar & Davidar (2002) in the Sigur region of the Nilgiri highlands in southern India. A population of 200-300 birds disappeared by 1987, after which there have been only rare sightings of a very few birds in the late 1990s and in 2001. After the 1970s there were no nestings in an area that previously had at least ten nests each year; up to 50 vultures were observed at tiger *Panthera tigris* and leopard *Panthera pardus* kills through the 1970s, but none thereafter. The application of poison to carcasses to kill predators preying on livestock caused the deaths of a number of vultures in the area as well as the temporary extirpation of tigers, whose numbers have since recovered.

White-backed Vultures had traditionally been residents of the city of Mumbai (formerly Bombay); a flock of several hundreds had participated in the disposal of human bodies in the Towers of Silence maintained by the Parsi community (Tappan 1914). By the early 1990s the number of vultures visiting the Towers had significantly declined and was no longer sufficient to dispose of the available food; by the end of the decade only 2-3 birds were sporadically observed over the Towers (R. Naoroji, pers. comm. 2002).

In September 1994, two years before Dr Prakash resumed his studies of raptorial birds in Keoladeo National Park, Dr M. Gilbert (pers. comm.) found a freshly-dead White-backed Vulture on a trail in the Park that he had traversed an hour previously; the body condition was good and there were no signs of trauma. No White-backed Vultures nested in KNP in the 1999-2000 season, the first time there was no nesting in the park in historical times (Rahmani & Prakash 2000). During a visit in January 2001 no *Gyps* vultures were recorded (Ouweneel 2001).

Since at least the late 1990s, there has been a consistent and continuing downward trend in numbers over the Subcontinent with no indication of a levelling off. Censuses in Rajasthan in early 2000 and repeated in December 2002 recorded a 50% decrease, from 8.8 to 4.3 in the average number of vultures counted per person/group dedicated to counting vultures on a specified day (no. of persons/groups 2005, 1044 respectively; Vardhan *et al.* 2000, 2004). Grubh and Vijayan (1999) surveyed in August 1999 a site of previous studies in the Gir Forest (Grubh 1974) and areas of northern and north-western India where a 7-year bird-strike hazard study had been conducted in the 1980s

(Ali & Grubh 1980, 1984; Grubh & Ali 1984; Grubh 1989). No vultures had visited a site used for dumping slaughter-house wastes in the Delhi area over the previous two years, but had frequented the area in thousands in former times. No vultures were seen at the carcass dumping location in Haryana where 100s were formerly present, nor at the Agra public slaughterhouse site where there had been thousands. About 550 White-backed Vultures, however, were present at a public carcass dump in Gujarat. There "were satisfactory numbers of vultures in some parts of Gujarat that we visited, including the Gir forest" (Grubh & Vijayan 1999).

In 16-19 June 2000, however, a survey undertaken by the Bombay Natural History Society found no *Gyps* vultures in the Gir forest and, in adjacent areas of Gujarat, a road survey of over 1,000km found only 35 White-backed Vultures, all on a single carcass (Prakash & Rahmani 2000; Prakash *et al.* 2003). These observations in Gujarat in 2000 were part of a survey over major portions of India undertaken by BNHS in April-June 2000. Data were recorded as km of road travelled per vulture observed, with habitat distinguished among protected areas (2714km), adjacent areas (1396km) and along highways (7233km). A total of only 953 White-backed Vultures and 563 'Long-billed Vultures', not separated by species, was recorded. A similar road survey of all raptors had been undertaken in 1990-93 (Samant *et al.* 1995). White-backed and Long-billed Vultures, however, were not included in the counts. Samant *et al.* (1995) referred to the White-backed Vulture as "An extremely common Vulture. No specific data on this species was collected as it was not possible to count it in most cases because of its numbers". Estimates of the magnitudes of population decline by Pain *et al.* (2002) and Prakash *et al.* (2003) based on the earlier report are therefore subject to wide margins of uncertainty; there is, however, no uncertainty in their conclusion that population declines were "in excess of 90% in all areas" and "in some areas approached or reached 100%" (Prakash & Rahmani 2000; Prakash *et al.* 2003). The 2000 survey also recorded no vultures at carcass processing plants near Mumbai, Delhi and Jaipur, where they had been extremely abundant a decade earlier (Prakash & Rahmani 2000; Prakash *et al.* 2003).

Observations elsewhere in India in 2000 indicate that the same or very similar mortality factor was operating over a broad area. In Ranthambhore National Park in eastern Rajasthan on 22 April 2000, a cluster of nests was located in the vicinity of the water hole in the Lahpur area of the Park. Within a radius of 50m were five adults, a fledgling that was apparently healthy, five dead birds on nests, suspended on branches or on the ground, and one bird on the ground that was near death, and which was dead later in the day. Another dead bird had been picked up the previous day by Park personnel. Of these seven dead birds five were juveniles and two were adults (M.Z. Virani, R.W. Risebrough and H. Vardhan, unpublished).

About 50 deaths of Long-billed Vultures of all age classes were recorded in the Bayana colony south of Bharatpur that contained 75 nests in the 1999-2000 nesting season. Eighteen dead birds were found during a visit on 20 September 2000 (Rahmani & Prakash 2000).

In Assam, both White-backed and Slender-billed Vultures were very common in the Brahmaputra and Barak valleys throughout most of the 1990s (Choudhury 1994, 2000; Barua & Sharma 1999). Numbers of both species were approximately equal; by 2000 vultures of both species had become rare over Assam, with fewer White-backeds recorded than Slender-billeds (A. Choudhury, pers. comm.).

In Pakistan, Roberts (1991) considered the White-backed Vultures as "abundant" throughout the valley of the Indus River. A survey over a distance of 1809 kilometres from 16-29 August 2000 by Virani and Khan recorded a total of 1,366 White-backed Vultures, including nesting colonies in Dholewalla in the Indus River Valley and about 500 in the Changa Manga Forest Plantation, 35km from the Indian border. A substantial population still existed therefore in 2000 (M. Virani and A.A. Khan, pers. comm.) During the following nesting season a total of 3,697 nests was recorded in Punjab Province, but 676 dead vultures were found between December 2000 and July 2001; the adult mortality rate was estimated to be 16% (Virani *et al.* 2001, Gilbert *et al.* 2002). In the following nesting season, the numbers of breeding pairs decreased by 80%, 40% and 15% in three colonies that were being intensively monitored (Virani *et al.* 2002; Gilbert *et al.* 2002).

In the Koshi Tappu Wildlife Reserve in Nepal 67 vulture nests were recorded in 2000/2001 (65 White-backed and 2 Slender-billed) of which 27 were active during the study; 19 successfully fledged young birds (Virani *et al.* 2001). In the following season only 12 nests were recorded, of which nine were active and only two produced young (Virani *et al.* 2002).

In conjunction with the Mumbai conference in 1999, another set of questionnaires was circulated by Dr Rahmani; the responses provided further documentation of the extent of population declines throughout India (Prakash & Rahmani 2000; Prakash *et al.* 2003).

THE RESPONSES

Following Dr Rahmani's conference in Mumbai in 1999, a workshop organized by the Bombay Natural History Society was held in Delhi in September 2000 (Rahmani & Prakash 2000). It was followed by sessions devoted to the South Asia vulture crisis at the 4th Eurasian Congress on Raptors in Seville in 2001 (Katzner & Parry-Jones 2001), at the 23rd International Ornithological Congress in Beijing in 2002 (Risebrough *et al.* in press), and at the 3rd North American Ornithological Conference in 2002 (Katzner & Parry-Jones 2002). The present conference represents the largest effort to date to consider the problem. Another vulture session is scheduled for the Centenary Seminar of the Journal of the Bombay Society of Natural History in November 2003.

A collaborative programme between The Peregrine Fund and the Ornithological Society of Pakistan began in 2000. In late 1999 a similar collaboration had developed between the Royal Society for the Protection of Birds and the Bombay Natural History Society; shortly afterwards it was expanded to include the Zoological Society of London and the Poultry Diagnostic and Research Centre in Pune. With funding from the Darwin

Initiative for the Survival of Species a Vulture Care Facility was constructed in the State of Haryana to which sick birds from the field could be brought for study and care.

THE HYPOTHESES

An extermination campaign?

Particularly in the Delhi-Agra area in the 1970s and 1980s, large flocks of vultures in the sky numbering into thousands of birds posed significant hazards to aircraft, prompting recommendations that would reduce their numbers (Ali & Grubh 1980, 1984; Grubh & Ali 1984; Grubh 1989). These were principally directed at removing food sources in the vicinity of airports and did not include a recommendation for an extermination campaign (Ali & Grubh 1984). Whether the Indian Air Force and/or other aviation authorities undertook a poisoning campaign remains a state secret, but in a country as populous as India with a vigorous free press, any widespread poisoning or shooting campaign undertaken at a level sufficient to cause a 99% reduction in population numbers, extending over most of India and into Nepal and Pakistan, repeated over a period of several years, is unlikely to have escaped public notice. In the absence of any supporting data, a hypothesis that such an extermination programme played a significant role in the decline of the vulture populations can not be given credence.

LONGER-TERM CHANGES AFFECTING VULTURE POPULATIONS IN ASIA

Since modernization of slaughter houses reduces over the longer term the food supply available to vultures, populations will inevitably decline in response. Moreover, socio-economic factors are also affecting the long-term food supply available to vultures. Cows are never killed by the Hindus of India and Nepal, who consider them sacred; when they die, carcasses are left for vultures. Increasingly, villagers in both countries are keeping fewer cattle and more buffalos, which also produce milk but may be slaughtered for meat before they succumb to old age (B. Mahato *per* H. Sagar Baral *in litt.* 1999; H. Vardhan *in litt.*1999). In the vicinity of Chitwan National Park, a major tourist area, carcasses of domestic animals are now routinely buried (H. Sagar Baral, Munir Virani pers. comm.), a factor likely to have contributed to the disappearance of vultures from that area.

As of 1999, however, some of the recommendations considered critical for reducing sources of food in the vicinity of airports, including the construction of modern slaughterhouses (Ali & Grubh 1980, 1984; Grubh & Ali 1984; Grubh 1989) had not yet been implemented. Instead, a surplus of available food at the slaughter houses in the Delhi-Agra-Haryana areas had persisted throughout the recent declines (Grubh & Vijayan 1999). Food shortage has never been a factor in the Keoladeo Park; many carcasses have remained unconsumed (Prakash 1999). Surveys undertaken in 1999 and 2000 demonstrated an abundance of food in the form of unconsumed carcasses in the countryside over much of India (Grubh & Vijayan 1999; Prakash & Rahmani

2000). Although clearly a longer-term factor affecting vulture populations of the subcontinent, food shortage cannot account for the unprecedented events in India that occurred within a single decade.

The felling of nesting trees, particularly along highways and in villages where trees are otherwise sparse, most likely contributed to the decline of White-backed and Slender-billed Vultures in Bangladesh (Sarker & Iqbal 1997) and may be now a significant factor in local declines in Assam (A. Choudhury pers. comm.). A reduction in productivity because of a decreasing number of nesting sites would, however, impact only slowly the total population numbers. In both Peninsular India and Pakistan, the availability of trees and particularly of cliffs for nest sites has not appreciably changed over the past decade and cannot therefore account for the precipitous declines in vulture numbers.

'PESTICIDES'

The 'pesticide' hypothesis proposed to explain the disappearance of Peregrine Falcons turned out to be the correct one, although the reproductive failures related to eggshell thinning were caused only by DDE, a derivative of one of the pesticides in use. Several pesticides, including DDT but particularly dieldrin, contributed to the population declines in Britain by causing a high rate of mortalities and surely contributed to the local extinctions of breeding populations in North America (Risebrough & Peakall 1988; Risebrough 1989). On the basis of these observations in North America and Britain, the Black Shaheen *Falco peregrinus peregrinator*, the local race in India of the peregrine, might be expected to be the Indian species that would show the greatest depression of productivity and perhaps also a decline in population numbers. As a predator of other birds it occupies the top of the food web. There are apparently no data on productivity or on residue concentrations that would confirm or negate this prediction. Yet shaheens have continued to breed near Mumbai and continue to be seen in the city during the non-breeding season and elsewhere in India (R. Naoroji and L. Pereira, pers. comm.). In part this has been attributed to a lower level of DDT use in India than during the peak years of use in the USA, and in part to higher rates of volatilization of DDT to the atmosphere in India (Risebrough 2003).

Several students of the vulture crisis, i.e. Cunningham *et al.* (2003), have referred to "high rates of ... nesting failure". Yet it would appear that all of the 'failures' could be attributed to the deaths of either an adult or of the young bird, a very different effect from the breeding failures experienced by peregrines or other species sensitive to the effects of DDE.

Pesticide use in agriculture and to a much lesser extent in public health programmes has caused or contributed to the deaths of countless numbers of raptors through secondary poisoning in many countries of the world. In earlier years the majority of deaths was caused by organochlorine compounds, particularly dieldrin; properties of persistence, mobility, and lipid solubility permitted these compounds to accumulate to toxic levels (Newton 1979; Nisbet 1988; Risebrough 1989). In India, Sarus Cranes *Sarus antigone* have been killed by dieldrin poisoning after consuming food contaminated with aldrin,

which converts to dieldrin in the environment (Muralidharan 1993). Unlike the organochlorines, monocrotophos is not persistent, mobile in the environment or lipid soluble, but is equally very toxic to both vertebrates and invertebrates (van den Bosch 1969). It has poisoned many raptors in Israel (Mendelssohn & Paz 1977) and in Argentina (Woodbridge *et al.* 1995; Goldstein *et al.* 1999) that had consumed insect prey exposed to it. Carbofuran is sufficiently persistent to kill raptors, including Bald Eagles *Haliaeetus leucocephalus,* from secondary poisoning (Elliott *et al.* 1996, Allen *et al.* 1996). Poisoning by monocrotophos, carbofuran and other highly toxic but relatively non-persistent pesticides may be cumulative with repeated exposures to sublethal doses (Hudson *et al.* 1984).

These and most other pesticides, however, are nerve poisons, inducing body tremors in dying birds (Hudson *et al.* 1984), a condition not observed in dying vultures. To account for the very rapid population declines observed in several areas, a pesticide hypothesis would require not only that the pesticide not be a nerve poison, but also that it be a newly-introduced pesticide or a new usage of one already in use for other purposes i.e. application to the skins of cattle to control warble flies *Hypoderma* sp.; such usage has killed birds of prey in North America (Franson *et al.* 1985; Henny *et al.* 1985, 1987). This possibility of a new treatment for warble fly control was investigated in the State of Rajasthan, site of many of the documented mortalities; Mr Harsh Vardhan (H. Vardhan *in litt.* 1999) was informed by the Director of Animal Husbandry for Rajasthan State in Jaipur that no new pesticides were being used for warble fly control and that there had been no significant shift in the pattern of pesticide use throughout the State during the 1990s. Like the parallel hypothesis that the mortalities have been caused by one or more poisons applied to carcasses, a hypothesis that the mortalities have been caused by one or more pesticides used in agricultural and public health programmes would require that *Gyps* vultures be much more sensitive than are other species.

Extensive analyses for organochlorine compounds, organophosphate and carbamate insecticides, depression of cholinesterase activity, and a range of heavy metals in the tissues of birds found dead in Pakistan yielded no evidence for a toxicant effect except for one case of lead poisoning (Oaks *et al.* 2001, 2002, 2004). Two eggs and tissues of White-backed Vultures from the Bharatpur area contained low levels of DDT compounds and traces of dieldrin, well below thresholds of harm (S. Muralidharan, R. Jaykumar, V. Prakash, P.H. Bloom & R.W. Risebrough, unpublished).

No evidence has therefore emerged to support the 'pesticide' hypothesis.

Poisoning

Deliberate poisoning of cattle or buffalos, or incidental poisoning of their carcasses upon which vultures feed in the vicinity of Keoladeo National Park appeared initially to be the only plausible cause of the mortalities observed in the 1996-97 nesting season. The slaughter of cattle for the harvesting of hides is illegal in the state of Rajasthan, but hides may be collected from dead animals. Administration to cattle of the rodenticide zinc phosphide for the purpose of collecting the hides was later confirmed (Prakash 1999). The absence of observed or reported mortalities of the numerous village dogs that

also feed on the carcasses indicates, however, that the extent of this practice was relatively small.

Carcasses have sporadically been poisoned over much of southern Asia to kill jackals *Canis aureus*, hyenas *Hyaena hyaena*, wolves *Canis lupus*, leopards or tigers; frequently vultures that subsequently feed on these carcasses have also been killed. The disappearance of vultures from the Sigur Region of Tamil Nadu by the early 1980s coincided with the poisoning of carcasses with pesticides to kill tigers and leopards (Davidar 1997; Davidar & Davidar 2002). Mundy *et al.* (1992) identified between 33 and 43 mass poisonings in Africa, which collectively killed 1,253 birds. A population of 20 Red-headed Vultures *Sarcogyps calvus* in the Huai Kha Khaeng Wildlife Sanctuary in western Thailand fed on carcasses of large mammals at tiger kills up until the mid-to-late 1980s, when it was largely or totally extirpated through the use of poisoned baits to obtain tiger bones and parts for the Chinese medicine trade (P. Round *in litt.* 2000). There have been sporadic mortalities in Assam from the inadvertent or deliberate poisoning of carcasses, principally to decrease the numbers of jackals. In April 2001 at least 60 vultures died in Rongjuli in the Goalpara district after feeding on a dog that had died from poisoning. Earlier, on 30 March 2001, 23 vultures, most of which were Slender-billeds but including a few White-backeds, died at Mukalmua in the Kamrup District after eating poisoned meat (Choudhury 2001). I have found, however, no reports of the deaths of vultures in recent years from poisoned carcasses in the Delhi-Agra-Bharatpur area where the vulture declines have been best documented and where the wildlife species that have been targets of human persecution have become rare.

Accumulative and slow-acting poisons usually cause loss of body weight and the depletion of fat reserves, as have been documented in both California Condors *Gymnogyps californianus* and Bald Eagles poisoned by lead (Janssen *et al.* 1986; Pattee & Hennes 1983). A hypothetical toxin responsible for the vulture mortalities would exert its lethal effects without causing any loss of body weight, as shown by the presence of abundant body fat in many of the vultures that have been necropsied (Cunningham *et al.* 2001; Oaks *et al.* 2001, Mishra *et al.* 2002). These conditions are not met by any of the conventional slow-acting poisons (Hudson *et al.* 1984). The majority of the poisons that have been used to kill wildlife on the list maintained by the Poison Working Group, Endangered Wildlife Trust, South Africa, are pesticides. These account for 80% of the poisonings of wildlife in South Africa, more than 90% of which have been of deliberate intent. The chemical most frequently used for the specific purpose of killing wildlife species considered to be pests has been the highly toxic organophosphate pesticide monocrotophos (Fourie *et al.* 1996). Carbofuran, a carbamate pesticide that is also highly toxic to birds, has killed seven Cinereous Vultures *Aegypius monachus* in Greece (Antoniou *et al.* 1996). Of the commonly-used poisons applied to carcasses to poison scavengers, 1080 (sodium fluoroacetate) is particularly toxic to canids (Braverman 1979; Casper *et al.* 1986; Gooneratne *et al.* 1995) and could not have been used to poison carcasses in India without massive mortalities of village dogs. Similarly, all other poisons that might have been applied to

carcasses would be expected to kill other species in addition to vultures on the basis of published toxicity data (i.e. Hudson *et al.* 1984).

As noted above, analyses of tissues from Pakistan by The Peregrine Fund showed no evidence for the presence of any of the recognized poisons (Oaks *et al.* 2001, 2002, 2004). Since the observed mortality patterns would require repeated applications of the hypothetical toxin over much of the Subcontinent over a period of several years, the plausibility of a poison hypothesis appeared to be very low until a frequently-used veterinary medicine was shown to be exceptionally toxic to vultures.

A DISEASE FACTOR

Many infectious diseases of wildlife have in fact been shown to have originated in other species in which they may be relatively harmless (Daszak *et al.* 2000; Mahy & Brown 2000). The Ebola virus, whose 'natural' host has not yet been identified, is currently decimating remaining populations of Chimpanzees *Pan troglodytes* and Gorillas *Gorilla gorilla* in Gabon and the Democratic Republic of Congo (Walsh *et al.* 2003). The recent passage to humans of the HIV virus from Chimpanzees and Sooty Mangabeys *Cercocebus atys* (Hahn *et al.* 2000), and of the Nipah and Hendra viruses from pigs and horses (Chua *et al.* 2000; Hooper *et al.* 2000a, 2000b; Westbury 2000) which in turn acquired them from fruit bats *Pteropus* spp. (Halpin *et al.* 2000; Enserink 2000), provides examples of new human diseases that had been resident in other species and for which humans have no natural defence mechanisms. Daszak *et al.* (2001) point out that emerging diseases in wildlife are frequently associated with human-induced ecological changes; no such changes, however, were obvious in South Asia that would account for a 'disease factor' affecting the *Gyps* vultures.

Since raptors are generally solitary or live as pairs they would be less sensitive to transmission of a disease factor than more social species. Vultures, particularly of the genus *Gyps*, are an evident exception; not only is there intensive body contact during feeding, there is also the possibility of consuming either faeces or regurgitate of diseased birds. The rapid spread of mycoplasmal conjunctivitis among finches at crowded feeding stations in eastern North America has provided an example of transmission of a disease factor from bird to bird through body contact (Fisher *et al.* 1997; Dhondt *et al.* 1998).

A review of all of the possible causes proposed to explain the mortalities and population declines of the vultures at the 1999 conference in Mumbai concluded that only the appearance in the *Gyps* vultures of the Indian Subcontinent of a disease factor that had 'jumped' from another species in which it is benign, or the mutation into a more virulent form of a previously benign disease factor, was a viable hypothesis, all other proposed causes having fatal flaws (Risebrough 2000).

It became the principal working hypothesis in looking for an explanation of the mortalities (Oaks *et al.* 2001, 2002; Cunningham *et al.* 2001, 2003; Prakash *et al.* 2003; Pain *et al.* 2002, 2003; Risebrough *et al.* in press). None of the intensive efforts undertaken by the Poultry Diagnostic and Research Centre in

Pune, the Zoological Society of London, nor The Peregrine Fund, however, yielded any evidence for the presence of a disease factor.

RESOLUTION

The paper presented at this conference by Oaks *et al.* reports on the presence of the non-steroidal anti-inflammatory drug diclofenac in tissues of White-backed Vultures that had died in the field in Pakistan with visceral gout, its absence in vultures that had died of known causes, and that ingestion by vultures of doses of this drug prescribed to domestic mammals are lethal. Visceral gout, the deposition of uric acid crystals throughout the visceral cavity as a result of kidney failure, was reported from the first necropsies of birds that had died from the 'disease' (Mishra *et al.* 2002) and from later necropsies (Cunningham *et al.* 2003: 5 of 7 adults and subadults found dead; Oaks *et al.* 2001: 49 of 69 adult vultures found dead). Its induction in captive birds given doses of diclofenac that are commonly prescribed for domestic animals, and the induction of histological lesions identical to those observed in birds that had died with visceral gout in the wild, further support the conclusion that diclofenac used in veterinary medicine could have caused the high rate of mortalities that has produced the population collapses of the three affected species. Carcasses of domestic animals have traditionally been left to vultures for disposal; those of diseased animals that had been treated with diclofenac provide the route to vultures.

Oaks *et al.* (2004) provide additional data supporting the diclofenac hypothesis as applied to Pakistan and that are also highly relevant to interpreting the causes of the disappearance of the vultures throughout the Subcontinent.

Were it not for a series of almost fortuitous events, these species of *Gyps* vultures would have become extinct in South Asia with the cause of their extinction remaining a mystery.

POSTSCRIPT

Investigations undertaken after the conference confirmed that diclofenac has been widely used in veterinary medicine in India since about 1994, frequently as a placebo; it is cheap and readily available in a minimum of 48 formulations produced by a minimum of 27 companies (Risebrough, in press). Whether it has been the only veterinary medicine that is toxic to vultures consuming carcasses of treated animals is, however, an open question. In January 2003, an African White-backed Vulture *Gyps africanus* died with visceral gout at the San Diego Zoo two days after being treated with ketoprofen, a related non-steroidal anti-inflammatory drug (M. Busch and B.A. Rideout, quoted by Oaks *et al.* 2004). NSAIDs work by inhibiting the cyclo-oxygenase enzyme complex (COX) that is responsible for the biosynthesis of prostaglandins which induce the expression of pain and inflammation (Zimmerman *et al.* 1995; Kawai 1998; Bjarnason 1999; Larousse & Veyrac 2000). It is the depression of renal function resulting from prostaglandin inhibition that creates the toxicity of diclofenac to vultures. The depression of renal function appears to be a common adverse effect of other and perhaps all NSAIDs (O'Brien 1986; Brater

1999; Zhao *et al.* 2001; Niccoli *et al.* 2002). Rofecoxib induces a particularly high level of renal dysfunction (Papaioannides *et al.* 2001). Another NSAID can not therefore be recommended as a replacement for diclofenac without extensive testing of its toxicity to vultures. Proposals to ban diclofenac use without an acceptable substitute in place, which is also fully acceptable to the veterinary community, are likely to be counter-productive.

CONSERVATION PRIORITIES

Well-considered conservation priorities proposed in the recent past largely based on the disease hypothesis, i.e. from the round-table discussion at the International Ornithological Congress in Beijing in 2002 (Risebrough *et al.* in press) are now largely irrelevant.

Two programmes to be undertaken in parallel with equal priority are proposed:

1. the bringing into captivity of a sufficient number of each of the three species, in the order of 100 each, at several different facilities such that extinction in the wild will not imperil their long-term survival. At the present time relatively few White-backed Vultures, very few Long-billed Vultures, and no Slender-billed Vultures are in captivity;
2. looking for, and testing potential substitutes of diclofenac for their toxicity to vultures. In the absence of an acceptable substitute - one that will not kill vultures and is endorsed by the veterinary community - calling for a ban on the use of diclofenac as a veterinary medicine can not be expected to be effective.

Although Peregrine Falcons became extinct as a breeding species during the DDT era in the eastern United States and adjacent regions of Canada, small numbers of the subspecies *Falco peregrinus anatum* survived in other areas of North America, including northern California, Arizona and Baja California. After the ending of DDT use, when environmental levels of DDE had fallen below thresholds of effects on reproduction, increased productivity resulted in recolonization of adjacent areas. Although it is possible that small groups of vultures might survive in isolated areas, this remote possibility, because of its uncertainties, should not be included in any kind of conservation strategy. Populations of all three species are declining too fast. A conservation strategy might more productively be modelled on that developed for the California Condor - a programme of captive breeding associated with reintroduction into the wild.

A critical factor in demonstrating the impact of diclofenac on vultures was the ability to experiment with captive birds, exposing them to potentially lethal doses. In the United States and the Netherlands, political pressures from animal rights activists have prevented experiments with captive marine mammals from populations suffering from premature births and reproductive failures. They would have been fed doses of DDE or PCBs equivalent to those they might ingest in fish while in the wild, yet the administration of 'poisons' to captive animals was considered politically and ethically unacceptable. Consequently it remains unknown whether DDE or the PCBs, or something else, was the responsible agent for the injuries being incurred (Risebrough 1999). Finding an

acceptable substitute for diclofenac will require the testing of potentially acceptable drugs for toxicity to captive vultures, most likely *Gyps africanus*. Opposition to such experiments might be anticipated in order that the strongest case supporting them might be made.

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