RECENT CHANGES IN POPULATIONS OF RESIDENT *GYPS* VULTURES IN INDIA[1]

V. PRAKASH[2,6], R.E. GREEN[3], D.J. PAIN[4,12], S.P. RANADE[2,7], S. SARAVANAN[2,8], N. PRAKASH[2,9], R. VENKITACHALAM[2,10], R. CUTHBERT[4,13], A.R. RAHMANI[2,11] AND A.A. CUNNINGHAM[5]

[2]Bombay Natural History Society, Hornbill House, S.B. Singh Road, Mumbai 400 001, Maharashtra, India.
[3]Conservation Science Group, Department of Zoology, University of Cambridge CB2 3EJ, UK. Email: reg29@cam.ac.uk
[4]Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire SG19 2DL, UK
[5]Institute of Zoology, Zoological Society of London, Regent's Park, London, NW1 4RY, UK. Email: a.cunningham@ioz.ac.uk
[6]Email: jatayuprakash@sify.com
[7]Email: sachinranade@yahoo.com
[8]Email: sarvan_wlb@yahoo.com
[9]Email: jatayuprakash@sify.com
[10]Email: venkatsacon@yahoo.co.in
[11]Email: bnhs@bom3.vsnl.net.in
[12]Email: debbie.pain@rspb.org.uk
[13]Email: Richard.Cuthbert@rspb.org.uk

Nine species of vultures are recorded from Indian subcontinent. The populations of three resident *Gyps* species, namely Oriental White-rumped Vulture *Gyps bengalensis*, Long-billed Vulture *Gyps indicus* and Slender-billed Vulture *Gyps tenuirostris* crashed during the mid nineties of the last century. Vulture declines were first documented at Keoladeo National Park, Bharatpur, Rajasthan. Subsequently, the crash in populations was documented across the country. During the present study, surveys on identified tracks were done in 2007 to repeat surveys done previously in 1992, 2000, 2002 and 2003. This was done to determine the population trend in the three species of vultures and also to get a rough estimate of the surviving population of vultures in 2007. The latest repeat surveys were carried out from March to June 2007 by driving in a motor vehicle and recording vultures within 500 m on the either side of each transect. The results indicate that the population of the three species of vultures continues to decline at an alarming rate. Numbers of Oriental White-rumped Vulture declined by 99.9% between 1992 and 2007 on the transects surveyed each year during that period. The equivalent decline in the combined total of *Gyps indicus* and *G. tenuirostris* was 96.8%. The population of Oriental White-rumped Vulture has an average annual rate of decline of 43.9% between 2000-2007, whereas the combined average annual rate of decline of *G. indicus* and *G. tenuirostris* is over 16%. A complete ban on the use of diclofenac in livestock and the establishment of conservation breeding centres are suggested to prevent the extinction of these three species of vultures.

Key words: Oriental White-rumped Vulture, Long-billed Vulture, Slender-billed Vulture, annual rate of decline, population estimates, diclofenac, extinction, conservation breeding

INTRODUCTION

Nine species of vultures are recorded from India of which five belong to the genus *Gyps* (Prakash 1999). Three *Gyps* vultures, namely the Oriental White-rumped Vulture (OWRV) *Gyps bengalensis*, Long-billed Vulture (LBV) *Gyps indicus* and Slender-billed Vulture (SBV) *Gyps tenuirostris* are residents, and the remaining two, the Eurasian Griffon *Gyps fulvus* and Himalayan Griffon *Gyps himalayensis* are largely wintering species (Prakash *et al.* 2003). OWRV and LBV were abundant across large parts of India until the 1990s. The SBV, which was not distinguished as a separate species from LBV until recently (Rasmussen and Parry 2001), was also locally common in north and north-eastern parts of the Indian subcontinent (Ali and Ripley 1983). During the 1980s, OWRV was thought to be the commonest large bird of prey in the world (Houston 1985). *Gyps* vulture densities were so high in some areas that they were considered a hazard to aircraft (Grubh *et al.* 1990). This abundance was the result of plentiful food supply, in the form of the carcasses of domesticated ungulates. The keeping of livestock for milk production is common in rural areas, and cattle are abundant in many towns and cities. In large parts of India, Hindu beliefs prohibit the slaughter of cows and consumption of their meat. Dead feral and domestic cows are left in the open in rural areas or disposed of in carcass dumps around towns and cities (Prakash *et al.* 2003). Whilst vulture populations were able to exploit the large amounts of food available, Indian society benefited from the rapid and hygienic removal of dead livestock by vultures, a flock of which can pick a cow carcass clean in a matter of minutes (Ali and Ripley 1983).

The population of resident *Gyps* vultures in the Indian subcontinent crashed during the 1990s. This was first reported in the media in 1996-97 and later documented by the Bombay Natural History Society (BNHS), whilst monitoring raptor numbers in Keoladeo National Park, at Bharatpur in Rajasthan

(Prakash 1999). The BNHS conducted nationwide raptor surveys in many parts of India between 1991 and 1993 using a road transect method (Samant *et al.* 1995). The survey was repeated in 2000 and the results were dramatic. Both OWRV and LBV had almost disappeared from the areas surveyed. The populations of OWRV and LBV had declined by more than 92% between 1991-93 and 2000 (Prakash *et al.* 2003; 2005). Repeat surveys (in 2002 and 2003) showed that between 2000 and 2003, average annual decline rates were 48% for OWRV and 22% for LBV (Green *et al.* 2004). SBV and LBV were considered, and counted, as one species until the 2002 count, when SBV was found to comprise less than 2% of the combined total of LBV and SBV (Green *et al.* 2004). Results from the 2002 and 2003 counts suggested that the population of SBV was declining in India at approximately the same rate as the other two species.

In the Punjab province of Pakistan, an annual population decline rate of 50% was reported for breeding pairs of OWRV in nesting colonies between 2000 and 2003 (Gilbert *et al.* 2004; 2006; Green *et al.* 2004). Monitoring of nesting LBV in Sind province, Pakistan (Gilbert *et al.* 2004), showed that the numbers there had declined by about two-thirds between 2002 and 2006; an average annual decline rate of 25% per year (AVPP 2007). These results indicate that in both India and Pakistan, LBV has declined at a slower rate (22% and 25% per year respectively) than OWRV (48% and 50%). All three resident *Gyps* spp. in India are now listed as critically endangered by the IUCN.

The veterinary use of the non-steroidal anti-inflammatory drug (NSAID) – diclofenac - in livestock 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 toxic levels of diclofenac when they feed on carcasses of livestock which have died within a few days of treatment, and which contain residues of the drug (Oaks *et al.* 2004). Vulture that consumes sufficient tissue from such carcasses die from the effects of diclofenac induced kidney failure. Green *et al.* (2004) estimated that no more 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. Schultz *et al.* (2004) found that a high proportion of Oriental White-rumped and Long-billed vultures found dead in the wild had severe visceral gout, consistent with diclofenac poisoning being the main or sole cause of the population declines. The license to manufacture the drug diclofenac was withdrawn by the Drug Controller General of India via a letter dated May 11, 2006 addressed to all the State Drug Controllers. The toxicity of diclofenac to vultures and the strong evidence of its effect on their populations were the reasons for withdrawal.

In this paper, we report the results of surveys across much of India during March to June 2007, which follow the same methods and transects as those used during 2003, 2002, 2000 and 1992. We use these results to estimate the present population trend of the three critically endangered species of *Gyps* vultures and to make a rough assessment of the number of vultures which might remain.

METHODS

Vulture surveys

In 2007, vultures were counted on road transects widely distributed across northern, central, western and northeastern India. Transects were positioned in and near protected areas and also along roads distant from protected areas. The core set of transects repeated a survey carried out in 1991-1993, but additional transects were added during further surveys in 2000, 2002 and 2003. The first set of surveys, carried out during 1991-1993, will be referred to as the 1992 surveys for brevity. Routes followed in 2007 were the same as in previous surveys. Each transect was driven in a motor vehicle by a driver and observer, and vultures seen by the observer within 500 m on either side of the route were recorded. Vultures were identified to species, but *Gyps indicus* and *G. tenuirostris* have only been separated recently. Hence, the 1992 and 2000 counts do not distinguish between these two species, whereas the 2002, 2003 and 2007 surveys record them separately. In the 1992 surveys, only vultures in groups of five or more were counted because they were so numerous then, but in 2000, 2002, 2003 and 2007 all vultures were recorded. Transects were driven between March and June. The numbers of transects surveyed in 1992, 2000, 2002, 2003 and 2007 were 92, 98, 159, 149 and 165 respectively. The total length of transects driven in 2007 was 18,884 km. Further details of the methods are given by Prakash *et al.* (2003) and a map showing the area in which transects were carried out is in Green *et al.* (2007).

Estimates of population trend

Not all transects were surveyed in all years. Some transects were only surveyed for the first time after several previous surveys had been carried out elsewhere, some ceased to be surveyed after a few years of coverage and some had gaps in coverage. For this reason it is not possible to estimate changes in population by comparing the total number of vultures counted on all surveys across years. Furthermore, it is also not desirable to compare numbers of vultures seen per kilometre of transect across survey years because vulture density varies substantially geographically and the composition of the sample of transects changes over time. We adopted two approaches to overcome this problem: (1) we compared total number of vultures recorded on subsets of transects all of which were surveyed in all years within a specified period, and (2) we fitted log-linear Poisson regression models that allow for the effects of changing composition of the sample of transects.

In the Poisson regression analyses, the vulture count on each transect was treated as the dependent variable. The effects of transect and survey year on the number counted were modelled as factors. Including the effect of transect allows to some extent for changes across years in the representation of transects in the surveyed sample. Models were fitted in GLIM 4, with a Poisson error term and a logarithmic link function. The regression coefficients representing the year effects are the logarithms of the abundance of birds in a given survey year as a proportion of the abundance during the first survey year. Hence, the analyses yield an index of population density, which is relative to that to the first year of the series. In some analyses we included all the surveys (1992-2007), but in others we only considered the surveys during the periods 2000-2007 or 2002-2007. In particular, we analysed data for 2002-2007 for *Gyps indicus* and *Gyps tenuirostris* because these two species were separately recorded only during this period. In other periods we modelled the population index for the combined counts of these two species. However, because the total numbers of *Gyps tenuirostris* are much smaller than those of *G. indicus* (<2%), the index for the two species together can be regarded as approximately representing the situation for *G. indicus* alone.

We wished to estimate the average annual rate of population change and also to determine if it was changing over time. To do this, we fitted Poisson regression models with a logarithmic link function and transect as a factor, as described earlier, but with the effect of year modelled as a continuous explanatory variable; the number of years elapsed since the first year of the series being used. We only did this for the period 2000-2007, and not 1992-2007, because the vulture population decline probably began during 1992-2000, so it would be unrealistic to expect a constant rate of decline over the whole of this period. With this approach, the regression coefficient b of count on year represents the natural logarithm of the population multiplication rate ë, which is the ratio of the population in one year to that in the previous year. Hence, ë can be obtained as $\exp(b)$. To determine whether the rate of population change accelerated or decelerated during the study period, we fitted quadratic Poisson regression models in which both the year and the square of year were included as explanatory variables. The rate of decline is considered decelerating if the regression coefficient for the square of year is positive and is considered accelerating if this coefficient is negative.

We carried out significance tests of hypotheses about population changes using F tests, with the ratio of the residual deviance of the model with the most estimated parameters to its residual degrees of freedom being used as the error mean square. Likelihood-ratio tests were not performed because vultures often occur in groups, leading to counts being overdispersed. For this reason, asymptotic standard errors of parameter estimates are likely to be unreliable, so we obtained 95% confidence intervals for estimates using a bootstrap method. We took random samples of k transects, with replacement, from the k transects available for a particular time period. We then fitted the regression model for this bootstrap sample and recorded the value of the parameter estimate of interest. This procedure was repeated 1,000 times and the central 950 of the bootstrap estimates were used to define the 95% confidence interval. Further details of log-linear Poisson regression modeling of vulture counts are given by Green *et al.* (2004) and Green *et al.* (2007).

Crude estimates of vulture population size in 2007

We calculated rough estimates of vulture population size in northern, western, central and north-eastern India by assuming that the transect routes covered a random sample of this region. In fact, we think that this assumption is incorrect because many routes are located in or near protected areas, but we have ignored this problem in order to obtain crude estimates. We assumed that all vultures within the 1 km-wide recording strip on either side of the transect were detected. Hence, the area in square kilometres covered by a transect is approximately the same as its length in kilometres. We divided the total number of vultures counted on the transects covered in 2007 by their total length in kilometres to obtain an estimate of the number of vultures per square kilometre. We took the total size of the region of northern India within which the surveys were made as being approximately given by that of the states of India, excluding Goa, Andhra Pradesh, Karnataka, Kerala and Tamil Nadu. Multiplying this area by the vulture densities gives rough estimates of population size.

RESULTS

Long-term trend in vulture populations

Comparison of numbers of vultures counted on subsets of transects in which the same routes were surveyed in all years indicates very marked declines in numbers over the period 1992-2007 (Table 1). Numbers of *Gyps bengalensis* declined by 99.9% between 1992 and 2007 on those transects surveyed in every year during that period. The equivalent

Table 1: Number of vultures counted in each year on comparable sets of road transects in India. Each row shows the total number of vultures of a given species recorded in a set of transects covered in all of the survey years within the specified time period

Species	Time period	Transects	1992	2000	2002	2003	2007
G. bengalensis	1992 - 2007	70	21,204	888	283	130	31
	2000 - 2007	17		213	180	7	23
	2002 - 2007	35			566	37	1
	2003 - 2007	10				41	25
G. indicus & tenuirostris	1992 - 2007	70	6,574	17	414	102	213
	2000 - 2007	17		223	201	238	12
	2002 - 2007	35			206	8	108
	2003 - 2007	10				3	9
G. indicus	2002 - 2007	135			812	346	333
	2003 - 2007	10				1	4
G. tenuirostris	2002 - 2007	135			19	2	2
	2003 - 2007	10				2	5

decline in the combined total of *G. indicus* and *G. tenuirostris* was 96.8%.

The population indices derived from log-linear Poisson regression models give similar results to those from the simpler approach adopted in Table 1. The population index for *Gyps bengalensis* in 2007 was 0.1% of that in 1992 and the index for *G. indicus* and *G. tenuirostris* was 2.6% of the 1992 value (Table 2). Even over the shorter period 2000-2007, the declines have been large. The index for *G. bengalensis* in 2007 was 2.7% of that in 2000 and the index for *G. indicus* and *G. tenuirostris* was 34.1% of the 2000 value. Averaged over the whole period 2000-2007, the declines have proceeded at an average rate of 43.9% per year for *G. bengalensis* and 16.1% per year for *G. indicus* and *G. tenuirostris* combined (equivalent to ë = 0.5608 and 0.8387 respectively; Table 2).

Recent trends of *Gyps tenuirostris*

By 2007, the population index for *G. tenuirostris* has fallen to 13.4% of its value in 2002, when the species was first surveyed separately. Although, the index values suggest that the entire decline occurred between 2002 and 2003, the confidence intervals for the indices for this species are large because few individuals are recorded. For this reason, we cannot be sure about the exact pattern of decline, though the overall reduction in numbers from 2002 to 2007 is statistically highly significant.

Have rates of population decline slowed recently?

Inspection of graphs of population index against year suggests that the population decline of *G. bengalensis* showed no clear tendency to speed up or slow down over the period 2000-2007. If the rate of decline had remained constant, a straight line relationship would give a good fit to the data in a plot of index against year, with index on a logarithmic scale. A straight line relationship appears to give a reasonably good fit to these data (Fig. 1). A statistical test for progressive acceleration or deceleration of the rate of decline is provided by comparing a quadratic log-linear effect of year with the log-linear model. This test indicates no significant tendency for a change in rate of decline in *G. bengalensis* ($F_{1,190} = 0.05$, $P > 0.4$). For *G. indicus* and *G. tenuirostris* combined, inspection of Fig. 2 and Table 2 suggests that the rate of decline might have slowed because the index values for 2003 and 2007 are similar. However, the statistical test for a change in rate shows no significant slowing ($F_{1,167} = 1.20$, $P > 0.2$). This is because the confidence intervals for the population indices are too wide for the apparent pattern to be reliable.

Crude estimates of vulture population size in 2007

During the 2007 survey, 80 *G. bengalensis*, 337 *G. indicus* and 7 *G. tenuirostris* were counted on transects, i.e. a density of 0.0042, 0.0178 and 0.0004 birds per sq. km respectively.

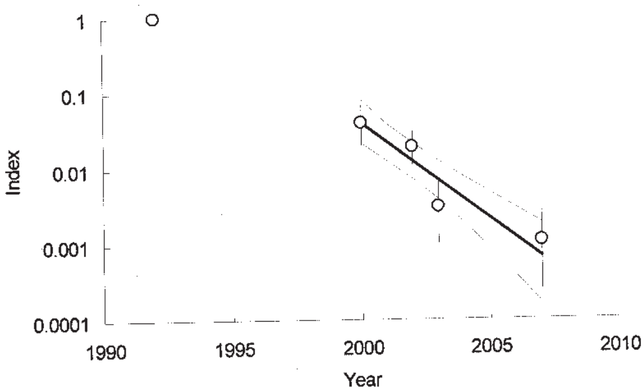

Fig. 1: Population indices and trend of Oriental White-rumped Vulture *Gyps bengalensis* from road transect counts in India. Circles show indices of population density, relative to that in 1992, estimated by log-linear Poisson regression, together with their 95% bootstrap confidence limits (vertical lines). The thick line shows the log-linear population trend fitted to data for the period 2000 - 2007 and the thin curves show 95% bootstrap confidence limits about the fitted line.

Table 2: Population indices and trends of vultures estimated by log-linear Poisson regression from road transect counts in India. Each column shows results for a particular species and time period. Informative transects are those that were surveyed more than once and on which at least one vulture of the species concerned was recorded during the time period. Population indices are estimates of the population density as a proportion of that in the first year of the period. A 95% bootstrap confidence interval is shown for each index (in brackets). The log-linear average population trend over a given period is shown as the population multiplication rate λ, together with its 95% confidence internal (in brackets).
F tests of significance are shown with P values indicates as; *** P<0.001, ** P<0.01

Species	*G. bengalensis*	*G. indicus & tenuirostris*	*G. bengalensis*	*G. indicus & tenuirostris*	*G. indicus*	*G. tenuirostris*
Time period	1992 - 2007	1992 - 2007	2000 - 2007	2000 - 2007	2002 - 2007	2002 - 2007
Informative transects	119	100	78	65	33	10
Year	Population relative to that in first year of series					
2000	0.0392	0.0746				
	(0.0196 - 0.0696)	(0.0332 - 0.1325)				
2002	0.0192	0.0636	0.4923	0.8521		
	(0.0102 - 0304)	(0.0268 - 0.1055)	(0.2572 - 0.9274)	(0.3116 - 2.0417)		
2003	0.0031	0.0259	0.078	0.3465	0.4100	0.0765
	(0.0010 - 0.0072)	(0.0058 - 0.0546)	(0.0229 - 0.2080)	(0.0657 - 1.1734)	(01497 - 0.7106)	(0.000 - 0.4800)
2007	0.0011	0.0255	0.0269	0.3413	0.4078	0.1340
	(0.0002 - 0.0028)	(0.0092 - 0.0483)	(0.0060 - 0.0793)	(0.1227 - 0.8138)	(0.1920 - 0.8182)	(0.0000 - 0.6666)
Significance of variation in population among survey years						
F	1130.75***	269.61***	68.11***	10.13***	8.29***	5.51**
d.f.	4,378	4,329	3,189	3,166	2,62	2,16
Annual population multiplication rate λ						
			0.5608	0.8387	0.8476	0.7773
			(0.4394 - 0.6737)	(0.6974 - 0.9429)	(0.7108 - 1.0040)	(0.0001 - 1.0887)
Significance of log-linear population trend						
F			157.53***	19.58***	7.15**	2.05
d.f.			1,191	1,168	1,63	1,17

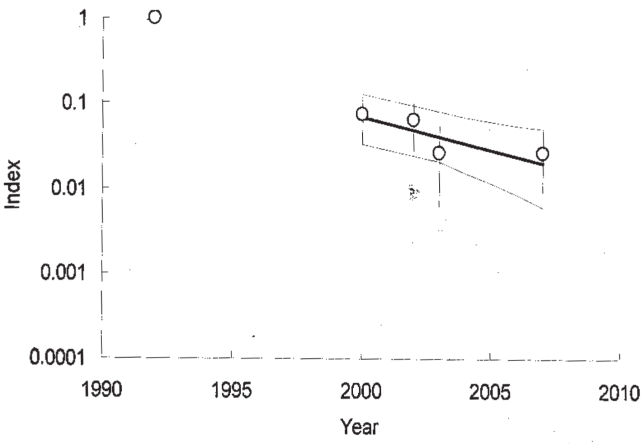

Fig. 2: Population indices and trend of Long-billed and Slender-billed Vultures combined (*Gyps indicus* and *G. tenuirostris*) from road transect counts in India. Circles show indices of population density, relative to that in 1992, estimated by log-linear Poisson regression, together with their 95% bootstrap confidence limits (vertical lines). The thick line shows the log-linear population trend fitted to data for the period 2000 - 2007 and the thin curves show 95% bootstrap confidence limits about the fitted line

Multiplying these densities by the approximate area of the region gives a total population of 11,000, 45,000 and 1,000 birds for the three species respectively.

DISCUSSION

The OWRV, which was the most numerous vulture species in India, is now in dire straits, with only one thousandth of the 1992 population remaining. The poisoning of vultures when they feed on the carcasses of diclofenac-treated livestock is well established and appears to be the major or the only cause of the vulture declines (Oaks *et al.* 2004; Green *et al.* 2004, 2007). Simulation modeling has indicated that less than 1% of the livestock carcasses available to vultures need to contain levels of diclofenac lethal to vultures to cause the recorded rates of decline across the country (Green *et al.* 2004). A recent study carried out on the prevalence of diclofenac in the livers of livestock carcasses across India reveals that over 10% of livestock carcasses contain diclofenac. Modeling based upon diclofenac concentrations in tissues available to vultures relative to that in the liver, and the proportion of vultures killed after feeding on a carcass with a known level of contamination, indicates that there is sufficient diclofenac in livestock carcasses to have driven the vulture population declines in India (Taggart *et al.* 2007; Green *et al.* 2007).

The results of the recent surveys of vultures indicate that the three species of resident *Gyps* vultures in the Indian subcontinent continue to be in great peril. Although numbers of two species (LBV and SBV) appear to have declined less rapidly since 2003, the numbers available counted are now so small that there is no statistically robust evidence of any deceleration of the rate of decline. The population of OWRV is evidently continuing to decline rapidly. Annual rates of decline consistently over 5% are very unusual in slow-breeding and long-lived birds like vultures and place them at grave risk of extinction (Newton 1979; Sarrazin *et al.* 1994). With average decline rates (2000-2007) of 43.9% and 16.1% for OWRV and LBV/SBV respectively, these species are at severe risk of extinction in India unless survival increases dramatically over the next few years.

Although our estimates of vulture population trends are likely to be reliable, our crude estimates of the absolute numbers of vultures remaining in northern India are tentative and must be treated with caution. Their most serious defect is that they assume that the densities of vultures in the areas surveyed are representative of the whole of northern India. This is unlikely to be the case because transect routes were not selected at random, and even if they had been, they must follow roads and tracks, which may not have typical vulture densities in their vicinity. If anything, because the transects cover more protected areas than a random set would have done, our surveys may overestimate total numbers. Although thousands of vultures may remain, they are now spread very thinly across a huge area. This is a dangerous situation for such social birds, which nest and roost communally and rely on information gained from one another when searching for widely dispersed food sources. Our population estimates and measurements of decline rates suggest that all three species could be down to a few hundred birds or less across the whole country, and thus functionally extinct, in less than a decade.

If wild vultures are to persist in India, it is essential that their survival is increased both rapidly and dramatically. The ban on diclofenac production for veterinary use was an excellent first step. However, this action is insufficient on its own to save these species. It is essential that diclofenac is no longer used for the treatment of livestock, and this requires a rapid ban on the use of diclofenac in livestock. The manufacture of diclofenac for veterinary use was banned by the Drug Controller General of India in August 2006. The drug has a shelf life of 2-3 months and remaining stocks should have been out of the system by now. However, the drug continues to be available at many retail outlets and diclofenac formulated for human use filters into the veterinary sector (Nita Shah, BNHS Vulture Advocacy Programme *pers. comm.*). It is imperative that the drug is removed completely from use in livestock without any further delay to avoid the extinction of the three vulture species.

In addition, with small populations and the continued high mortality rates suggested by the rapid decline, it is essential that birds are brought into conservation breeding programmes as rapidly as possible, to ensure that birds are available for reintroduction once the environment is free of diclofenac. It is important to do this for all three species, but the strong evidence for continued rapid decline of OWRV makes vigorous action to safeguard this species in captivity an especially urgent priority. The rapidity of vulture decline and the uncertainty about when diclofenac contamination will be removed make the rapid expansion of the conservation breeding programme a continuing necessity. The recommendations of the Vulture Recovery Plan 2004 (ISARPW 2004.) of setting up six Vulture Conservation Breeding centres in South Asia with three in India should be implemented forthwith. It is urgent to have the full complement of 25 breeding pairs of each of the three species in each of the centres to provide a viable captive population with sufficient genetic diversity and security against stochastic events. The Conservation Breeding Programme appears to be the only effective method for ensuring that further delays in removing diclofenac from the vultures' food supply do not lead to their extinction in India.

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