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Counting the cost of vulture decline—An appraisal of the human health and other benefits of vultures in India

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ABSTRACT

Widespread use of the non-steroidal anti-inflammatory drug (NSAID) diclofenac to treat livestock has resulted in dramatic declines in the populations of vultures across India. This has become an issue of considerable concern as vultures are a keystone species and their decline has a range of socio-economic, as well as cultural and biodiversity impacts. In this paper, we review these impacts and estimate in detail the economic cost of one of them: the human health impacts of the vulture decline. Livestock carcasses provide the main food supply for vultures, and are also eaten by dogs. Dogs are the main source of rabies in humans in India, and their populations have increased substantially in parallel with the vulture decline. The potential human health impact of rabies associated with the vulture decline is found to be significant. This, and a wide range of other impacts suggest that significant resources should be put into (1) testing of pharmaceutical products to ensure that similar situations are not repeated, (2) helping vulture populations to recover through the use of alternative drugs to diclofenac that are of low toxicity to vultures, and (3) through conservation breeding programmes.

1. Introduction

1.1. *The problem of vulture decline across India*

Vultures are significant spiritually, economically and environmentally. They have historically played a very important role in environmental health, by disposing of animal and human remains. The vulture God 'Jatayu' plays a part in Hindu mythology. Widespread acknowledgement of the important ecosystem services played by vultures has led to concerns about the socio-economic consequences of their decline. In this paper we review the potential impacts of the decline.

A rapid population decline of three species of vultures, the long-billed vulture (LBV: *Gyps indicus*), slender-billed vulture (*Gyps tenuirostris*), and oriental white-backed vulture, (OWBV: *Gyps bengalensis*) across India was first reported in the late 1990s. The decline was documented by comparing results from road transect surveys of raptors across Northern and Central India in 1991–93 and 2000 (Prakash et al., 2003a). Results showed annual decline rates of 33% for OWBV and 27% for LBV respectively (Green et al., 2004). Repeat surveys in 2000, 2003 and 2007 showed that the declines had continued, at annual rates of 44% and 16% for OWBV and LBV respectively (Green et al., 2004). The estimated decline during the period 1992–2007 is 96.8 (LBV) to 99.9 (OWBV) percent (Prakash et al., 2007). Declines of this rapidity and geographical extent are unprecedented. Research results have found the major, and possibly sole, cause of the dramatic vulture population decline

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across South Asia (India, Nepal and Pakistan) to be the veterinary use of diclofenac, a non-steroidal anti-inflammatory drug widely administered to livestock across the Indian subcontinent (Oaks et al., 2004; Green et al., 2004; Shultz et al., 2004). Vultures are obligate scavengers, feeding primarily on the carcasses of large ungulates, and are exposed to diclofenac when they scavenge the carcasses of livestock treated with the drug shortly before death.

The structure of the paper is as follows. First, an overview of the socio-economic impacts of vulture declines is given. Methods for economic valuation are then presented. Data on vulture declines and the impacts on dog numbers are then identified. The human health endpoints are then assessed and valued. A key issue is that of the policy implications of this research and these are presented before some general conclusions are drawn.

1.2. *The nature of the socio-economic impacts of vulture decline*

Vultures can be regarded as a natural resource, like air and water, which provide society with a number of 'services', most notably the disposal of carrion, especially livestock carcasses. These services have an impact on human health, economic activity and on environmental quality. An overview of these impacts is provided below.

1.2.1. *Human health*

An increase in uneaten livestock carcasses may pose a direct threat to human health because they provide a breeding ground for pathogenic bacteria leading to the possibility of direct or indirect infections. As such, these carcasses can be sources of a range of infectious diseases, such as anthrax, which is common in livestock in parts of India (George et al., 1994; John, 1996; Vijaikumar et al., 2002). In removing carcasses rapidly and efficiently, vultures cleanse the environment and help protect humans, livestock and wildlife from infectious diseases. Fig. 1 illustrates the hypothetical relationships between the decline in vulture population and human health impacts including dog bites and rabies. A fall in the vulture population could result in an increase in the dog population (Prakash et al., 2003a). India has the highest rate of human rabies infections in the world, and dog bites are the main source (APCRI, 2004). Over 95% of human deaths due to rabies are due to dog bites (Kale et al., 2006).

An increase in dogs could result in an increase in the incidence of dog bites and rabies among humans. There have been reports in the Indian media of rabid dog attacks on children and domestic stock (e.g. The Times of India, 8th June 2003), as well as recent reports of direct mortality from dog attacks (e.g. India Press Service News Agency, Jan 17th 2007, Bangalore). Dogs also suffer from a variety of other diseases including brucellosis and canine distemper, some of which have the potential for transmission to humans, domestic livestock and/or wildlife. It is true that it might be possible to mitigate the increase in dog numbers through measures such as neutering—and programmes including the Animal Birth Control programme (ABC) are in place. However, over the period 1987 to 2003 dog numbers continued to grow (Ministry of Agriculture (2003) 17th Livestock Census. Available online from www.dhd.nic.in).

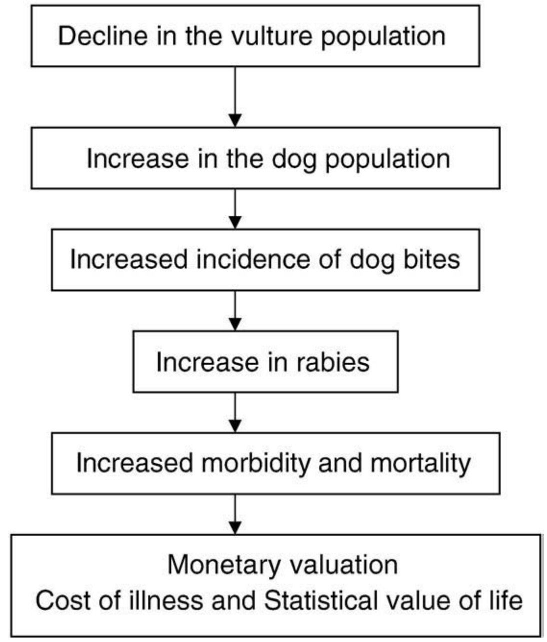

Fig. 1 – Valuing health damages from reduced vulture populations in India.

In addition, the loss of vultures might contribute to the number of rotting livestock carcasses and thus environmental pollution (air, soil and water), resulting in an increased incidence of infectious diseases among people. Vultures probably helped control livestock diseases such as brucellosis, tuberculosis and anthrax by disposing of infected carcasses (Swan et al., 2006).

Increases in other scavenger populations may also have significant socio-economic impacts. Rats, feral cats and other species may increase in numbers, leading to spread of disease. The spread of rabies is largely attributable to dog populations, but increases in prevalence rates of other diseases may be an issue. For example, rodents are a reservoir of leptospirosis (CD Alert, 2000a).

1.2.2. *Costs to industry*

There is a range of potentially important economic impacts of the vulture declines related to economic activity. There are several commercial uses for animal by products in India, the most notable being in the tanning, gelatin and fertilizer industries. As soon as cattle die, a skinner will remove the skin for the tanning industry. This then makes the carcass available for vultures (who have difficulty breaking through the skin) to remove the flesh. After rapid removal of the flesh by the vultures the stripped bones then dry rapidly and can be gathered shortly afterwards by bone collectors, an old trade among India's poor, who supply the fertiliser industry. Vulture decline has impacts on both these professions. The first impact is loss of supply if livestock carcasses are disposed of by burial or incineration as is happening in several regions (authors own data). The second results from incomplete removal of flesh by dogs and other scavengers. Among extant vertebrates, vultures are the only obligate scavengers (Ruxton and Houston, 2004), and are more efficient at cleaning carcasses than most other scavengers. Incomplete removal of flesh on carcasses, due both to the reduced number of scavengers and changes in scavenging species, is likely to increase the period necessary for bone drying prior to collection, may reduce bone quality, and, in cases where considerable flesh remains, make bone collection difficult, thus increasing the effort needed.

1.2.3. Disposal costs to local communities

When livestock die in rural areas, in the absence of vultures, locals or local authorities must either accept the disamenity of the stench of rotting flesh and the increased disease risks, or incur the costs of carcass disposal (e.g. by burial or incineration). Even in areas where dogs have increased considerably, they do not remove the need for carcass disposal because there are often insufficient dogs; and, as they are not such efficient scavengers, they leave part of the carcass unscavenged.

1.2.4. Recreation

Other important benefits society receives from the protection of vultures derive from the pleasure people might receive by viewing them. For example, some ecotourism companies include the possibility of seeing vultures within their itineraries, and several tour operators offer bird watching tours in India specifically to see vultures.[1] Tourism attracted by viewing vultures generates additional income for sectors, which supply the tourism industry.

1.2.5. Existence values

Many people derive an 'existence' or 'non-use' value by simply knowing that the species continue to live in their natural habitat at a sustainable level. Charity collections, such as those raised by the Royal Society for the Protection of Birds (RSPB) in response to the vulture decline, may be able to capture some of these values. The values placed on vultures may also include values on the option of viewing or bequest values for future generations. Such values include those of people inside and outside of India.

1.2.6. Cultural and religious values

Vultures are important for the considerable cultural and religious significance that some communities (such as the Parsee in India) attach to their role of disposing of human bodies: for thousands of years and in different parts of the world, humans have laid out their dead for consumption by vultures (Schüz and König, 1983). In the Hindu religion, animals, birds and snakes are considered important for human existence, and within Hindu mythology, the vulture God Jatayu is regarded as a holy bird. Jatayu gave up his life while attempting to protect Sita, wife of Rama. He is one of the principal characters of the Hindu epic "Ramayana" and tries to rescue Sita from Ravana, one of her former suitors that kidnapped her while Rama was away hunting.

Here we focus on the impact on the Parsi community, a small religious and ethnic group making up less than 0.02% of population of India and living mostly in the cities of Mumbai, Delhi, Lucknow, Ahmadabad, and Hyderabad. The followers of this community are called Parsis because the religion, Zoroastrianism, arrived in India with them from what was then Persia. The Parsis believe that fire, water, air and earth are pure elements that need to be preserved. Therefore they do not cremate or bury their dead but dispose of dead bodies in "Towers of Silence", built on top of hills or low mountains in desert locations distant from population centres, where the corpses are left exposed in the open. The corpses are then disposed of by scavengers. Historically, this has involved vultures, which remove the majority of the flesh rapidly, followed by crows and other scavenging birds. They consume the flesh until only the skeleton remains.

In order to ascertain the views of Parsis, members of this community in Mumbai, Delhi, and Hyderabad were contacted during June–July, 2005. The President and many members of the Parsi Panchayat of Mumbai were interviewed on 29th July, 2005 in Mumbai. A questionnaire was designed explaining the decline in vultures. Respondents were asked about the value the members of the community place on the services vultures provide to them. This questionnaire was circulated to the members of Mumbai Parsi Community two weeks before meeting them.

The survey found that vultures do not play a spiritual role per se, but are recognised for their practical utility in aiding in the disposal of corpses, as observed by the president of the Parsi Panchayat in Delhi in a written communication:

> *"The study is of interest to the Parsi Community, because we Zoroastrians are enjoyed to preserve all God's creations: Mother Earth, man, animals, and the vegetation. The Gyps Vulture is a bird, which provides great service to mankind in keeping clean the environments. It is recognised as valuable link in the chain or creation, destruction and regeneration. It is thus not a 'spiritual value' as you put it, but a recognition of its practical utility, which Parsis recognise.*
>
> *It may not be equally well known that the Tower of Silence method of the disposal of our dead, in which the Vultures play an important part is practiced only in the original Parsi settlements. Places in what was earlier called the Bombay Presidency and a few other locations viz. Bangalore, Hyderabad and Kolkata have Towers of Silence. The concept of disposal of the dead with the help of birds goes back to Central Asia, the old homeland of the Zoroastrians. It is also followed by Tibetans, and others originating from that region. But even in Iran, the homeland of Zoroastrians, it has fallen into disuse. In most other places in India, we have 'Aramaghas' where the dead are buried".*

Therefore the only cost associated with the vulture decline from the Parsi community perspective that can be identified is the lack of services provided by vultures at the Towers of Silence. As vultures have declined and disappeared from Mumbai, the Parsis have had to find alternative means of disposal of their dead. In Mumbai, this has involved the use of 8 solar concentrators installed at a cost of Rs.200,000 each, which amount to Rs.1.6 million. The solar concentrations produce heat of 120 °C, which is sufficient to turn a body into a skeleton in 3 days.

[1] Naturetrek (www.naturtrek.co.uk) and Wildlife Conservation & Restoration Tourism (http://www.restorationfarms.com/index.html) are among the tour operators that provide tours in India to watch vultures in their natural habitat and in captive breeding programme centres.

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A full Contingent Valuation Method (CVM) study (Mitchell and Carson, 1989) would be required to ascertain the cultural and religious values of the vultures in India, but this was beyond the scope of our research.

1.2.7. *Other environmental impacts*

Wider environmental impacts may include those associated with increases in scavenger populations other than dogs and water pollution due to the fouling of watercourses by rotting carcasses. Water pollution is a major issue in India. The values placed on clean water have been assessed by Markandya and Murty (2000), among others. The linkage between the number of rotting carcasses in water and vulture declines is hard to assess, due to alternative disposal methods. This is an issue that may warrant further investigation.

2. Methods of economic valuation

Direct methods to value the costs of vulture declines would include the application of contingent valuation techniques. Previous studies on the existence value of bird species show significant willingness to pay to preserve species, though these have largely been based in the United States. Reaves et al. (1999) show willingness to pay to restore the red cockaded woodpecker of between $7.57 and $13.25 per person per year in South Carolina. Stevens et al. (1991) show a willingness to pay for bald eagle preservation of $28.25 from a mail survey. Bowker and Stoll (1988) find a willingness to pay of between $21 and $42 for whooping cranes. Such techniques have been used in Israel to value the impact of vulture populations in terms of the benefits of viewing vultures (Becker et al., 2004) and in Nepal to value the decline in vulture populations (Baral et al., 2007). The transferability of these results is difficult given the different nature of the species and cultural significance—as well as the context—in the Israeli case and the survey design in the Nepali case. Baral et al. (2007) show a willingness to pay $1.55 to $1.62 per household for preserving vultures in a CV study in Nepal. This study surveyed households within a 2 km radius of vulture colonies and had a relatively small sample ($n=103$). To generalise a value from this for the Indian case would be difficult given that most of the population lives further from vulture colonies and the differing social conditions in Nepal and India.

It was not possible in this study to employ contingent valuation methods, due to budget constraints. We decided to employ a more ecosystems based approach to value the indirect impacts of vulture decline in the Indian case, drawing on data on health and the nature of the relationship between dog numbers and the vulture population decline. This is a partial valuation and involves a number of assumptions due to a lack of knowledge by the authors of a model of the food web in the Indian case. Nevertheless, we believe it offers an important and useful perspective to understanding the problem.

Fig. 1 illustrates only one set of possible human health effects that could result from the vulture declines; there are many other human health effects, and other socio-economic effects as discussed above. Table 1 provides a summary of impacts and the methods of valuation associated with them. In this study, treatment and loss of work through dog bites, and potential increases in human rabies have been valued, but the majority of impacts have not. Consequently, the monetary valuation of effects in our study is likely to be a substantial underestimate of the true benefits provided by vultures.

Table 1 – Impacts and costs of decline in vulture numbers

Impact	Method of valuation
Potential costs of vulture declines	
Increased dog bites	Costs of illness and loss of earnings
Increased human rabies from dog bites	Costs of premature mortality as value of statistical life
Increased human diseases resulting from increased populations of other scavengers and altered disease dynamics (e.g. rodent increase, leptospirosis etc.)	Costs of illness and loss of earnings and premature mortality
Direct human mortality from dog attacks	Costs of premature mortality as value of statistical life
Mortality and disease increase in domestic stock	Cost of reduced working life of stock
Increases in other scavenger populations	Costs of illness
Water pollution	Contingent valuation of water quality
Cultural value	Survey of affected communities (Parsis)
Utility value to Parsis	Replacement cost of corpse disposal
Tourism	Survey methods or by analysis of expenditure of visitors to bird viewing sites
Bone collectors	Additional costs of cleaning bones or risk of disease
Tanners	Reduced availability of carcasses for skinning
Local communities/ municipalities	Increased costs of carcass disposal through burial or incineration
Increased existence value placed on remaining vultures	Contingent valuation
Potential benefits of vulture declines	
Impacts on air accidents	Costs per accident as assessed by air transport authority

3. Impacts data and associated values

3.1. *Estimated vulture numbers*

It is important to have an estimate of both absolute vulture numbers and rates of decline to help assess what relationship may exist between them and other scavengers. In 1992, the number of vultures seen per kilometre of transect driven was 4.336 (Prakash et al., 2003a,b). As observers counted within 500 m on either side of the road this is the same as the number per sq km. Assuming a vulture range within India of

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2,200,000 km^2 (the surface area of India is 3,288,000 km^2) this leads to an estimated total population of 9,538,250 vultures. However, only groups of 5 or more birds were counted in 1992.[2] Counts from 2000–2003, indicated that 3.9% of birds were individuals or in groups of less than 5. The proportion of birds in small groups may have altered in either direction as densities of vultures changed over time, but assuming this remained constant, we can increase the 1992 estimate by 3.9% to 9,910,242, or about 10 million birds. Results from surveys conducted in 2000 and 2003 (Green et al., 2004) gave mean densities of vultures of 0.164 and 0.033 per km of transect. Assuming the same vulture range within India of 2,200,000 km^2 (RSPB, pers. comm.) and assuming the same proportion of birds in small groups, this gives estimated populations of 374,871 and 75,431 vultures in 2000 and 2003 respectively, corresponding to a decrease of about 99% in vultures with respect to the 1992 estimates.

3.2. *Increase in numbers of dogs*

One of the major hypothetical impacts of a decline in vultures is believed to be an increase in the dog population. Dogs have replaced vultures as the main scavenger at carcass dumps monitored, and now litter at the carcass dumps. It is thus reasonable to assume that the increase in dogs has partially resulted from the decline in vultures. This is likely to result in an increase in dog bites, and consequently rabies cases in humans. Dog bites are thought to account for the majority of human rabies cases (96.2%, APCRI, 2004), and the majority of dog bites are from feral or stray dogs (APCRI, 2004; Chhabra et al., 2004).

There are no accurate estimates of the dog population in India. Dogs cannot be categorised as either domestic or stray, as a variety of levels of dependency by dogs on humans exists in India. Levels of dependency for food, and restriction of movement by man range from total, such as for many domestic pets, through to none, for feral dogs. There is also a wide gradation between these two extremes with neighbourhood dogs that are semi-dependent and semi-restricted, and unrestricted dogs that are still semi-dependent upon man for food (e.g. WHO, in press). One set of national estimates that appear comparable over time is from the Ministry of Agriculture (2003) 17th Livestock Census (available online from www.dhd.nic.in). Participants in the census were instructed to count dogs owned by households as domestic, and all other dogs, including dogs fed by households but not owned by them as 'other'. Total counts are therefore likely to include the majority of semi-dependent dogs around count households, but may not include a high proportion of truly feral dogs. The Livestock census figures nonetheless give an indication of the trends in populations of dogs that depend, at least partly, upon food other than that directly provided by humans. The estimates are, however, likely to be underestimates of total dog populations.

The Census data indicate that dog numbers increased by an estimated 7.25 million (from 21.77 to 29.02 million) between 1992 and 2003, over a period when vultures declined from an estimated ten million to 72,600 (35–110,000). This increase happened despite dog sterilisation programmes, for example resulting from the Animal Birth Control (Dogs) Rules 2001.

3.3. *Linkage of vulture decline to dog population increases*

It is impossible to know the exact contribution of the vulture decline to the increase in dog numbers and indeed estimates of dog numbers themselves vary between different sources.[3]

One way of evaluating the proportion of the increase in dog numbers that could potentially be accounted for by the vulture declines is to look at the amount of food that has become available over this period. Vultures need about 0.341 kg of ungulate tissue a day which contains approximately 490 cal or 2050 kJ (Swan et al., 2006, Supporting information Protocol S1). An average sized dog[4] needs about 660–1320 cal a day (Dewey and Bhagat, 2002), or 0.46–0.92 kg of ungulate tissue. The food for one vulture is approximately equivalent to the food for 0.37 to 0.74 dogs. Consequently, enough food will have been made available because of a decline of about 10 million vultures (between 1992 and 2003) to support an increase in the dog population of 3.7–7.3 million dogs. Therefore, the increase in the dog population of 7.25 million calculated by the Census over this period is consistent with these figures assuming that the dog population was in equilibrium with food supplies prior to the decline in vultures and remains in equilibrium now.

That some kind of causal relationship exists between the vulture declines and increased dog population is supported by the relative stability of the dog population between 1982 and 1987, over a period when vulture numbers were very high in India and were not considered to be declining. We take an average of 0.555 dogs per vulture as the estimated increase in the dog population attributable to the vulture decline over the period 1002 to 2003 based on this food availability assumption.

An alternative approach to estimating the effect of vulture population change on the dog population is to fit a regression of dog population on vulture population. It is important to note that this is based on a very small number of observations, some of which have been interpolated from available data—hence the results should be used with caution. Ideally one would have a full food web model to assess the complex interactions between populations, but this was not available at the time of writing. Table 2 shows the results of regression analysis on the numbers of dogs and vulture numbers. From the results we can see a link between the two populations, with the lin-log performing best in terms of explanatory power. All coefficients are significant. In the analysis that follows the regression linkage will be based on the lin-log model.

Although the regression supports an inverse relationship between dog and vulture populations, the nature of the

[2] The actual survey was conducted over the period 1991 to 1993.

[3] For example, another survey (NICD, 2000) estimated the dog population in India at 22 million although they did not state the date of the estimate, and the Association for the Prevention and Control of Rabies in India (APCRI) estimated the number of domestic dogs alone to be 28 million (APCRI, 2004).

[4] An average sized dog weighs 10–20 kg, based upon body weight of a Pariah Dog (12–20 kg) and a Dhole *Cuon alpinus* (10–13 kg for females and 15–20 kg for males). See http://www.dogbreedinfo.com/pariahdog.htm and www.sandiegozoo.org/animalbytes/t-dhole.html.

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Table 2 – Regression analysis of linkage between dog and vulture numbers

Functional form	Linear	Log–log	Lin-log
Coefficient	27.94904***	4.09606***	47.3352***
Vulture numbers	−6.44E-07**	−0.0621***	−1.5688***
R^2	0.8508	0.9553	0.9607
N	5	5	5

Notes: natural logs used. Dogs reported in millions, vultures in absolute terms. **—significant at 95% level, ***—significant at 99% level.

relationship is different. The food availability argument would suggest a linear relationsip but dog numbers appear to have increased linearly over time since the late 1980s as vulture numbers have decreased exponentially. The relationship is obviously not a straightforward one, and one might not expect a significant relationship. Reproductive and other behavioural time lags may affect the speed with which dogs can exploit a new resource, and other factors will influence dog numbers, such as dog sterilisation programmes, diseases, the availability of other food supplies, and populations of other scavengers. However, whilst such results, especially direct comparisons between dog and vulture population trends, should be interpreted with considerable caution, it is highly likely that the decline in vulture numbers is, at least partly, responsible for the increase in the dog population. From the analysis conducted we think it reasonable to assume that the dog population increase attributable to vulture decline to be in the range of 3.7 to 7.3 million to 2003.

3.3.1. *Number of dog bites and cases of rabies*

The next stage in the analysis is to estimate the number of bites and the number of cases of rabies relative to both the dog population and to the human population (i.e. number of bites per dog and number of bites and rabies cases per 1000 of population). A recent study APCRI (2004) estimates an annual national incidence of animal bites of 17.4 million in 2003; with 96.2%, or 16.7 million bites from dogs. Given the dog population of 29.02 million in 2003, this gives an incidence of 0.58 bites per dog. For the purposes of this study, we also assume the relationship between number of dogs and number of dog bites to be linear, although this may not be the case as, for example, the behaviour of dogs (and people) may change with the density of dogs.

APCRI (2004) also provides some estimates of the incidence of rabies in the human population and its economic cost in India. This study uses two datasets from a sample of hospitals and from a sample of households in India. The data from the hospitals were collected in 1992–2002 from the annual hospital admissions of human rabies cases from 22 district hospitals spread throughout the country, covering a population of 10.8 million to establish the overall trend of human rabies in India. Their estimates included an active community search; a recall time of 5 years was assumed in rural areas, and 3 years in urban areas due to increased population mobility.

The main findings of the ACPRI report include the following:

Cases of rabies: Fig. 2 provides estimates of human rabies cases from 1992–2002 in 22 hospitals from 18 states in India. Overall, rabies cases appeared to fluctuate and fall slightly over this period, although exact data on rabies cases in India is not available because few surveillance mechanisms exist (Chhabra et al., 2004). The decline in rabies cases in urban areas, as revealed in the hospital admissions data, is attributed by Sudarshan et al. (2007) to an improvement in overall socio-economic development and a significant increase in the use of rabies vaccines. Overall, given a constant infection rate, one would expect a decline in human deaths from rabies, even with an increased rate of dog bites and an increased human population, as the vaccination rate increased by 80% between 1997 and 2004. In reporting to the World Health organization in 1997, India estimated Post Exposure Treatments (PETs) of 1 million for that year while official estimates from the NICD reveal a huge increase in post exposure treatments (PET), from 1.1 million in 2001 to 1.4 million in 2002 to 1.8 million in 2004 (NICD, pers. comm. & CD Alert, 2000b).[5] Evidence from APCRI (2004) and Sudarshan et al. (2007) suggest much higher levels of vaccination. The APCRI survey reveals that 47.9% of those bitten seek treatment while Sudarshan et al. assert that 60% of rabies exposed people are vaccinated and that nearly 5 million doses of vaccines are sold every year. Sudarshan et al. (2007) point out that the observed decline in rabies cases from admissions to urban hospitals may not be representative of trends in rural India, where two thirds of the population live and where the majority of rabies cases occur. From the household survey, suspected cases of rabies reported increased considerably over time in both rural and urban situations. The authors considered this to be due to memory recall attrition or migration/mobility of the affected families. Consequently, they based their estimates of rabies on only the previous 16 months. However, an alternative explanation is that rabies incidence had actually increased in the communities surveyed over that period.

Distribution of deaths from rabies: The APCRI (2004) report also provides the distribution of deaths from rabies by social and economic groups emerging from the household survey. The incidence is very high among the poor, the more vulnerable sections of the population accounting for majority of deaths (87.6%). In addition, adult and male sections of population are relatively more affected indicating significant income losses to the households (Table 3).

Estimates of deaths from rabies: The APCRI (2004) estimated 20,565 rabies deaths annually (2.06 cases per 100,000).[6]

In summary, we conclude that the annual number of rabies cases in India was about 2 per 100,000 persons at the time of the study.

[5] See: http://www.phac-aspc.gc.ca/publicat/ccdr-rmtc/00vol26/dr2602eb.html for 1997 estimate.

[6] This estimate is slightly lower than the estimates based on projected hospital statistics: 25,000 for the year 1985 and 30,000 for the year 1998 (WHO, 1999). Although not directly comparable, the two estimates are broadly similar. The APCRI data are based on structured representative surveys, and the WHO estimates on from hospital records (APCRI, 2004).

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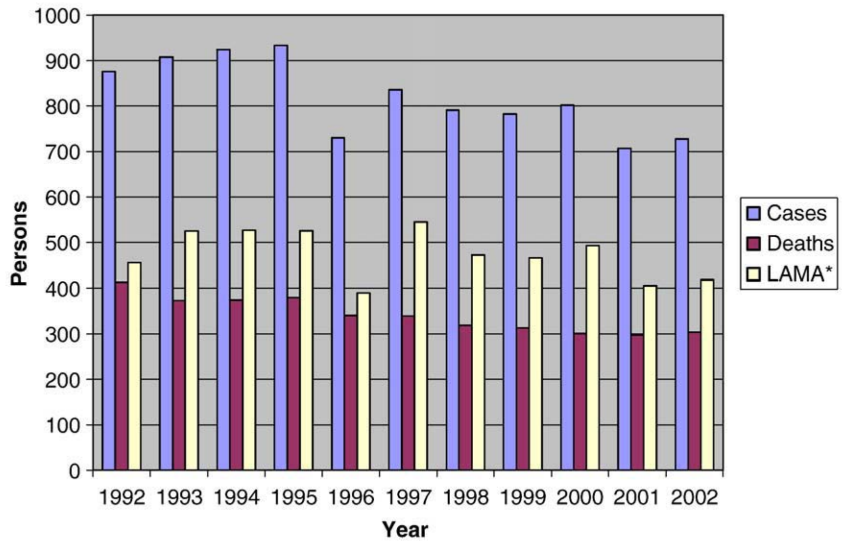

Fig. 2 – A decadal hospital incidence of human rabies (clinical epidemiological diagnosis in 22 medical hospitals from 18 states during 1992–2002). Source: APCRI (2004). *A high proportion of people left hospital against medical advice (LAMA) following rabies diagnosis. Deaths are recorded for those that remained hospitalized but it is likely that the majority of people diagnosed as rabies cases will have died. Cases are probable cases based on clinico-epidemiological diagnosis so deaths plus LAMA should add up to cases.

3.4. *Human health costs of the vulture decline*

3.4.1. *Estimated physical impacts of vulture decline*

In this section we use the cost of illness approach (Harrington and Portney, 1987) to quantify the human health morbidity costs of vultures decline. A dose–response function links dog bites to days of illness. These predicted days of illness are then multiplied by the monetary costs of illness, calculated as the sum of the medical expenses, plus lost wages.

On the basis of the foregoing analysis, we assume that a significant proportion of the 7.25 million increase in the dog population calculated by the Census Ministry of Agriculture (2003) 17th Livestock Census (available online from www.dhd.nic.in) between 1992 and 2003 could have resulted from the vulture decline. As the estimates of dog populations do not include many of the dogs that have no dependency on humans, the increase is likely to be greater than the Ministry of Agriculture (2003) 17th Livestock Census (available online from www.dhd.nic.in) estimates. We use both the food linkage and regression linkage estimates to assess the impacts of vulture declines on dog bites. As number of dog bites, we use the annual incidence of dog bites of 16.7 million calculated by APCRI (2004). This leads us to an estimate of between 38.5 million to 39.7 million additional dog bites in the period 1992 to 2006.

In terms of fatal rabies cases, APCRI (2004) estimated 20,565 fatalities due to rabies in 2003. This leads to a rate of 1.23 deaths per 1000 bites for 2003. Taking this rate as being a conservative estimate of the rate of rabies deaths related to dog bites (given advances in postexposure treatments), this leads to an estimate of the number of additional deaths caused by increases in the dog population of 47,395 to 48,886 in the period 1992 to 2006. These are conservative estimates given the evidence of increasing use of PETs over the period. Taking the point estimate for 2003 is therefore likely to underestimate impacts in the years before this date and overestimate impacts in the years following.

Hence, it is possible to estimate the change in human health impacts due to vulture declines. We use both the statistical relationship identified above for linking dog numbers and the vulture population and the relationship derived from the relative consumption of food. The estimated cumulative increase in dog numbers over the period to 2006 ranges between 5.5 million and 9 million dogs. 5.5 million is the mid point of estimated increases based on the food linkage and 9 million is based on the

Table 3 – Human rabies incidence based on household survey

	Urban	Rural	Total
Human rabies deaths (Number)	56	179	235
Age distribution (%)			
Children (≤14)	25.5	38.3	35.3
Adults(>14 years)	74.5	61.7	64.7
Sex distribution (%)			
Male	72.7	70.6	71.1
Female	27.3	29.4	28.9
Economic level (%)			
Poor and low income	81.9	89.3	87.6
Middle income	14.5	7.8	9.4
Upper income	1.8	1.7	1.7
Not reported	1.8	1.2	1.3

Source: APCRI 2004.

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Table 4 – Summary of costs 1992–2006 from vulture declines (Rs billion)

Dog/Vulture linkage		Dog bites	Mortality	Total
Regression linkage	Low estimate	37.26	992.14	1029.39
	High estimate	103.81	992.14	1095.95
Food based linkage	Low estimate	36.12	961.88	998.00
	High estimate	100.64	961.88	1062.52

regression analysis extrapolated to 2006. In the next section we attempt to place a monetary value on this increase in the dog population.

3.4.2. *Valuation of health impacts*

To value the impacts of vulture decline, we apply the values for morbidity and mortality endpoints as described below.

3.4.3. *Morbidity endpoints*

APCRI (2004) estimates that, on average, an animal bite results in 2.2 person days of work lost and the cost of Rs.252 for medicine and visiting the doctor. Assuming that wage loss per day to a worker in India is on the average is Rs.100 (based on India's per capita income at current prices of about Rs.24,000 during the year 2004–2005) there is a wage income loss of Rs.220 per animal bite. Thus the total cost of an animal bite is Rs.472. However, in reality the cost of Rs.252 for rabies vaccine and doctors consultation is a subsidized cost by the Government. The market price of rabies vaccine could cost a dog bite victim anywhere between Rs.1500 and Rs.5000, resulting in a true cost per bite of between Rs.1720 and Rs.5220. We should note that only those who seek treatment incur these costs. As noted, there is evidence to suggest that the number of people bitten who seek treatment exceeds the number of PETs administered as estimated by the NICD. However, to be conservative we base treatment costs on the NICD figures which suggest just 8% of those bitten receive treatment. We assume this percentage has remained constant over the period.

We estimated the morbidity endpoints based on upper and lower bounds used for the costs of dog bites and estimated increases in dog bites associated with increased dog numbers. The costs for bites alone amounts to Rs.13.1 to Rs.24.4 billion in total over the period 1993 to 2006.

3.4.4. *Mortality endpoints*

For the cases of mortality there are only a few monetary estimates of the value of a statistical life for the Indian population. Probably the most accurate and recent is that of Madheswaran (2004). He made estimates using a hedonic wages model in which the compensation paid to workers to accept a higher risk of death was calculated. This provides estimates of value of statistical life for the workers in Chennai and Mumbai as Rs.15.4 million and Rs.14.8 million respectively. It is problematic to take these values and apply them to all deaths in India but as there are no other studies, and as these estimates are not out of line from what we would expect from international studies, we believe it is reasonable to use these estimates.[7] The only adjustment made to the value of a statistical life is when it is applied to children. Recent studies have shown that parents are willing to pay more to reduce the risk of death in children and that a ballpark estimate is a payment of double the VSL for adults (OECD, 2004). Hence we take a mean value of Rs.15 million for adults and Rs.30 million for children.

The value in monetary terms for mortality endpoints for the vulture-dog linkage based on the regression analysis and food linkage was estimated. The value was in a range from Rs.962 to Rs.992 billion depending on the scenario.[8]

3.4.5. *Total health cost—summary*

Table 4 gives a summary of the health costs that are attributable to vulture declines for consistent scenarios for both the case where the vulture–dog linkage is based on food and the case where it is based on a regression model. It should be noted that the mortality costs represent a large proportion of the costs. The total costs range from Rs.998 billion to Rs.1095 billion, or an average of 71 to 78 billion per annum over the period. It should be noted that the costs are not evenly distributed across the years—with annual costs being more heavily weighted to later periods.

To put these costs in perspective, taking the average, a total cost of Rs.1046 billion over the 14 years 1993–2006 would amount to about $34 billion, taking the average exchange rates prevailing over the period. These are not insignificant figures, especially taking into account that they are borne disproportionately by the relatively poorest sectors of the population. In addition, the loss of vultures has also given rise to costs to the Parsi community of Rs.1.6 million and a loss of user and non-user benefits that have not been quantified.

4. Policy analysis

A policy to address the vulture decline must involve both the banning of the use of diclofenac and the creation of vulture breeding centres to conserve and enhance vulture populations. However, this will only remediate the problem over a very long time, as vulture populations have low potential population growth rates and will take a long time to recover—given their low base it could take decades for populations to reach their previous levels. Hence the present health and other related impacts of vulture decline cannot be addressed though their re-introduction. Additionally, it may not be possible to design any economically feasible program with which we could restore the entire lost populations of all the three species of vultures.

In terms of the economic cost and benefits of a recovery programme, the major cost considerations are the replacement of Diclofenac with a safe alternative and the costs associated with captive breeding and eventual release and ex situ conservation management.

[7] In the UK, for example, values of statistical life of GBP2 million have been estimated. The Indian values are about GBP187,500 which are about 9% of the UK values. Although per capita income in India is only about 2%, the higher ratio of the value of statistical life to per capita income in poor countries has also been found in other studies (Chestnut et al, 1997; Ortiz, 2005).

[8] It should be noted that this estimate is likely conservative as it assumes the PET coverage of 2003 for the entire period.

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A programme of captive holding, breeding and releasing into wild as recommended by BNHS (2004) is already underway. This is supported by the Central Zoo Authority and the Ministry of Environment and Forests, Government of India, and should help to restore a proportion of lost populations. The programme has been designed, *ceteris paribus*, on the assumptions that (a) the Diclofenac is the only reason for the extinction of vultures (which the weight of scientific evidence indicates is the case, see Green et al., 2004) and (b) holding and captive breeding of birds would continue up to the time that the use of this drug is phased out. The birds released into the wild after the phase out will slowly increase to fill the ecological niche available, which will, in part, be determined by food availability. That means the objective of this programme is to establish and maintain sustainable number of birds in the wild.

The cost of vulture conservation includes the cost of in house holding and breeding and eventual release. The Pinjore Vulture Care Centre currently houses 125 birds Construction costs for 3 centres are estimated at US$820,000 (Rs.34.7 million). The recovery plan aims to have 300 birds at the 3 centres with annual food costs per bird estimated at US$480 (Rs.20,300). Staff costs are in the range of US40,000 (Rs.1.7 million) a year and additional costs of US$200,000 (Rs.8.5 million) are foreseen during the pre release phase of the programme. (RSPB pers comm.) It should be noted that the Centres also produce a number of economic benefits. The salaries of the staff induce further economic activity, the visits by scientists and other researchers boost hotel income and the required inputs such as construction materials, labour and a regular supply of goats, stimulate local economic opportunities. These have not been valued.

The other major component of cost is of course that of removing diclofenac and replacing with meloxicam. Evidence from the Indian Veterinary Research Institute (pers corres) in 2006 indicated that injectable forms of meloxicam were around 4.8 times more expensive than diclofenac whilst bolus forms were equivalent in terms of costs. Scale economies can be expected as production volumes of meloxicam increases. We do not feel that estimates of this replacement costs are sufficiently robust to be used in a full cost benefit analysis (which in any case needs valuation of other impacts such as the benefits to communities like the Parsis). However, here for indicative purposes we present these cost estimates, based on annual domestic sales and assuming meloxicam is 4.8 times more costly. The total costs of rehabilitation are likely to be around Rs.4.3 billion (US$96 million), assuming a 20 year programme and a discount rate of 10%.

One way of seeing how justifiable it would be to incur such a cost we can ask ourselves what the WTP would have to be among Indian households to have a total benefit greater than this cost. Restricting ourselves to households that could be classified as ‘middle class’ (i.e. with incomes in excess of $6000[9]) we have a population of around 20 million. A WTP, to prevent the extinction of the three respective vulture species, of R218 ($4.79) would then justify the remediation programme. This payment would not need to be made in one year: it is a capital cost based on estimates of the costs of drug substitution. If spread over 10 years at a 10% discount rate the annual cost would be around Rs.32.37 for such households, or about 70 US cents. In addition there are certain to be nature lovers from outside the country who would be WTP to avoid the extinction of this species. Hence, in the view of the authors, the vulture remediation strategy including the banning of diclofenac sodium is amply justified.

5. Conclusions

Vultures are a keystone species and their decline has had, and will continue to have, many repercussions. In addition to the ecological effects, the declines have health implications for humans, wildlife and domestic stock, direct economic implications for local communities through the costs of livestock disposal and cultural and religious impacts for ancient professions such as skinners and bone collectors amongst others. In this paper, we have estimated the costs to society of just two of the key impacts of vulture declines. The total impact on health estimated from vulture declines over the period 1992 to 2006 is between Rs.998 billion and Rs.1095 billion, with the costs being more heavily felt in later periods. The cost to the Parsi community of Rs.1.6 million for alternative measures to dispose of the dead only reflect the welfare effect of vulture declines to a partial extent. A full contingent valuation study would be required to ascertain the cultural and religious values of the vultures in India, which are likely to be significant.

Many assumptions were made in our calculations, and the figures given can only be considered as indicative. However, we are very confident that the vulture declines have imposed very high costs upon Indian society. In particular, it appears that poor rural communities will have had to bear the brunt of these impacts, whether human health impacts, costs of carcass disposal, or effects upon ancient professions.

We recommend that further work be carried out to gather such information and further quantify the costs of the vulture decline.

In addition to the impacts described above that have been predicted and/or estimated in monetary terms, this decline is likely to have had a wide range of ecological impacts. Some of these, such as changes in the populations of other scavenging species are predictable. However, there is also likely to be a range of unpredictable, and currently unnoticed, effects. We cannot even guess at the currently unrecognized impacts that the vulture decline is likely to provoke.

The dramatic population decline in vultures is unprecedented in rapidity and geographical extent. This resulted in the governments of three affected countries, India, Nepal and Pakistan, banning the production and importation of the important veterinary drug diclofenac. The arguments used in lobbying for these bans were based predominantly on biodiversity conservation, and not quantified socio-economic impacts. This paper provides both economic support for the decisions made by these governments and suggests that considerable resources should be made available to ensure that a similar situation is not repeated and to help the vulture populations to recover.

Recently published research (Cuthbert et al., 2007) provides evidence that some NSAIDs other than diclofenac (including carprofen, flunixin, phenylbutazone and ibuprofen) may also be toxic, both to vultures and other scavenging birds. One

[9] From World Resources Institute: pdf.wri.org/hammond_india profile_xls.pdf.

NSAID, meloxicam, has been tested and found relatively safe for vultures, is already available in veterinary formulations in India, and is considered a suitable alternative to diclofenac (Swan et al., 2006, Swarup et al., 2007). It is essential that the Departments of Drug Administration or similar national licensing authorities reject applications for licenses to import or manufacture veterinary formulations of any other NSAIDs in the absence of adequate safety testing data.

Vulture population recovery requires that the environment is free from diclofenac and other potentially toxic NSAIDs, and that sufficient vultures persist to enable recolonisation. As decline rates were so rapid, (Prakash et al., 2003a,b, Green et al., 2004) it was considered that persistence of the three affected species required the establishment of conservation breeding centres across South Asia (SAVRP, 2004). Whilst steps have been made towards reducing diclofenac availability to vultures, there is so far no ban on the sale and use of veterinary diclofenac, and it is possible that large stocks still exist and will be used. It is important that mechanisms are found to further reduce the veterinary use of diclofenac, and not just its manufacture and importation. Three conservation breeding centres have so far been established in India, but more are required (SAVRP, 2004); it is important that sufficient resources are made available to enable this to happen within the next few years to maximize chances of successful re-introduction of these species. In addition to biodiversity conservation arguments, we believe that there are strong economic arguments for working towards this aim. It is hoped that eventually vulture populations will be reinstated and able to perform their historical ecosystem service role.

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