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Rapid population declines of Egyptian vulture (*Neophron percnopterus*) and red-headed vulture (*Sarcogyps calvus*) in India

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Abstract

Since the early 1990s, large and rapid population declines of three species of vulture (*Gyps* spp.) endemic to south Asia have occurred on the Indian subcontinent and have led to these species being listed by IUCN as critically endangered. Evidence of rates of population decline, cause of death and toxicity is consistent with these declines being caused by poisoning of vultures through the ingestion of tissues from livestock treated with the anti-inflammatory drug diclofenac. In this paper, analysis of repeated surveys in and near protected areas widely spread across India shows that populations of two other vulture species, Egyptian vulture *Neophron percnopterus* and red-headed vulture *Sarcogyps calvus*, have also declined markedly and rapidly, but probably with a later onset than *Gyps* vultures in the same region. The declines continued at least up to 2003. It is recommended that these two species are considered for inclusion in the IUCN Red List and for urgent remedial conservation measures. Research is needed to determine whether or not the principal cause of these declines is diclofenac poisoning and to establish population trends in other scavenging birds in the Indian subcontinent.

Introduction

Populations in the Indian subcontinent of at least three vulture species endemic to south and south-east Asia, Oriental white-backed vulture *Gyps bengalensis*, long-billed vulture *Gyps indicus* and slender-billed vulture *Gyps tenuirostris*, have declined by more than 98% since the early 1990s (Gilbert *et al*., 2002; Prakash *et al*., 2003; Green *et al*., 2004; The Peregrine Fund, 2006). They are all now listed as critically endangered in the IUCN Red List (Hilton-Taylor, 2000). Veterinary use of the non-steroidal anti-inflammatory drug diclofenac is the main, and perhaps the only, cause of the population declines (Green *et al*., 2004; Oaks *et al*., 2004; Shultz *et al*., 2004). Vultures are exposed to diclofenac when they feed from carcasses of livestock that die within a few days of treatment and contain residues of the drug (Oaks *et al*., 2004). Green *et al*. (2004) estimated that less than 0.8% of ungulate carcasses available to foraging vultures would need to contain a lethal dose of diclofenac to have caused the observed population declines, and found that the high proportion of Oriental white-backed and long-billed vultures found dead in the wild that had severe visceral gout was consistent with diclofenac poisoning being the main or sole cause of the population declines.

The geographic extent and scale of the decline in these three *Gyps* species raises the question of whether populations of other species of scavenging birds are being affected by diclofenac. However, little is known of the population trends of other species that may be at risk or of their susceptibility to diclofenac poisoning. Among the raptor species present in India, those most likely to feed on diclofenac-contaminated carcasses are Eurasian griffon vulture *Gyps fulvus*, Himalayan griffon vulture *Gyps himalayensis*, cinereous vulture *Aegypius monachus*, Egyptian vulture *Neophron percnopterus*, red-headed vulture *Sarcogyps calvus*, steppe eagle *Aquila nipalensis* and black kite *Milvus migrans*. Counts of Egyptian and red-headed vultures carried out in 13 Indian protected areas between 1991 and 1993 were repeated in 2000 and revealed a significant decline of around 48% for red-headed vulture and a non-significant decrease of 22% for Egyptian vulture (Prakash *et al*., 2003). In this paper, we report additional information from other areas counted in 1991–1993 and 2000 with further counts of these two species in 2002 and 2003 for the same study areas.

Methods

Surveys

Surveys of Egyptian and red-headed vultures were conducted in and around 18 national parks and wildlife sanctuaries spread across the north, west and east of India (Fig. 1; Table 1), where most vultures formerly occurred because of the abundance of cattle in these areas (Grubh, Narayam & Satheesan, 1990). We carried out repeat surveys in 2000, 2002 and/or 2003 in 14 protected areas where counts were made in one of the years 1991–1993 as part of a nationwide survey of raptors undertaken by the Bombay Natural History Society (Samant, Prakash & Naoroji, 1995). Four additional protected areas were surveyed in 2000 and in at least one subsequent year (Table 1). Surveys were made from roads and tracks following the methods of Fuller & Mosher (1981). Repeated surveys at a given site followed the same routes and involved the same effort. Counts were made by an observer and driver from a vehicle driven at 10–20 km h^{-1} within protected areas and forests adjoining protected areas, and at 50 km h^{-1} on highways within a 25 km zone outside the boundary of the protected area. Birds perching or soaring within 500 m of the road were recorded. Counts were made between March and June at the end of the breeding season. Routes in and around the original 14 protected areas surveyed in 1991–1993 covered 5800 km, with a further 1000 km in new study areas added in 2000. The data in our Table 1 correspond to those in Samant *et al.* (1995) for 1991–1993 and to those in table 5 of Prakash *et al.* (2003) for 2000, except that the 1993 count of Egyptian vultures in Desert National Park was reported in error as 36, rather than 54, in the latter.

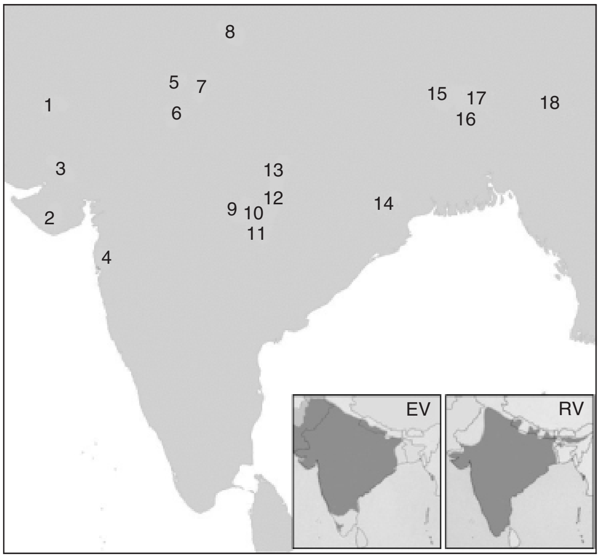

Figure 1 Map of India showing the locations of protected areas at which surveys were undertaken and the breeding range of the Egyptian vulture *Neophron percnopterus* (EV) and red-headed vulture *Sarcogyps calvus* (RV). Numbers identify sites listed.

Statistical analysis

Sites at which the study species were not recorded on any of the surveys did not contribute any information to the analysis and were excluded. This left 11 informative sites for Egyptian vultures and 10 sites for red-headed vultures (Table 1). Population changes were estimated from the count data by fitting linear models with a log link function and a Poisson error term using GLIM 4. Site was treated as a factor to allow for sites that were not surveyed in every year. Survey year was also treated as a factor in some analyses, the model being

$$\log_e(c_{ij}) = g_i + h_j$$

Table 1 Numbers of Egyptian *Neophron percnopterus* and red-headed vultures *Sarcogyps calvus* counted at protected areas in India 1991–2003

				Egyptian vulture						Red-headed vulture					
Code	Site name	Latitude	Longitude	1991	1992	1993	2000	2002	2003	1991	1992	1993	2000	2002	2003
1	Desert National Park	26.389	70.751	nc	nc	54	36	16	13	nc	nc	5	4	0	0
2	Gir National Park	21.333	70.792	nc	nc	nc	0	2	0	nc	nc	nc	0	0	0
3	Wild Ass Sanctuary/Little Rann of Kutch	23.545	71.195	nc	15	nc	0	0	0	nc	2	nc	0	0	0
4	Sanjay Gandhi National Park	19.270	72.960	nc	1	nc	0	0	0	nc	0	nc	0	0	0
5	Sariska Sanctuary	27.430	76.464	nc	nc	0	7	0	3	nc	nc	4	5	0	0
6	Ranthambore National Park	26.037	76.481	nc	nc	4	4	0	0	nc	nc	10	2	0	0
7	Keoladeo Ghana National Park	27.159	77.519	nc	nc	25	15	8	5	nc	nc	8	7	4	1
8	Corbett National Park	29.590	78.916	9	nc	nc	8	0	nc	13	nc	nc	5	0	nc
9	Pench National Park	21.672	79.303	nc	nc	nc	0	0	0	nc	nc	nc	2	0	0
10	Nagzira Sanctuary	21.313	80.068	nc	nc	nc	0	0	0	nc	nc	nc	0	0	0
11	Navegaon National Park	20.945	80.183	nc	1	nc	0	0	0	nc	0	nc	0	0	0
12	Kanha National Park	22.221	80.722	1	nc	nc	0	0	0	2	nc	nc	0	2	0
13	Bandhavgarh National Park	23.608	80.952	nc	nc	nc	0	0	0	nc	nc	nc	0	4	1
14	Similipal National Park	21.931	85.995	nc	0	nc	0	0	0	nc	0	nc	0	0	0
15	Mahananda Sanctuary	26.860	88.413	0	nc	nc	2	0	0	0	nc	nc	0	0	0
16	Jaldapara Sanctuary	26.516	89.469	0	nc	nc	0	0	0	0	nc	nc	0	0	0
17	Buxa National Park	26.767	89.567	0	nc	nc	0	0	0	0	nc	nc	0	0	0
18	Kaziranga National Park	26.655	93.348	0	nc	nc	nc	0	0	3	nc	nc	nc	0	2

Site-years with no count are denoted nc. Latitudes and longitudes are in decimal degrees north and east, respectively.

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where c_{ij} is the expected value of the count at the *i*th site in the *j*th year, g_i is the site effect for the *i*th site and h_j is the year effect for the *j*th year. Surveys at a given site were undertaken in just one of the three years 1991–1993; hence all surveys in this period were treated as having occurred in 1992. Population indices, scaled relative to the first year of the series, were calculated as $\exp(h_j)$. In an alternative formulation, it was assumed that the population was stable until year k, after which it declined exponentially. Hence, the model is then $\log_e(c_{ij}) = g_i$ for $t_{ij} < k$ and $\log_e(c_{ij}) = g_i + b(t_{ij} - k)$ for $t_{ij} > k$, with b being a fitted constant and t_{ij} being the calendar year of the *j*th survey at site *i*. The model was fitted in GLIM 4, as described above, except that a macro was used to obtain the value of k at which the residual deviance was minimized. The population multiplication rate λ during the period of decline was estimated as $\exp(b)$ and the annual percentage rate of decline as $100(1-\lambda)$. The statistical significance of effects was tested using F ratios, and standard errors were calculated after correcting for overdispersion by rescaling by the ratio of residual deviance to residual degrees of freedom (Crawley, 1993). Because the small number of survey sites and possible lack of statistical independence of records of individual birds make the use of parametric statistics questionable, we also used a non-parametric test of the significance of population trends. To do this, we first fitted the model $\log_e(c_{ij}) = g_i + b_i t_{ij}$ by Poisson regression for all sites that were surveyed in both 1991–1993 and 2000–2003. We ranked the b_i, ignoring their sign, and then affixed the sign of each b_i to its rank. These signed ranks were then used to calculate the test statistic t for the Wilcoxon signed ranks test (Siegel & Castellan, 1988). To examine whether population changes have occurred during the last few years, we repeated the analyses using only data for 2000–2003. For this analysis we assumed that the exponential decline occurred through this restricted period.

Results

There were substantial declines in the counts of Egyptian and red-headed vultures during the period from the early 1990s until 2003 (Figs 2 and 3). The population of Egyptian vultures in 2003 was estimated to be 20% of that in the early 1990s [95% confidence limits (CL) 10–42%]. The population of red-headed vultures in 2003 was estimated to be 9% of that in the early 1990s (95% CL 2–39%). Declines occurred at eight of 10 sites at which Egyptian vultures were counted in both 1991–1993 and 2000–2003 and in all eight such sites for red-headed vultures (Table 1).

The model that assumed a period after 1992 in which the population was stable, followed by a period of exponential decline, indicated that the decline began in about 1999 for both species. We compared the results of these models with those of a simpler version in which the declines were already in progress at the time of the surveys in the early 1990s. The fit of the model without the assumption of a stable period was significantly poorer for Egyptian vultures ($F_{(1,29)} = 7.70$, $P < 0.01$) and the equivalent test was almost significant for red-headed vultures ($F_{(1,24)} = 4.04$, $P = 0.06$). Hence, it seems unlikely that populations of these two species have been declining exponentially at a constant rate since 1992 or earlier.

From 1999 onwards, the Egyptian vulture population was estimated to decline by 35% per year (95% CL 24–44%) whereas that of the red-headed vulture declined by 41% per year (95% CL 26–53%). Both parametric and non-parametric tests indicated that declines were statistically significant for both species (Table 2). F-tests indicated that the

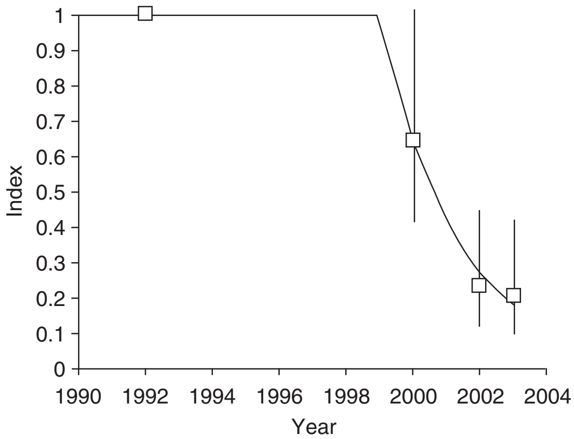

Figure 2 Population trend of Egyptian vultures *Neophron percnopterus* from counts on transects in 11 protected areas in India. Squares show population indices from log-linear Poisson modelling, with 95% confidence limits. The index is the ratio of the population in a given year to that in 1991–1993 (plotted at 1992). The fitted line uses data from all survey years and assumes that an exponential population decline began at a certain time (estimated as the year 1999).

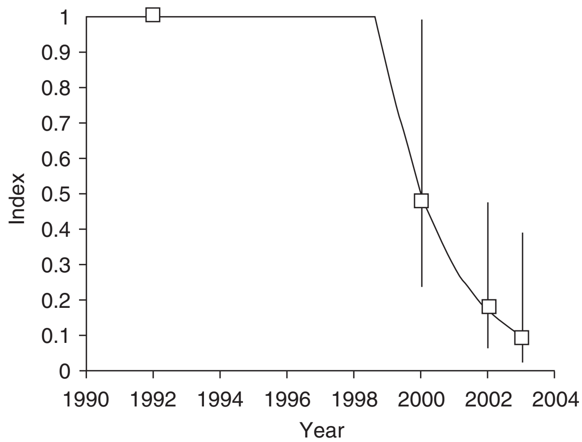

Figure 3 Population trend of red-headed vultures *Sarcogyps calvus* from counts on transects in 10 protected areas in India. Squares show population indices from log-linear Poisson modelling, with 95% confidence limits. The index is the ratio of the population in a given year to that in 1991–1993 (plotted at 1992). The fitted line uses data from all survey years and assumes that an exponential population decline began at a certain time (estimated as the year 1999).

Table 2 Significance tests of trends in counts of Egyptian *Neophron percnopterus* and red-headed vultures *Sarcogyps calvus*

Species	Period covered	Model specification	Number of sites	Test statistic for time effect	*P*
Egyptian	Early 1990s–2003	Survey year modelled as a factor	11	$F_{(3,28)}=12.51$	<0.001
Egyptian	Early 1990s–2003	Stable population followed by exponential trend	11	$F_{(2,29)}=18.90$	<0.001
Egyptian	Early 1990s–2003	Signed ranks test on site-specific log-linear trends	10	$t=49$	0.027
Egyptian	2000–2003	Survey year modelled as a factor	7	$F_{(2,11)}=7.90$	<0.01
Egyptian	2000–2003	Exponential trend for whole period	7	$F_{(1,12)}=15.97$	<0.001
Egyptian	2000–2003	Signed ranks test on site-specific log-linear trends	7	$t=27$	0.031
Red-headed	Early 1990s–2003	Survey year modelled as a factor	10	$F_{(3,23)}=8.38$	<0.001
Red-headed	Early 1990s–2003	Stable population followed by exponential trend	10	$F_{(2,24)}=13.07$	<0.001
Red-headed	Early 1990s–2003	Signed ranks test on site-specific log-linear trends	8	$t=36$	0.008
Red-headed	2000–2003	Survey year modelled as a factor	9	$F_{(2,14)}=3.44$	0.07
Red-headed	2000–2003	Exponential trend for whole period	9	$F_{(1,15)}=7.28$	<0.025
Red-headed	2000–2003	Signed ranks test on site-specific log-linear trends	9	$t=33$	0.25

Test statistics are shown for the effect on count of survey date modelled by Poisson regression as described in the Methods. The number of sites that contributed data to each analysis is also shown. All *P*-values are for two-tailed tests.

declines were highly significant ($P<0.001$), whereas Wilcoxon signed rank tests indicated a lower level of significance ($P<0.03$), as would be expected because the non-parametric test makes fewer assumptions.

When the analysis was restricted to 2000–2003, the evidence for population decline remained statistically significant for Egyptian vultures, but was significant only by the *F*-test for an exponential decline for red-headed vultures (Table 2). The population of Egyptian vultures in 2003 was estimated to be 32% that in 2000 (95% CL 15–65%). The population of red-headed vultures in 2003 was estimated to be 16% that in 2000 (95% CL 3–91%). The model that assumed an exponential decline throughout 2000–2003 indicated that the Egyptian vulture population declined by 35% per year (95% CL 19–47%) whereas the red-headed vulture population declined by 44% per year (95% CL 12–64%).

Discussion

This study shows that there have been substantial declines in populations of both Egyptian and red-headed vultures at the study sites. The declines are statistically significant even though they are based upon data from a small number of sites (11 and 10 sites for the two species, respectively). The study sites may not be typical of all parts of India, but they are widely distributed across the northern and central part of the country (Fig. 1), where most vultures formerly occurred, and where the selection of protected areas might be expected to bias the results towards population stability rather than decline.

The annual rates of population decline observed for Egyptian vultures (35%) and red-headed vultures (44%) during 2000–2003 were intermediate between those found for *G. bengalensis* and *G. indicus/tenuirostris* over the same period (48 and 22% per year, respectively; Green *et al.*, 2004). If it is assumed that the declines of Egyptian and red-headed vultures have occurred exponentially at a constant rate, then it appears that they began in about 1999. This is later than the decline of Oriental white-backed vultures, which is thought to have begun in the early 1990s (Prakash *et al.*, 2003). When analyses equivalent to those carried out here for Egyptian and red-headed vultures were carried out on road transect data on *Gyps* vultures in India for 1991–2003 (data from Prakash *et al.*, 2003; Green *et al.*, 2004) and nest counts of *G. bengalensis* in Keoladeo National Park (Prakash *et al.*, 2003), they indicate declines beginning in 1995 or earlier (R. E. Green, unpubl. analyses). Of course, none of these analyses exclude the possibility that population declines began earlier than indicated, but that declines were slower during their early stages. The indication that populations of Egyptian and red-headed vultures showed only slight trends throughout the 1990s is supported by regular counts of nesting pairs of both species in Keoladeo National Park, which indicated that the numbers of these two species remained stable whereas both Oriental white-backed and long-billed vultures were declining rapidly over the same period (Prakash, 1999). The apparent difference between the timing of the start of the population declines may be either because Egyptian and red-headed vultures are subjected to another undiagnosed source of mortality, or because before the collapse in *Gyps* vultures they were not exposed to diclofenac. Given that *Gyps* vultures used to comprise over 99% of all vulture sightings in India and tend to dominate several other vulture species at carcasses (Houston, 1983; Mundy *et al.*, 1992), it is possible that they prevented Egyptian and red-headed vultures from being exposed to substantial levels of diclofenac until after *Gyps* populations had crashed.

Populations of Egyptian and red-headed vultures have decreased less so far than those of the three south Asian *Gyps* vultures. However, their high annual rates of decline are a cause for serious conservation concern. Red-headed vultures are restricted to the Indian sub-continent and south-east Asia and, because of their territorial behaviour, have always been less abundant than *Gyps* vultures (del Hoyo, Elliot & Sartagal, 1994). Historical records indicate that red-headed vultures were previously

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widespread and abundant; however, a contraction in range (particularly from south-east Asia) and population declines in recent decades mean that this species is listed as globally near threatened (BirdLife International, 2005*a*). If the annual rates of decline (41%) found in this study are representative of the whole of India, then the species would be expected to decline by more than 90% within 10 years. India forms the present main range for the species, and as a consequence the observed declines suggest that red-headed vultures should be placed into the IUCN Red List category of critically endangered, according to the criteria of BirdLife International (2005*a*). Egyptian vultures are more widespread, also occurring in Europe and Africa (del Hoyo *et al.*, 1994). However, concerns have recently been raised about population trends of this species in Europe (Liberatori & Penteriani, 2001; Donazar *et al.*, 2002), and the species is classified as endangered within Europe (BirdLife International, 2004). The global population of this species is estimated between 10 000 and 100 000 individuals, with around 50% of the global population within the Indian subcontinent (del Hoyo *et al.*, 1994; BirdLife International 2005*a*). With an annual decline rate of 35%, populations of Egyptian vultures in India would decline by more than 90% within 10 years, placing them as critically endangered within the country. Given the uncertainty in the global population and declining numbers in Europe, these results suggest that the conservation status of the Egyptian vultures should be upgraded to endangered.

Although there is currently no direct evidence to link the declines in these two species with diclofenac poisoning, the geographic extent and rate of declines are very similar to the declines in *Gyps* vulture populations for which the impact of diclofenac poisoning is now established. Other potential causal agents of decline that could be affecting Egyptian and red-headed vultures include food shortage, persecution, chemical contaminants and infectious disease. However, the first three hypotheses were ruled out for the threatened *Gyps* species (Prakash *et al.*, 2003; Pain *et al.*, 2004). The same evidence is likely to apply to the two species considered here, and the discovery of the role of diclofenac makes this a more likely candidate than disease. Consequently, there is a real and alarming possibility that diclofenac is affecting populations of these species and other scavenging raptors across the Indian sub-continent. There is an urgent need for better surveillance of populations of these and other scavenging bird species and research on the causes of declines. Post-mortem examination of dead birds and testing the toxicity of diclofenac and other veterinary drugs to a range of scavenging birds and raptors is a vital area of research to assess the potential wider impact of diclofenac in the Indian sub-continent. The report of the International South Asian vulture recovery plan workshop (Anon, 2004) recommended a ban on the veterinary use of diclofenac throughout the range states of *Gyps* vultures and the establishment of captive breeding centres to ensure the long-term survival of the affected three species. An announcement by the Government of India in March 2005 (BBC South Asia News, 2005; BirdLife International, 2005*b*) of its intention to phase out the manufacture and veterinary use of diclofenac within 6 months is a substantial step towards this goal. The other major recommendation of the recovery plan workshop was to establish captive populations of all three critically endangered *Gyps* vulture species, a process that is underway at two centres in India. Given the observed rapid rates of decline, in particular for the scarce red-headed vulture, securing captive populations of other rapidly declining vulture species needs to be given very serious consideration.

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