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REVIEW

Systematic mapping on the importance of vultures in the Indian public health discourse

Smriti Jalihal[1] · Shweta Rana[1] · Shailja Sharma[2]

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Abstract

Vultures are of immense ecological significance to forest and urban ecosystems. These birds play a major role in curbing environmental contamination through scavenging on carcasses. Prevention of spread of diseases is pivotal for public health and is an inexorable economic burden for any country. We present the crucial role vultures can play in disease mitigation and public health by regulating or decreasing the spread of zoonotic diseases. We elaborate examples from three zoonotic diseases; rabies, brucellosis and tuberculosis, which spread among dogs and cattle as well as human population. We establish the viable links in the transmission of these diseases from the infected dead and alive animals to humans and their possible exacerbation in the absence of vultures. These indirect links help formulate the case for increased interventions for disease spread and control along with conservation of these scavengers. Their role as natural and effective cleaners of the environment in the Indian health discourse is of importance because they can reduce the expenses of the government in waste management and maintenance of public health.

Keywords Conservation · Disease · Ecological importance · Vultures · Zoonosis

Introduction

India has faced zoonotic diseases such as Swine flu (Kshatriya et al. 2018), Nipah virus encephalitis (Chadha et al. 2006; Rana and Singh 2015) in the recent past and is grappling with ongoing COVID-19 (WHO 2020). The role of scavengers in limiting the diseases at host level holds value ecologically as well as economically. Vultures contribute to ecosystem services and are beneficial to public health, primarily because they can get rid of tonnage of carcasses (Balmford 2013) and maintain adequate sanitation levels in the ecosystem (Kanaujia and Kushwaha 2013). The carrions and rotting bodies of all animals are decomposed by the action of microbes, flies, beetles, raccoons and vultures primarily. Vultures feed upon soft tissues as well as the hard parts as bones, teeth and hair of the carcasses. The ingested dead remains are released as nutrients through their faeces (Mondor et al. 2012) and this cycling of nutrients is favourable for maintaining a healthy ecosystem. Vulture's abilities to aerial search confers advantage over terrestrial scavengers to spot carcasses from a faraway range. They are efficient consumers owing to the large size of their bodies and usually benefit from the heavy mortality in the migratory ungulate populations while following them. The steep decline in vulture population is increasing the potential of disease spread and transmission to other species (Ogada et al. 2011).

Exceedingly high population of managed livestock, various wild animals along with several unorganised carcass disposal sites contribute in abundance of dead meat in India (Singh et al. 2013). The 20th Livestock Census 2019 reported an increase of 4.8% over the 2012 census, with total livestock population of 536.76 million. An increase of 4.56% and 11.19% livestock population in the rural and urban areas respectively, has been reported by Ministry of Fisheries, Animal Husbandry & Dairying, Government of India (MoFAHD 2019). Dead organisms are disease reservoirs and the disease can spill over through intraspecies

✉ Shweta Rana
shweta@flame.edu.in

Smriti Jalihal
smriti.jalihal@flame.edu.in

Shailja Sharma
sharmas@aiimsjodhpur.edu.in

[1] Department of Physical and Natural Sciences, FLAME University, Pune 412115, India

[2] Department of Biochemistry, All India Institute of Medical Sciences Jodhpur, Jodhpur 342005, India

or interspecies transmission. The vultures curb the disease spread in a comprehensive way as opposed to the ones they spread themselves, sometimes through their contaminated feathers and feet (Ogada et al. 2012). Vultures have a higher immunity and tolerance and their low stomach pH (1–2) act as the biological filter for pathogens. Scavengers and carnivores often have shorter guts than omnivores or herbivores, which reduces the chance of bacterial pathogen multiplication as the chances of food remaining in the gut reduces (Ogada et al. 2011; Beasley et al. 2015).

Ability of vultures to scavenge prevents spread of a variety of diseases among the same species (through cannibalism if there is a dearth of resource) and to other species of higher trophic levels (Vicente and VerCauteren 2019). Some carnivores can feed on the carrions but all of them are not capable of killing pathogens efficiently as vultures and so they can become reservoirs of these microbes and can further infect humans or other animals, making it a public health hazard (Soulsbury and White 2016). Due to the decrease in the vulture population in Kenya, the number of animal carcasses increased three times, so did the amount of time to clear them out. Correlating this with the probability of disease spread, the risk posed on human health (Ogada et al. 2012) and the economic burden surged threefold. Vultures are known to dispose more than 22% of the organic waste in urban areas. Such biological controls are better alternatives to chemical treatments. They also serve to be effective in agriculture by consuming problem species, thereby reducing crop loss (O'Bryan et al. 2018).

Reasons for declining vulture population

The vulture population started decreasing severely during 1990s, alarming several conservationists and public health experts who understood their importance. The survey conducted by the Ministry of Environment, Forest and Climate Change (MoEFCC), India, with the coordination of State Forest Departments and Bombay Natural History Society (BNHS) reported a sharp decline in the vulture population in India. The numbers decreased from 40 million to 19,000 in a span of three decades. Between 1992 and 2007, 99% of the three species of critically endangered resident Gyps vultures; white-backed vulture, long-billed vulture and slender-billed vulture were almost wiped out with their population reducing to 6000, 12,000 and 1,000, respectively (MoEFCC 2020).

The use of diclofenac on cattle and other ungulates (to increase milk production and provide immediate pain relief) has led to a massive decrease in vulture numbers globally from the early 1990s (Pain et al. 2003; Prakash et al. 2003; Swan et al. 2006; Buechley and Sekercioglu 2016; Bindra 2018). Kidney failure was reported in the vultures fed on cattle treated with these anti-inflammatory drugs (Green et al. 2004). Various reasons for threats and decline in different species of vultures in India have been summarized in Table 1. Extensive use of pesticides and insecticides in the agricultural practices are reported to have shown deleterious effects to many avian species.

Dhananjayan et al. (2011) confirmed the presence of cyclodiene insecticides and organochlorine pesticides in the plasma samples of three species viz. white-backed vulture (*Gyps bengalensis*), Egyptian vulture (*Neophron percnopterus*), and Himalayan griffon vulture (*Gyps himalayensis*) from India. In a study carried out in southern India (Tamil Nadu), Malik et al. (2018) found p,p´-DDE (Dichlorodiphenyldichloroethylene) in concentrations associated with the eggshell thinning and premature hatchings of 106 species of birds.

Poharkar et al. (2009) concluded malaria as major reason for the decreasing vulture numbers as they isolated an intracellular malarial parasite from the alive as well as dead white-backed vultures in the Indian subcontinent. Mobile towers have also resulted in decreasing avifaunal diversity (Kale et al. 2012) and almost 50% reduction in vulture numbers (Verma et al. 2018). The elctromagnetic radiaitons from the towers can interfere with the sense of direction and altitude of birds, and therefore disable the avian compass disorienting them (Balmori 2015). Recreational hunting and lead poisoning from spent ammunition have been identified as one of the main contributors in decline of vultures in Europe, Africa and America (Margalida et al. 2013; Garbett et al. 2018). Pain et al. (2003) reviewed eight *Gyps* species and evaluated accidental poisoning, hunting, human interferences and electrocution as likely causes of decline in south east Asia, western Europe and Africa.

Data collection and methods

The present study extracted data from extensive research available on search engines such as Google Scholar, PubMed, research databases as EBSCO, Jstor and websites of World Health Organisation (WHO), Centers for Disease Control and Prevention (CDC), United Nations Environment Programme (UNEP), Government of India (GOI) directory and ScienceDirect. The websites of Ministry of Health and Family Welfare, Centre for Disease Prevention and Control (CDC), Ministry of Fisheries, Animal Husbandry and Dairying and Ministry of Environment and Forest and Climate Change; Government of India, were referred for the disease transmission, livestock numbers and management data, and vulture conservation plans respectively. The inclusion criteria are based on the articles on ecosystem services by vultures, causes for their decline, spread of zoonotic diseases, conservation plans and actions, English language/

Table 1 Various reasons for threats and decline of vultures in India

Scientific name	Common name	Threats and Reasons for decline	IUCN Red list Status in India	References
Gyps bengalensis	Oriental White-backed Vulture	Changes in livestock husbandry, kidney failure due to diclofenac exposure, overhunting, poisoning, habitat loss, decline in food availability	Critically endangered	Prakash et al. (2003), Botha et al. (2017)
Gyps tenuirostris	Slender- billed vulture	Changes in livestock husbandry, overhunting, poisoning, persecution, diclofenac exposure	Critically endangered	Prakash et al. (2003, 2012), Pain et al. (2003)
Sarcogyps calvus	Red-headed vulture	Changes in livestock husbandry, overhunting, poisoning, persecution, diclofenac exposure, decline in food availability, habitat loss	Critically endangered	Pain et al. (2003), Cuthbert et al. (2006), Botha et al. (2017), Bindra (2018)
Gyps indicus	Long billed vulture	Exposure to diclofenac, electrocution, poisoning, human disturbances in nesting sites	Critically endangered	Prakash et al. (2003), Bindra (2018)
Neophron percnopterus	Egyptian vulture	Hunting and poisoning, pesticides (organochlorine, polychlorinated biphenyls, carbamates and organophosphorus), diclofenac exposure, electrocution	Endangered	Pain et al. (2003), Cuthbert et al. (2006), Ogada et al. (2011), Bindra (2018), Plaza et al. (2020)
Gypaetus barbatus	Bearded vulture	Unintentional poisoning by feeding on carcasses, persecution and electrocution, lead poisoning, decline of food availability, habitat loss, human disturbance in nesting sites (aviation, paragliding), climate change	Near threatened	Buechley and Sekercioglu (2016)
Gyps himalayensis	Himalayan griffon vulture	Exposure to diclofenac, pesticides (organochlorine, polychlorinated biphenyls, carbamates and organophosphorus)	Near threatened	Das et al. (2011), Prakash et al. (2012), Plaza et al. (2020)
Gyps fulvus	Eurasian Griffon	Diclofenac, lead poisoning from spent ammunition, human interference, habitat degradation	Of least concern	Green et al. (2004), Buechley and Sekercioglu (2016)

translated articles only and articles post 1990. The exclusion criteria was articles on decline, conservation and action plans for birds other than vultures and articles before 1990. The key words vulture, scavenger, decline, human, environment, diclofenac, zoonotic diseases, brucellosis, rabies, tuberculosis, conservation, public health, ecological value, economic load, waste management, contamination, carcass, forest, rural and urban ecosystem, prevention were used to check the title, abstracts and the full texts of the articles and reports. The articles meeting the inclusion criteria were selected for the assessment of full text and abstracts. We referred to 351 articles from the mentioned sources and out of which 234 articles meeting the inclusion criteria were selected. Substantial literature was checked to understand the extent and the harm zoonotic diseases can have on the humans and other animals with context to vulture population decline. All articles looked at were after 1990, when the vulture population started to steeply decline in India. A total of 78 articles (journals-69; reports-United Nations (CMS-UNEP-Convention on the Conservation of Migratory Species of Wild Animals-United Nations Environment Programme)-1, WHO-1; CDC-1; Government of India-3; e-books-3) were included in the final study (Fig. 1).

Disease spread due to carcass decay

Zoonotic diseases are transmitted from animals to humans, so controlling the zoonoses, pathogen and their vector becomes critical. They have resulted in high morbidity and mortality rates across the world among human and animal populations. Such emerging healthcare threats present high prevention and curing costs for governments around the world. It is thus important to curb these diseases at the level of animals, before they spread to human populations (Belay et al. 2017). Some of the zoonotic diseases that have posed a large social and economic costs in the recent years are zika virus disease (Qureshi 2017), COVID-19 (Chaudhary et al. 2020), Nipah virus encephalitis and swine flu (Chadha et al. 2006). Transmitted from animals to humans first, they have resulted in high rates of human-to-human transmission thereafter. Scavengers play role in disease regulation by reducing host and vector densities, through local competitive exclusion, minimising the pathogen numbers or feeding on the hosts directly. For example, leopards in Mumbai (India) have played an important role in controlling of dog population and thus, reduction in the cases of dog bites and transmission of

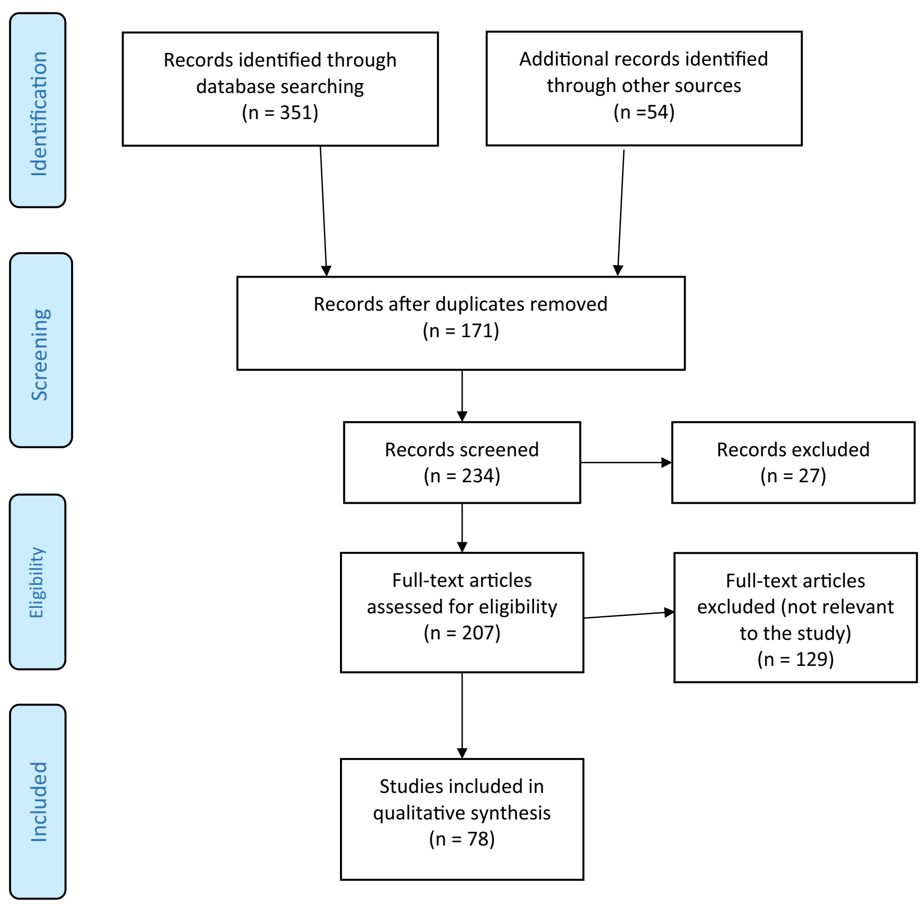

Fig. 1 Prisma Diagram showing the identification, screening, eligibility and inclusion of the articles for the review

rabies to humans (O'Bryan et al. 2018). On the basis of existing evidences, many studies reinforce the fact that absence of vultures will increase the transmission of infectious diseases to humans as well as their livestock (Markandya et al. 2008; Ogada et al. 2011, 2012; Moleón et al. 2014).

Decaying carcasses are undoubtedly a huge lingering threat to human health (Shearer et al. 2018). They act as breeding grounds for a large number of pathogens that can lead to transmission of infections. Waterborne diseases easily spread through the fouling of watercourses by rotting carcasses, however, this link is not that easy to establish (Markandya et al. 2008). The reduction in the number of vultures leave quite a few carcasses un-scavenged, invariably increasing other organisms and abiotic resources exposed to a large number of diseases. The absence of vultures can cause the "piling up of corpses in the land of the living" (Van Dooren 2010).

Anaerobic pathogens are the largest threat to human health as they spread through the soil from carcasses. *Clostridium perfringens* an anaerobic human pathogen, has been isolated from water, soil, air, dust, fresh meat, milk, and vegetables. It has been found that humans are most susceptible to get infected by this bacterium in poor hygienic conditions, similar to what is fostered by uncleared carcasses (Haagsma 1991).

Additionally, carcasses are an easy feast for rodents, which has led to the increase in the rat population, thus escalating the diseases spread by them among both, the wildlife and human populations (Speer 2015). A reduction in prime scavenger species like vultures disturbs the food chain and leads to an increase in mesoscavenger species, many of them being disease-spreading pests (O'Bryan et al. 2019). Carcasses can play a role in the introduction and reintroduction of some viruses in the air, water, and soil. An excessive number of decaying carcasses cause environmental contamination, which can further interfere with the functioning of the endocrine system among humans and animals and is strongly linked to the spread of emerging diseases (Movalli et al. 2018). Exposed carcasses can easily spread zoonotic diseases to humans, animals in urban and rural areas and wild animals in the forests. Farmers and people engaged in animal husbandry, who live in close proximity to the cattle are most susceptible to these diseases (Singh et al. 2013). Diseases like rabies, brucellosis, tuberculosis, and others are spread by pathogens (Sokolow et al. 2019) that travel from carcasses into soil and water and further enter the human body through different means; such as by the consumption of water, food or through direct contact (Swan et al. 2006; Makandya et al. 2008; Plaza et al. 2020). Mudur (2001) has linked the possibility of human anthrax outbreaks with the decline in vulture population. The contact with the carcass was ascribed as one of the reasons for the disease spread.

The rapid increase in stray dogs and rabies has coincided with the rapid decline in vulture population (Pain et al. 2003; Prakash et al. 2003). Most street dogs in India are not adequately vaccinated and the incidents of dog bites are common. This spreads rabies, from dogs to humans, which increases both mortality and morbidity. Preying on or contact with dead rabid dogs can transmit the pathogen to other animals and humans. (Markandya et al. 2008; Lembo et al. 2008). Theimer et al. (2017) reported that laboratory studies have demonstrated the potential of rabies transmission via ingestion of rabid animals. Bindra (2018) reported incidences of stray dogs homing and breeding in the garbage dumps and decaying carcasses led to increased disease spread in dogs as well as transmission of infections to humans. India has approximately 25 million dogs, with an estimated dog: human ratio of 1:36 (Menezes 2008) as compared to mean ratio of 1:9.5 and 1:12.3 for Asia and Africa regions respectively (Knobel et al. 2005). Since 1985, India has reported 25,000–30,000 deaths by rabies annually (Sudarshan 2004). Approximately INR1046 billion is reported to be the economic burden associated with dog bites, rabies spread in humans and simultaneous vulture decline between 1992 and 2006 (Markandya et al. 2008; Brookes et al.2019). Though rabies is also caused by the scratches and bites of cats, bats, rabbits etc., the high death rate is mainly attributed to the large stray dog population in the country (NHP India 2018). Brookes et al. (2019) reported outbreak of rabies in dairy cattle and buffaloes and death of farmers in a village in Punjab, India. The role of vulture as a scavenger becomes more critical and economical in the urban areas co-inhabited by stray and unvaccinated dogs. Heever et al. (2021) concluded that vultures can regulate the spread of rabies and brucellosis and cut on costs required for their treatment and prevention.

Brucella melitensis is the main cause of brucellosis in humans (Franco et al. 2007). Humans get the disease by direct contact with infected live or dead cattle, eating or drinking contaminated milk or meat (Assenga et al. 2015) or by inhaling the airborne pathogen (Zhang et al. 2020). Hence it becomes more critical to prevent it's spread in humans by controlling it in the dead or alive host animal. Brucellosis is a massive public health problem mainly because of the fact that there is a lack of a cohesive plan to respond to such cases on the part of hospitals and the government (Rossetti et al. 2017). This disease has been a major problem in parts of the Mediterranean, Western Asia, Latin America and Africa and is emerging as one of the most severe health problems in India. Like any other lesser-known disease, there is a strong link between brucellosis and economic loss, as the government needs to spend more money to diagnose it and find cures (Singh et al. 2018). Measures as controlling cattle herding, movement and milk production due to its massive economic implications are unviable.

Brucellosis can also spread from dogs to humans through direct contact with infected individuals, or through their blood, vaginal or seminal fluids. *Brucella canis* can continue to be an unrecognized pathogen, in both dogs and humans. Vultures can clear carcass of infected dogs and cattle, and effectively regulate the spread of disease (Hensel et al. 2018; Brookes et al. 2019).

Gumi et al. 2012 studied the zoonotic transmission between pastoralists and their livestock in Ethiopia. The study that was conducted over a span of 2 years, reported 32 suspected tuberculosis (TB) cases for transmission of the pathogen through their cattle. Though *Mycobacterium tuberculosis* is the most commonly found cause of TB, people in direct contact with wound of dead or alive cattle may also acquire another form of the disease known as bovine tuberculosis, caused by *M. bovis*. Factsheet released by CDC has also mentioned it's spread to humans by inhaling the bacteria directly from the infected animals (https://www.cdc.gov/tb/publications/factsheets/general/mbovis.pdf). The spread of this disease is a large public health concern, especially in rural areas (Amanfu 2006; Gumi et al. 2012; Cowie et al. 2015). Across countries, this disease has also been the cause of economic losses. The proportion of bovine TB in humans was less than 5% of the total number of cases till 2012. These cases were predominantly reported in areas of Chad, Niger, Ghana, Uganda, and Ethiopia (Ukwaja et al. 2012). Once a human is infected with the disease, it can rapidly spread among the population through coughing and sneezing (Hassan et al. 2014). Srinivasan et al. (2018) in their systematic review and meta-analysis reported that there may be an estimated 21.8 million cattle infected with bovine tuberculosis in India-a population greater than the total number of dairy cows in the United States. The decrease in vulture population can cause the cattle carcass numbers to increase, which can have indirect linkage to increased spread of bovine tuberculosis in human population (Markandya et al. 2008; Vicente and VerCauteren 2019).

Conservation programs and future strategies

Owing to high ecological and economic value of vultures, their conservation is crucial. Majorly the attention and resources in India are diverted to the big species of tourism importance like elephant, asiatic lion, royal bengal tiger, rhinoceros, Olive Ridley Sea turtle etc, but not vultures, which carry least aesthetic appeal. Appreciating their significance, the Government has recently initiated action plans and policies for conservation. In 2006, the governments of India, Pakistan, Nepal and Bangladesh banned use of diclofenac on cattle (Cuthbert et al. 2014). In 2010 these countries negotiated further coordination and improved action plans for vulture conservation (Balmford 2013). After the ban on diclofenac and implementation of captive breeding programs, population of the critically endangered vulture species in India have started increasing (Prakash et al. 2012; Bindra 2018). The MoEFCC has devised the Action Plan for Vulture Conservation which advocates for the prevention of cattle poisoning, increased monitoring and vulture breeding programs and describing the role of the state and central governments in curbing the leak of diclofenac by the veterinary industry. Vulture conservation breeding centres have been established in eight states in India (Haryana, West Bengal, Assam, Madhya Pradesh, Gujarat, Odisha, Telangana and Jharkhand) that are being managed by State Forest Departments with support from BNHS and MoEFCC. Financial support of INR125.3 million has been given to five states (Punjab, Haryana, Kerala, Uttarakhand and West Bengal) and a mega project has been sanctioned to the Indian Veterinary Research Institute, Uttar Pradesh on assessing the safety and conservation of vultures. The status upgradation of white-backed, long-billed and slender-billed vultures from Schedule IV to Schedule I of the Wild Life (Protection) Act, 1972 along with various initiatives in mass educating and spreading awareness have been implemented. The action plan credits the vulture as the most efficient soldier of the *'Swachh Bharat Abhiyaan'* (MoEFCC 2020).

Successful vulture conservation programs across the world have reinforced the awareness towards the dwindling vulture population. About a third of all the vulture species globally are successful outcomes of captive breeding and reintroduction projects (Houston 2005). Margalida et al. (2010) modelled the effects of sanitary policies on European vulture conservation and stressed upon the creation for vulture programs with special feeding centres and policy level strategies, such as regulating the use of animal by products. Vulture management in Southern Europe has recovered more than 200 percent of Eurasian Griffon Vultures (Margalida et al. 2014). As per the Memorandum of Understanding on the Conservation of Migratory Birds of Prey in Africa and Eurasia, and Convention on Migratory Species have adopted the Vulture Multi-species Action plan (MsAP), which is a strategic conservation plan covering 128 states of all 15 species of migratory African-Eurasian vultures in a coordinated international effort to save them from further decline and extinction (Botha et al. 2017). Safford et al. (2019) proposed flagship projects to support vulture MsAP. Badia-Boher et al. (2019) have evaluated the success rate of conservation projects coupled with awareness campaigns and long-term monitoring, highlighting the improvement in vulture population in Europe. According to Becker et al. (2020) conservation practices can be refined by studying the microbiome of the vultures. Yee et al. (2021) have suggested examining ethical perspectives of the stakeholders responsible for conservation for effective decision making in conservation. Complementation of national and global efforts is the key for effective conservation (Santangeli et al. 2020).

Conclusion

Effective utilisation of the vultures as biological agents to control the diseases at the host level contributes towards disease regulation and may reduce the economic burden in maintaining the public health. Conserving vultures becomes more important in an agrarian society like India where people are often in close proximity with livestock and thus at a higher risk of exposure to zoonotic diseases, which can spread from live as well as dead animals. The international and national conservation efforts seem promising but consistency is required to maintain the sustainability of these programs. For future research, quantification of disease control by vultures is recommended. We need more studies establishing direct linkages between dwindling vulture population, escalation of zoonotic infections and consequent health threats. Economic valuation of the role of vultures in disease regulation is required to reassure further strengthening of vulture conservation policies and action plans. The consequences of decline in vulture population must be assessed with reference to economics linked with public health and animal care. At present both are lacking or largely not accessible to citizens in developing countries like India.

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Declarations

Conflicts of interest The authors declare that they have no conflict of interest in the publication.

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