Journal of
Geography & Natural Disasters

Paital, J Geogr Nat Disast 2016, 6:2
DOI: 10.4172/2167-0587.1000165

Research Article Open Access

Role of Cyclonic Storm as Natural Disaster and other Factors on Vulture Mortality in India

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Abstract

Post mortem analyses in vultures across India and its neighboring countries traced diclofenac and its derivative compounds in their carcasses. Therefore, it is inferred that biomagnification of diclofenac from the consumed infected domestic animal carcasses contributes mortality by causing renal failure and hepatic damages in vultures. However, reports also indicate that both extrinsic environmental and intrinsic cellular causes might also be contributing factors. It offers a debate to confirm whether only diclofenac is the primary cause of vulture mortality versus their susceptibility to microbial pathogens, diseases or physiological conditions, such as oxidative stress due to diclofenac biomagnification. It is observed that natural disasters such as heavy cyclonic storm which affect arboreal life may be one of the major causes of the death of vultures in some parts of India. Therefore, extrinsic insults such as heavy cyclonic storms are believed to be also contributing factor to affect arboreal life including vultures in some other parts of the world. A perspective is made on the above facts as a cause of catastrophic mortality of vultures in India.

Keywords: Arboreal life; Cyclonic storm; Metabolic depression; Natural disaster; Oxidative stress; Vulture extinction

Introduction

Scavengers perform several crucial roles in a food chain without which the ecosystem's maintenance of dead carcasses will either stop or be delayed [1,2]. It leads to disturb the relationships between prey and predators and between producers and consumers [3]. Vultures are highly significant in food webs as they play the key ecological role of consuming the carcasses of dead animals, which prevents the spread of diseases to livestock [4]. Vulture populations at national and global scales are declining and are on the threshold of extinction. Domestic animal carcasses are disposed of openly in the absence of safe alternatives, which not only leads to an increased risk of diseases, such as rabies, but also provides a platform for other livestock borne diseases, such as anthrax. Thus, it can be inferred that the scavenging role of vultures prevents the spread of dangerous diseases that could threaten wildlife, livestock and human beings [5]. Therefore, it is clear that vultures are very important to terrestrial ecosystems [6]. However, despite their role in maintaining the "balance of terrestrial ecosystems", not much work has been performed to protect these species. Many vultures such as *Gyps bengalensis* and *Gyps indicus* are now classified as critically endangered and some of them are either severely declining or already locally extinct [7-9]. For example, Gyps vulture populations across the Indian subcontinent began to decline in the 1990s and the process continues [5]. Repeated demographic surveys have shown that the rate of decline was so rapid that elevated mortality of adult birds must be a key factor [10].

Multiple reasons have been ascribed to the mortality of vultures worldwide. In India and Nepal, the biomagnification of diclofenac from the carcasses of domestic animals to vultures is considered to be the main cause of vulture mortality [11-18]. However, other causes seem to have key role on their mass scale collapsing [19]. Other factors, such as problems with vulture habits and habitats, food, diseases, breeding, and natural disasters may also contribute to mortality. These external and internal factors affect the normal physiology of animals and can lead to metabolic depression and eventually to death [20]. One of the important cellular responses that create metabolic depression in animals is oxidative stress (OS), which is resulted due to the oxidation of biological macro-molecules by the overproduced reactive oxygen species (ROS) [21]. OS is always positively correlated with the magnitude of any kind of stress. So other than natural factors (mostly disasters), susceptibility of vultures to OS due to infection by microbial pathogens, diseases or physiological disorders being the causes of their mortality are also anticipated.

The Status of Vulture Populations in Some Asian Countries

In some of the protected areas of India, vulture populations are remained in few countable numbers such as from 13 to 65 individuals in North Madhya Pradesh of India [5]. Approximately four decades ago, two vulture species, namely, the Indian white-backed (*G. bengalensis*) and long-billed (*G. indicus*) vultures, were abundant which are now on the verge of extinction [5,15]. It was observed the number of the park's white-backed in Rajasthan's Keoladeo National Park reduced from a peak number of 1,800 in 1985-86 to only 86 in 1998-99 while long-bills declined from 816-25 [22]. Long-billed vulture population was similarly reduced about 97 % between 1985 and 1999 in Keoladeo National Park [23]. Similar observations were noticed by several authors in some other south Asian countries such as Nepal and Pakistan [10,15,24-28].

Is Diclofenac Biomagnification the only Cause of Vulture Mortality?

Observations from different postmortem analyses of carcasses of vultures from different locations indicate that diclofenac and its derivative compounds can be the cause of their death. The reason is mainly defined to their renal failure and hepatotoxicity induced by diclofenac [29]. However, it is debatable whether diclofenac is

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Received March 11, 2016; **Accepted** April 01, 2016; **Published** April 04, 2016

Citation: Paital B (2016) Role of Cyclonic Storm as Natural Disaster and other Factors on Vulture Mortality in India. J Geogr Nat Disast 6: 165. doi:10.4172/2167-0587.1000165

the only main cause of vulture mortality or following diclofenac biomagnification, the increased susceptibility of vultures to microbial pathogens, diseases or physiological disorders, such as OS and metabolic depression or natural disasters are responsible for their mortality in large scale.

Other Reasons for Vulture Mortality

Several authors opined that the mortality of vultures is not only due to diclofenac contamination in their food but also multiple factors may contribute to their mortality (Table 1). The factors are believed to be mainly environmental in origin including some of the natural disasters. Biotic and abiotic environmental factors, such as extreme heat or cold, air and water pollution, cyclones, habitat loss, loss of forest canopy, imbalanced food chains, etc., are always detrimental to the survival of an arboreal species. For example, variable environmental drivers are found to push turkey vultures (*Cathartes aura*) for frequent movement and to change their habitat in North and South America [30]. Such factors are already covered in a recently published review article by Paital et al. [29]. The authors made a perspective that hunting [31], pollution [30,32-34], food scarcity and cannibalism [24,33,34], ingestion of contaminated food and food poisoning [35-41], multiple physiological disorders including nutritional problems [14,42], lack of proper nesting and resting places [8], genotoxic factors [43,44], problems related to breeding [24,45], electrocution and air traffic [38,46,47] epidemic and endemic diseases [38,48-51], pathological susceptibility [22,41,48,52-54] etc. may be contributing factors for vulture mortality. Especially environmental extremities can be major contributing factors for their large scale mortality [12,13].

Cyclonic Storm: The Natural Disaster and Vulture Death

Cyclone is believed to the one of the most important factors among all the natural hazards affecting arboreal lives. The magnitude of the adverse effects of such environmental factors is further enhanced by anthropogenic activities that threaten the lives of the species inhabiting an area. Although specific studies that attribute the mass destruction of vultures in India or elsewhere to such forces are lacking, environmental factors are viewed as playing a significant role in the decline of vulture populations. Odisha cyclone, also known as Paradip cyclone was Cyclone 05B (category 5 in Saffir-Simpson scale), and it was blown over the east coast of India on 29th October 1999. The speed of the cyclonic storm was 260 km h^{-1} which had affected mainly states of India such as Odisha, part of Andhra Pradesh and West Bengal and Myanmar. There was more than 10, 000 loss of human lives and uncountable death of wild life including many birds. It was the strongest tropical cyclone ever recorded in the North Indian Ocean, the deadliest tropical cyclone in the Indian Ocean since the 1991 Bangladesh cyclone, and was the deadliest Indian storm since 1971. It was a tropical depression formed over the Malay Peninsula on October 25. It moved to the northwest and became a tropical storm on October 26. It continued to strengthen into a cyclone on October 27. On October 28, it became a severe cyclone with a peak of 160 mph (260 km h^{-1}) winds. It hit India the next day as a 155 mph (250 km h^{-1}) cyclone. The area affected by the storm was districts such Balasore, Bhadrak, Kendrapara, Jagatsinghpur, Puri, Ganjam and Jajpur of Odisha state of India. Out of the above districts, areas of Jagatsinghpur such as Chakulia, Banipat, and Potak, padmapur were the centrally affected parts. Most visibly, the village Padmapur lost its 90% of landscape in the sore of the Bay of Bengal [55-58]. Due to large feather size and heavy weight it might have difficult on their part to leave the place prior to cyclone struck their habitat area. The author has personally observed that no vultures were found along the coastal belt of Jagatsinghpur District in Odisha State, India, in the areas of Patrapada, Kakatpur, Astaranga, Kusupur, Nandhara, Olara, Padmapur, Paradeep, Belapur, etc. after the Odisha super cyclone struck in the area on 28th October 1999. At least 11 vulture colonies totaling more than 125 individuals disappeared from these areas after the storm. Another cause of reduced vulture populations in the cyclone-affected areas could be the relocation of the birds prior to the arrival of the cyclonic storms, but no such documentation exists.

In 1990, a severe cyclone reduced a local vulture population of approximately 100 to almost 0 in the Guntur and Prakasham areas of Andhra Pradesh, India [31]. This implies that super cyclones might be a factor in the destruction of vultures by destroying the large trees used for nesting or the cyclone might directly destroy their colony.

Another environmental extremity is sharp rise in environmental temperature. Both high or low temperatures and cyclonic storms, might also affect their life. Irregular and unexpected weather conditions have resulted from the loss of ecosystem balance in general and the loss of green forests in particular. The loss of green canopy always disturbs biogeochemical cycles, and disturbances to biogeochemical cycles,

Reasons	Place	References
Cyclone	Guntur and Prakasham area of Andhra Pradesh state, India, 1990	[31]
Mycoplasma infection	Changa Manga forest plantation area of Pakistan, 2004	[37]
Malaria	India, 2009	[54]
Neck drooping	India, 2003	[22]
Neck drooping and temperature		[12]
Hunting of vultures for meat by Bandola (Banda) people	Guntur and Prakasham area of Andhra Pradesh state, India, 1990	[31]
Consumption of infected carcasses by pesticides	Moyar Valley and different area in India, 2008	[19, 33, 38, 39]
Metabolic depression related to oxidative stress and blocking in ATP synthesis	Across the world	[14]
Improper nesting and resting place	Turkey, 2008	[8]
Food scarcity and cannibalism	India, 1988, Keoladeo National Park, Bharatpur, Rajasthan, 2003	[6,34]
Breeding related problems	India, 2003	[34]
Pathological susceptibility	India and abroad, 2011	[39,49]
Electrocution and aircraft	All part of the world	[39,46,47]
Super cyclone	Coastal belt of the state Odisha, India, 1999	Personal observations of the authors
Modified after Paital et al. [65].		

Table 1: Multiple reasons for the vulture mortality other than diclofenac contamination.

such as the water and carbon cycles, directly influence rainfall and temperature, respectively, while the nitrogen cycle influences canopy growth and development. All of the above processes influence avian life to a great extent. As has already been mentioned, neck-drooping followed by mortality in oriental white-backed vultures (*G. bengalensis*) is correlated with a failure to thermoregulate under increased environmental temperature [29]. According to records available at the Regional Museum of Natural History in Bhubaneswar, India in 1992, slender-billed vultures (*G. tenuirostris*) were known to make their nests in large trees, such as banyan, mango, bullet wood etc., in the coastal belt of the Jagatsinghpur District of Odisha, but when the trees were cleared, the vulture population declined sharply [29].

Biochemical Insights

The analysis of metabolic indices is immensely important to the study of several core evolutionary concepts in animal biology, such as population ecology, life history tradeoffs, senescence, longevity and sexual selection in free-ranging organisms [59]. Oxidative metabolism is one such metabolic pathway where O_2 performs a major role in directly or indirectly regulating the biochemical processes related to the oxidation of nutrients to produce energy. The physiology of OS comprises the respiration of oxygen (O_2) by mitochondria, the leaking of O_2 to produce reactive oxygen species (ROS), the oxidation of tissues by ROS, the response of both enzymatic and non-enzymatic redox regulatory molecules or antioxidants against the level of ROS produced and the generation of ATP molecules. The status of all of the above biomolecules has a direct or indirect relationship to health and longevity. Therefore, the analysis of OS indices and antioxidant defense parameters is also of immense importance to animal biology, such as in the study of disease susceptibility, organ failure, and longevity in free-ranging organisms [21,59]. Therefore, the role of OS in relation to both the external and internal factors responsible for vulture mortality may be extrapolated.

During the exposure of an animal to various insults in their natural habitat, the normal physiology of animals is compromised. Postmortem analyses of vulture carcasses from different locations have found traces of diclofenac and its derivative compounds in their tissues, while the biomagnification of the drug diclofenac in vultures is believed to be the sole cause of mass mortality of their population. Many authors states that diclofenac contributes to renal failure and hepatotoxicity, is the only cause of vulture population decline in India [11-18,28,34,56-60]. However, the available reports are inadequate for arguing whether diclofenac is the only main cause of vulture mortality or whether, following diclofenac biomagnification, the increased susceptibility of vultures to microbial pathogens, diseases or physiological disorders, such as OS followed by metabolic depression, is responsible for their mortality in large scale [29].

The mechanism under which diclofenac can induce OS followed by cell death in vultures could be explained through the loss of mitochondrial membrane fluidity in the kidney. Because, renal failure is the main out come of the diclofenac contamination in these birds. *In vitro* experiments with the cultured kidney cells of vultures showed that diclofenac can induce cell death as evaluated by the inability of the cell culture to reduce the dye 3-(4,5-dimethylthiazol-2-yl)2,5-diphenyltetrazolium bromide. With the mitochondria being the only organelle capable of reducing the above dye to formazan, the resultant cell death could only be due to the death of the cellular mitochondria. This explanation is supported by the findings of Ng et al. [61,62], especially with the toxicity of diclofenac being associated with a 200% increase in ROS production in vulture kidneys. Therefore, the hepatotoxic or nephrotoxic effects of diclofenac in vultures seem to be associated with the generation of reactive oxygen species and the subsequent oxidative stress which could lead to mortality in birds.

Possible Conservation Plans in Modern Research

In a comparative study on *G. africanus, G. bengalensis* and *G. indicus*, it is observed that meloxicam, a veterinary medicine used in India, is of low toxicity to Gyps vultures and that its use in place of diclofenac would substantially reduce vulture mortality in the Indian subcontinent [59,60]. Maryam et al. [62] recently discussed about the use of different tissue culture techniques as a tool for the conservation of different endangered or threatened species which may be applied to revive vulture population.

Grivas et al. [42] described an automated surveillance system used to study siblicide in a bearded vulture (*Gypaetus barbatus*) nest in Crete from 2003-2006. On the basis of these results, the authors concluded that measures aimed at increasing the survival of the second chick should be undertaken when it is 1-2 days old. Although the above surveillance technique was used for monitoring the ethology between newborn and mother birds, it enables research on the morbidity of birds in nature, and it will undoubtedly help to reduce the steep decline of vulture populations in nature.

Concluding Remarks

Many environmental and internal factors cause the death of animals by switching off/on many pathways [63,64]. There could be multiple issues behind declining vulture populations besides diclofenac contamination (Figure 1), so restricting the veterinary use of diclofenac may not be sufficient to restrict their decline. Therefore multiple environmental and laboratory approaches must be implemented to revive vulture populations in India and else where the problem persists.

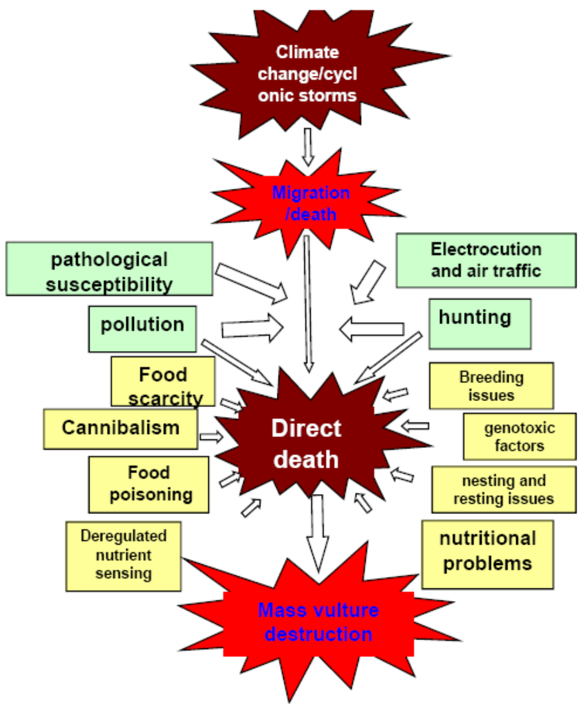

Figure 1: Multiple causes of declining vulture populations.

Acknowledgement

This research was supported by a postdoctoral fellowship to BRP from the University Grants Commission (UGC) (No. F. 4-2/2006 (BSR)/13-853/2013 (BSR)), New Delhi, India, under Dr. D.S. Kothari PDF scheme.

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