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Climate Change Impacts and Risks for Animal Health: Indian Context: A Review

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ABSTRACT

Climate change is a widely accepted truth that has impacted all ecosystems and will continue to do so if left unchecked. The effects of some elements have received more attention than others and animals fall into the latter category. Even among the components of climate change impacts on animals, production-related implications have received emphasis. In contrast, the implications on health in general and infectious illnesses in particular, have been overlooked. Despite not being well investigated, it may be predicted that, as with people, climate change, particularly global warming, will significantly impact animal health, both overt and covert. Temperature-related disease, death and animal morbidity during extreme weather events are direct repercussions. Indirect effects follow more complicated pathways and include those resulting from animals' attempts to adapt to thermal environments or the influence of climate on microbial populations, the spread of vector-borne diseases, feed and water scarcities, or food-borne diseases and host resistance to infectious agents. It is necessary to develop tools and strategies for an animal illness surveillance system that integrates animal data with appropriate climatic variables. The development and application of methods for integrating climate data with disease monitoring systems is necessary to improve animal illness prevention, mitigation and adaptive responses to heat stress.

Key words: Biodiversity, Immune suppression, Mitigation, Mortality, Oxidative stress.

The greatest evidence supporting the links between human, animal and plant health and weather or climatic conditions comes from systematic assessments of empirical research. Concerning the public health sector, Chapter 8 of the Intergovernmental Panel on Climate Change (IPCC) Working Group II report for 2007 includes an update on the state of knowledge about the links between weather/ climatic elements and public health outcomes for human populations (Patz *et al.,* 2005). Changing weather patterns are one example of direct exposure to climate change (increasing temperatures, more precipitation, rising sea levels and more frequent extreme events). Changes in water, air and food quality, vector ecology and changes in ecosystems, agriculture, industry and settlements are all examples of indirect exposure. Social and economic instability may result in further indirect exposure.

Climate change is described as the average weather state of a region that is characterized by its internal elements and can be influenced by changing external influences. Climate change is defined by the United Nations Framework Convention on Climate Change (UNFCC) as a change caused by long-term direct and indirect actions that cause changes in the comparative time that are significantly greater than natural change (UNFCCC, 1992). Weather, on the other hand, is a collection of all the occurrences that occur in a particular atmosphere at a given moment (Stephenson *et al.,* 2008). Climate change is a complex influence on the climate that includes physical properties, causes and implications (Visschers, 2018).

Concurrent direct-acting and modulating (conditioning) interactions of environmental, social and health system elements provide additional opportunities for adaptability.

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The severity of global warming as a hazard to public health has been investigated for various risk scenarios, including malaria, water scarcity, famines and coastal floods. Water scarcity is frequently connected with filthy water conditions and, therefore, with a significant effect of climate change on health, such as diarrhoeal illness. Unfortunately, detailed, official animal health studies are seldom (de la Rocque, 2008).

Climate change and other human variables influence both farmed and natural environments, affecting animal health in various ways. This research focuses primarily on climate change's impact on disease epidemiology and transmission dynamics. Changes in host distribution, density and availability to existing pathogens, for example, may result in disease development in animals and at the

animal-human interaction. A pathogen may: (i) adapt to new areas and host landscapes; (ii) become more host antagonistic in environments where hosts are plentiful and/or completely impervious; or (iii) undertake a host species hop, maybe in reaction to increased host species mixing of interactions. Geographic spread or incursion may result in range extension or a total pathogen genetic redesign in the event of saltation dispersal (Fig 1).

The disease emerging category characterized by geographic range expansion is both reasonably prevalent and more likely to be influenced by climate change and is thus the primary focus of this research. Insect pests, ectoparasites, endoparasites, arthropod-borne disease complexes and infections transported by foods and fomites are all part of this group of disease complexes. A series of global variables is thought to drive the global redistribution of hosts, vectors and infection.

Changing climate evidently plays a significant role in this regard, enhancing or decreasing disease agent introduction and invasions, even when caused primarily by other factors such as human and animal demography, intrusion of the natural resource base, territory use, agriculture, enhanced mobility of people and increased trade and traffic volumes. When it comes to the influence of climate change in disease epidemiology and pathogen evolution, the cumulative host-pathogen-environment interplay must be considered. Host-pathogen-environment complexes appear to become more embedded in a stable environment, a scenario of relative evolutionary stasis, with location-bound pathogen features chosen for. Pathogen adaptability and broad type flexibility, on the other hand, are important in a quickly changing environment.

Effects of changing climate on animals

The climate is one of several elements that have the capacity to affect disease processes and is likely to have a significant detrimental impact significantly harm human and animal health (Rabinowitz and Conti, 2013). Furthermore, some studies have revealed that increasing the temperature may reduce mortality and/or enhance health and welfare in humans and cattle living in cold-weather settings (Ballester *et al.,* 2011; Rose *et al.,* 2015). The impact of climate change on animal health can be direct or indirect (Fig 1) and it is primarily caused by changes in environmental conditions such as ambient temperature, humidity levels, precipitation and the frequency and magnitude of extreme events (*e.g.*, heat waves, severe droughts, high rainfall events and coastal floods). Although this article focuses on environmental factors, it should be noted that the factors that contribute to the effects of climate change on health are immensely complicated, involving not only environmental factors, but also social and ecological aspects, economic interests and social and collective behaviour (Forastiere, 2010).

Temperature-related sickness and mortality are direct consequences of changing climate on health. Indirect effects follow more complicated paths, such as those caused by climate change on microbiological density and transmission, the spread of vector-borne illnesses, water and food crises, or food-borne infections (Lacetera *et al.,* 2013; Belete *et al.,* 2021; Sharma *et al*., 2024). This article aims to outline the current understanding of the influence of climate change and global warming on the healthiness of food-producing animals.

Direct effects

Climate change's direct consequences on health seem to be mostly due to rising temperatures and the prevalence of heatwaves (Gaughan *et al.,* 2009). The creation of heat stress conditions mediates these effects. Heat stress can severely impact cattle health depending on its severity and

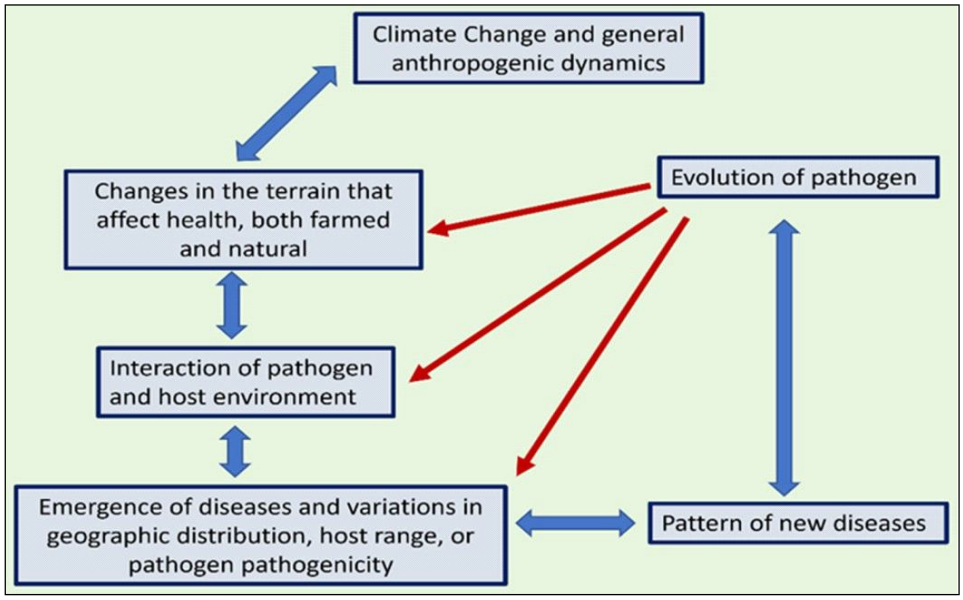

Fig 1: Effects of climate change on disease emergence.

duration, producing metabolic changes, oxidative damage, immunological suppression and mortality (Fig 2).

Metabolic disorders

In order to minimize increased body temperature, homeothermic animals increase heat loss and decrease heat production in response to high temperatures (hyperthermia). Increased respiratory and sweating rates and a reduction in feed intake are examples of such reactions. These physiological processes might help to explain the incidence of metabolic problems in heat-stressed animal. Heat stress has been linked to lameness in beef and dairy cattle (Shearer, 1999). Lameness in cattle is described as any foot defect that causes an animal to move differently. Lameness is one of the most serious health, welfare and productivity challenges since it can be caused by a variety of foot and leg diseases, which can be caused by illness, management, or environmental factors. Heat stress may contribute to lameness through ruminal acidosis or elevated bicarbonate production (Cook and Nordlund, 2009). Heat-stressed cattle consume less often at cooler times of day, but more at each meal. As the temperature rises, so does the respiratory rate, with panting developing to open-mouth breathing. As a result of the fast loss of carbon dioxide, respiratory alkalosis develops. Cattle adapt by increasing bicarbonate urine production. A reduction in the salivary bicarbonate pool affects rumen buffering. After heat stress, lameness with foot ulcer and white line infection will emerge in a few days to a few weeks.

Reduced feed intake and higher metabolic rate for maintenance may affect the energy balances. Describe why heat-stressed animals decrease body weight and/or mobilize adipose tissue. Early lactation dairy cows are more prone to undergo subclinical or clinical ketosis throughout the summer (Lacetera *et al.,* 1996) and are at a higher risk of developing hepatic lipidosis (Basiric *et al.,* 2009). Ketosis is a metabolic condition that develops when an animal is in a stressed condition of negative energy balance, goes through extensive lipomobilization and stores ketone bodies, which result from inadequate fat catabolism. Another side effect of excessive fat mobilization from adipose tissue is liver lipidosis. Decreased albumin production and enzyme activities of liver heat-stressed cattle indicate impaired liver function (Ronchi *et al.,* 1999).

Oxidative stress

Oxidative stress may be implicated in numerous pathological disorders in farm animals, including conditions that are important for animal productivity and individual wellbeing (Lykkesfeldt and Svendsen, 2007). Oxidative stress is caused by an imbalance of oxidant and antioxidant compounds and can be caused by an excessive oxidant and/or a shortage of antioxidant molecules. In the last 10 to 15 years, there has been a growing interest in the role of heat stress in generating oxidative stress in farm animals (Bernabucci *et al.,* 2002; Akbarian *et al.,* 2016). In the peri- and postpartum periods, total antioxidant levels in heifer serum were reduced in the summers than in the winter (Mirzad *et al.,* 2018). During the summer, plasma levels of active oxygen species metabolite compounds rose in mid-lactating cows. During the summer, total carotenoids and vitamin E levels fell. Increased oxidant and reduced antioxidants in blood have been documented in both dairy and buffalo cows during the hot summers. Finally, heat stress has been linked to an increase in antioxidant enzyme activity (*e.g.*, superoxide dismutase, catalase and glutathione peroxidase), which was regarded as an adaptive response to increasing reactive oxygen species levels.

Immune suppression

The immune system originated as a collection of processes to defend the host from harmful organism invasion. A variety of things can have an impact on the immune system's ability to operate properly (Lacetera, 2012). Several studies have found that heat stress can affect immune system performance in food-producing animals. Heat stress affects immunological function in a variety of ways, based on the species, breeds, genotype, age, social position, acclimation degree and intensity and length of exposure to adverse circumstances.

Immune suppression promotes the spread of diseases, reducing reproductive efficiency and total

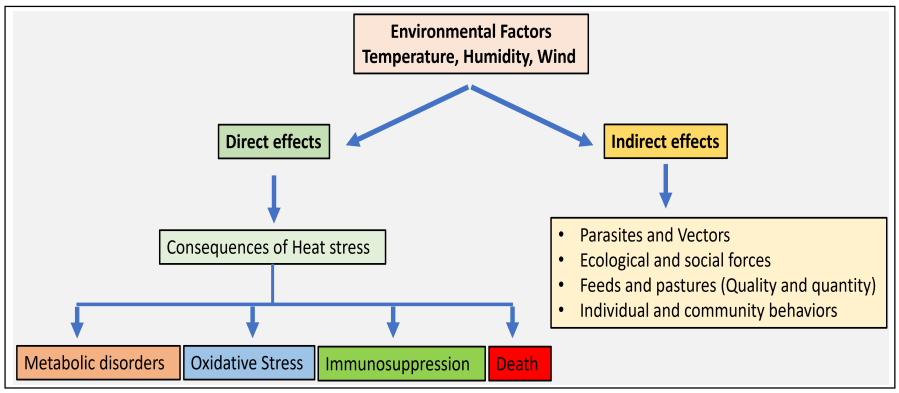

Fig 2: Schematic representation of the most frequent consequences on animal health.

production efficiency, compromising animal welfare and increasing the usage of antimicrobials. Antibiotic resistance in bacteria may emerge as a result of increased antimicrobial usage. The uncontrolled use and abuse of several antibiotics have resulted in the development of resistance, so adversely affecting the effectiveness of treating and preventing bacterial infections (Deshmukh *et al*., 2023, Suryawanshi *et al*., 2024).

Regnier and Kelley (1981) observed that persistent heat stress reduced immunological response in species of birds. According to Nardone *et al*. (1997), extreme heat stress lowered colostral IgG and IgA in dairy cows, which had a detrimental impact on vaccination and newborn calves′ survival. Lacetera *et al*. (2005) reported a substantial decrease in lymphocyte activity in extreme heat-stressed postpartum dairy cattle, which might elevate their exposure to infections and diminish immunization efficiency. Finally, Lecchi *et al*. (2016) discovered that high temperatures greatly reduced the functioning of neutrophils, which play an important part in the mammary gland's defense against infections. Mastitis is a common endemic illness of dairy cattle that often develops as an immunological reaction to invading microbes of the teat canal or as a response of chemical, mechanical, or thermal harm to the cow′s udder. Several studies have found that mastitis is more common in the summer (Morse *et al.,* 1988; Waage *et al.,* 1998). Recent two-year research on the largest Italian dairy farm found that the increased incidence of clinical mastitis in primiparous dairy cattle occurred in July (Vitali *et al.,* 2016). Heat stress may promote pathogen survival or growth (Chirico *et al.,* 1997) and it is possible that it is implicated in these major epidemiological discoveries. More epidemiological research is needed to evaluate whether high ambient temperatures are linked to a higher frequency of other illnesses. The possibility of impaired immune cell activity in a hot environment encourages the employment of management methods (*e.g.*, cooling, changed dietary programmes, enhanced animal cleanliness, *etc*.) that may assist to limit body temperature rise and hence minimize infection outbreaks.

Mortality

Several studies have found a higher risk of death during the warmest months (Dechow and Goodling, 2008; Vitali *et al.,* 2009) and a higher mortality rate during weather extremes (Hahn *et al.,* 2002; Vitali *et al.,* 2015). Heat stroke, heat exhaustion, heat syncope, heat cramps and eventually organ malfunction can all result from high temperatures. Heat-related issues develop when the body temperature rises by 3 to 4 degrees Celsius over usual.

Purusothaman *et al*. (2008) documented increased mortality in Mecheri sheep during the summer season in Indian research. Another study on the impact of temperature on farm animal mortality found increased fatalities during weather extremes. Hahn and Mader (1997) and Hahn *et al*. (2002) reported the effect of a week-long heat wave in the mid-central United States in July 1995 on livestock. A heat wave is often characterized as an extended stretch of extremely hot weather. Summer morbidity in dairy cattle was higher during heat wave days compared to non-heat wave days, according to Vitali *et al*. (2015). Moreover, the risk of death remained elevated for 3 days after the heat wave ended. The duration of the extreme heat also increased mortality. Heat waves did not impact cows up to 28 months old, however all other age groups of cows (29 to 60, 61 to 96 and >96 mo) exhibited increased mortality when subjected to a heat wave. During a heat wave, the mortality risk increased in the earlier summer months. The maximum risk of death was recorded during an extreme heat in June.

The temperature-humidity ratio integrates humidity and temperature into a single figure and is commonly regarded as a valuable tool for forecasting environmental impacts on farm animals. According to epidemiological research on dairy cattle (Vitali *et al*., 2009), the daily maximum and lowest temperature-humidity index values are 80 and 70, respectively, at which time the heat-induced mortality rate rises. Furthermore, the same study found that the daily critical values maximum and lowest temperature-humidity indexes are 87 and 77, respectively, at which the risk of heat-related mortality increases.

A recent Italian study with swine found that the month, duration of voyage and temperature-humidity index all influenced the mortality of hefty slaughter pigs (about 160 kg live weight) during transit and lairage (Vitali *et al.,* 2014). When considering both transit and lairage, the aggregated summer vs. non-summer months data revealed a higher risk of swine dying during the hot season. The month with the highest fatalities was July, while January and March had the lowest mortality risk ratios. For travels longer than 2 hours, the death risk ratio climbed considerably. Finally, the temperature–humidity index thresholds of 78.5 and 73.6 raised the death rate considerably during transit and lairage, respectively.

Indirect effects

Regarding climate change, it is critical to analyze the degree to which a pathogenic organism is exposed to environments outside the host organism. Even in the direct transmission of respiratory infections, a free-living pathogen stage plays a role. The survival of the common flu virus on doorknobs, through aerogene transfer and during handshakes is affected by environmental temperature (Lowen *et al.,* 2007). In the event of faecal-oral or water-borne transmission, the significance of environmental pathogen load may be much clearer. Food poisoning is typically caused by faecal contamination of food products.

Disease agents transmitted by arthropods are classified as a separate, but related, category. Three-host ticks may aid in the indirect spread of protozoan disease pathogens. Soft ticks that feed on warthog′s aid in the spread of African swine disease (ASF) (Kleiboeker and Scoles, 2001). ASF's causal agent, a DNA virus, can live in the tick vector for up to eight years. A latent pathogen stage

is also present in a variety of midge- or mosquito-borne disease complexes. Rift Valley fever (RVF) virus, for example, may live in mosquito eggs for years until a continuous heavy rain helps the waking of Aedes mosquitoes, who feed on ruminants and so initiate an RVF outbreak (Mondet *et al.,* 2005; Anyamba *et al.,* 2009).

Weather and climate change, as previously stated, are likely to influence the biology and spread of vector-borne illnesses. Temperature variations, continental wind and rainfall variations and changes in relative humidity, for example, would favorably impact insect reproduction and, as a result, population density in temperate areas. As a result, some tropical illnesses, particularly those spread by insects, may spread beyond their native endemic basin to neighboring nations.

Wittmann *et al*. (2001) evaluated a model that simulated a 2°C increase in temperature and found the likelihood of widespread transmission of *Culicoides imicola*, the main transmitter of the bluetongue virus. This virus causes an infectious arthropod-borne illness that mostly affects domestic and wild ruminants. Bluetongue virus infection is widespread across the world. Because of the shifting climatic condition required to maintain the Culicoides vectors, this virus has expanded significantly since 1990.

Another way by which climate change may affect cattle and human health is the beneficial impact of high temperatures and wetness on the development of mycotoxin-producing fungus. These fungi's growth and toxin production are highly tied to temperature and moisture levels, which are determined by harvest weather and grain drying and storage practises (Frank, 1991). Mycotoxins can trigger acute illness episodes when animals ingest large amounts of contaminated feed. These mycotoxins can harm certain organs and tissues such as the liver, kidney, oral and stomach mucosa, brain and reproductive tract. Most of the time, however, mycotoxin concentrations in feeds are below levels that might cause acute sickness. Mycotoxins may slow the development rate of young animals at low dosages. Some mycotoxins may interfere with natural disease resistance mechanisms and reduce immunologic response, rendering animals more vulnerable to infection (Bernabucci *et al.,* 2011).

Finally, parasitic infections are used to illustrate how changing climate may impair animal health. In this perspective, gastrointestinal nematodes are significant cattle parasites that cause death and morbidity. Because these parasites complete a large portion of their life cycle outside of the host, their survival and growth are vulnerable to climate change. In this context, a recent modelling research (Rose *et al.,* 2015) suggested that future atmosphere for a temperate climate will have an opposing influence (increase or reduction) on yearly infection pressure depending on parasite species.

Climate change in India

The IPCC′s predicted changes for the Indian subcontinent, depending on the General Circulation Model (GCM), anticipate warming of 2-4.7°C, with the most likely level being approximately 3.3°C by 2100 (A1B scenario) (Solomon *et al*., 2007). Warming is projected to be more pronounced in the winter (3.6°C) than in the summer (2.7°C) and greater in the northern than in the south. Most models predict a drop in rainfall during the inter dry phase and a rise for the remainder of the year. Around the same time, severe rain events are likely to increase, particularly in India's north. The worldwide sea level increase of 0.1 to 0.9 meters is predicted to be particularly significant in the Indian Ocean, particularly on the west coast.

Assessments by Indian scientists using the Hadley Centre Regional Model (HadRM2) climate simulations produce similar results, indicating that temperatures in the Indian subcontinent would rise by 3 to 4°C by the end of the 21st century. Warming might range from 2.1 to 2.6 degrees Celsius in the 2050s to 3.3 to 3.8 degrees Celsius in the 2080s (DEFRA/GoI, 2005). The many models/ experiments all show that the temperature will rise by 2-5°C across the country. The rise in mean annual temperature is in the range of 3 to 6°C.

The warming is expected to be widespread across the country, with northern India receiving the most attention. While rainfall is expected to rise, there will be variances in the geographical distribution, with some pockets enjoying increases and others suffering decreases. Most models predict an increase in rainfall of 10 to 40% from the baseline era (1961-90) through the end of the twenty-first century, with the greatest predicted rise across northwestern and central India. Over a large area of peninsular India, there has been little or no change in monsoon rainfall (Kumar, 2006). Climate change will cause global sea levels to increase by 0.09 to 0.88 m by 2100, amplifying severe occurrences such as heavy rain, flash floods, droughts, cyclones and forest fires (Shukla *et al*, 2021; Manjeet *et al*., 2022). A review of previous statistics dating back 100 years reveals that India ranks among the top ten globally in terms of deaths and economic losses from various disasters.

Natural disasters in India and endangering biodiversity

India is one of the world's most disaster-prone countries. India supports one-sixth of the world's population on only 2% of its landmass. Nearly 59 per cent of India's land area is vulnerable to earthquakes ranging from mild to very high intensities, over 40 million hectares (12 per cent of land) is prone to floods, nearly 5700 kilometers (8 per cent of its 7516 km coast line) is cyclone prone and vulnerable to tsunamis and storm surges, 2 per cent of land is prone to landslides and 68 per cent of India′s agricultural land is affected by droughts. As many as 27 of the 35 states/union territories are disaster-prone (GoI, 2004). The majority of disasters in India are caused by water.

The product of evolutionary development is biodiversity, which includes the multiplicity and variability of all species on Earth. Biodiversity supports human society in a variety of ways, including ecological, economic, societal, cultural, educational, scientific and aesthetic advantages. Massive

Table 1: Population trends in threatened Indian species.

Group	Threatened	No change or stable	Upwards or improving	Downwards or decreasing	Indeterminate	Trends not available
Mammals	213	4	1	47	87	74
Birds	149	2	-	80	10	57
Reptiles	033	-	-	2	2	29
Amphibia	148	5	-	68	73	2
Pisces	75	-	-	21	42	12
Crustacea	12	-	-	-	-	12
Mollusca	5	-	-	-	1	4
Hymenoptera	5	-	-	-	-	5
Lepidoptera	4	-	-	-	1	4
Odonata	3	-	-	-	1	3
Anoplura	1	-	-	-	-	1
Total	648	11	1	218	217	201

(Source: Red List of Threatened Species, IUCN, 2019).

human interventions and climate change in natural ecosystems have resulted in biodiversity loss. India has an unparalleled richness of species. The biodiversity of the area is represented by the diverse biomass and habitats found within its ecosystems. Millions of people rely on the rich natural landscape for their survival, wellbeing and livelihoods. Climate change will put ecosystems and biodiversity at risk. It will also have an impact on vegetation, production and biodiversity.

Climate change is expected to cause significant loss of plant cover in several ecosystems in India. Sea level rise, glacier melt and weather extremes will all have an influence on freshwater resources and inland wetlands. India has an abundance of biological resources. It encompasses a wide range of biogeographic zones, from the Himalayas to the seashore. India is ranked seventh in mammals, ninth in birds and fifth in reptiles. Forests and dense vegetation cover 23.39 per cent of India′s geographical area. India is home to four of the world′s 34 biodiversity hotspots, including the Himalayas, Indo-Burma, Western Ghats, Sri Lanka and Sundaland. According to the IUCN Red List, 2019 worldwide estimations, 10% of the vertebrate and 0.2 per cent of the invertebrate identified fauna is endangered. Table 1 depicts the population trends of endangered Indian species. 648 of the 1296 species were identified as threatened.

CONCLUSION

Climate change has become a worldwide issue due to its multifaceted consequences and influence on humans, animals, plants and the environment. According to research, change in the global or regional climatic patterns caused by climate change impact animal health both directly and indirectly.

Although more epidemiological study is needed, a substantial amount of research has so far indicated and predicted climate change will impact animal health and welfare. Heat stress conditions caused by global warming, high air temperatures and an increase in extreme weather events and droughts may significantly impact animal health and wellbeing. Such impacts can occur through direct and/or indirect processes. Developing tools and strategies for an animal illness surveillance system that integrates animal data with appropriate climatic variables is also necessary. To enhance animal illness prevention, mitigation and adaptive responses to heat stress, techniques for linking climatic data with disease monitoring systems should be developed and applied.

The following are specific recommendations for adapting to and mitigating the effects of climate change on animal health:

1. Research on climate-resilient livestock technologies and adaptability.
2. Maintain solid farming practices, tight farm biosecurity and animal health management for farm animals.
3. Updated vaccines and treatments for endemic and rising illnesses are being developed.
4. Consider Health, animal comfort, animal behaviour and climate change while designing animal enclosures.
5. Native animal genetic resources should be conserved and developed.
6. A long-term breeding strategy for disease resistance characteristics based on ongoing challenge and natural processes.
7. Methodology development and implementation to integrate climatic data with an animal disease surveillance system.
8. A coordinated and comprehensive research of the real-time effects of climate change on animals, followed by a policy decision.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Akbarian, A., Michiels, J., Degroote, J., Majdeddin, M., Golian, A. and De Smet, S. (2016). Association between heat stress and oxidative stress in poultry; mitochondrial dysfunction and dietary interventions with phytochemicals. *Journal of Animal Science and Biotechnology*. **7:** 1-14.

Anyamba, A., Chretien, J.P., Small, J., Tucker, C.J., Formenty, P.B., Richardson, J.H., Britch, S.C., Schnabel, D.C., Erickson, R.L. and Linthicum, K.J. (2009). Prediction of a rift valley fever outbreak. *Proceedings of the National Academy of Sciences*. **106(3):** 955-959.

Ballester, J., Robine, J.M., Herrmann, F.R. and Rodó, X. (2011). Long-term projections and acclimatization scenarios of temperature-related mortality in Europe. *Nature Communications*. **2(1):** 358.

Basiricò, L., Bernabucci, U., Morera, P., Lacetera, N. and Nardone, A. (2009). Gene expression and protein secretion of apolipoprotein B100 (ApoB100) in transition dairy cows under hot or thermoneutral environments. *Italian Journal of Animal Science.* **8(sup2):** 492-594.

Belete, K., Mulugeta, T. and Sharew, M. (2021). Climate change impacts on animal production and contribution of animal production sector to global climate change: A review. *Agricultural Science Digest*. **41(4):** 523-530. doi: 10. 18805/ag.D-344.

Bernabucci, U., Colavecchia, L., Danieli, P.P., Basiricò, L., Lacetera, N., Nardone, A. and Ronchi, B. (2011). Aflatoxin B1 and fumonisin B1 affect the oxidative status of bovine peripheral blood mononuclear cells. *Toxicology in vitro.* **25(3):** 684-691.

Bernabucci, U., Ronchi B., Lacetera N. and Nardone A. (2002). Markers of oxidative status in plasma and erythrocytes of transition dairy cows during hot season. *Journal of Dairy Science*. **85:** 2173-2179.

Chirico, J., Jonsson, P., Kjellberg, S. and Thomas, G. (1997). Summer mastitis experimentally induced by *Hydrotaea irritans* exposed to bacteria. *Medical and Veterinary Entomology*. **11(2):** 187-192.

Cook, N.B. and Nordlund, K.V. (2009). The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. *The Veterinary Journal*. **179(3):** 360-369.

De La Rocque, S., Rioux, J.A. and Slingenbergh, J. (2008). Climate change: Effects on animal disease systems and implications for surveillance and control. *Revue Scientifique et Technique*. **27(2):** 339-54.

Dechow, C.D. and Goodling, R.C. (2008). Mortality, culling by sixty days in milk and production profiles in high-and low-survival Pennsylvania herds. *Journal of Dairy Science*. **91(12):** 4630-4639.

DEFRA/GoI, (2005). 'Indian Climate Change Scenarios for Impacts Assessments, Key Sheet 2'. Indian Institute of Tropical Meteorology (IITM), Pune, India. In: Investigating the Impacts of Climate Change in India. Report by Department of Environment, Food and Rural Affairs (DEFRA), UK and Ministry of Environment and Forests (MoEF), Government of India (GoI), 2005.

Deshmukh, O., Suryawanshi, R., Kurkure, N., Kaore, M., Badar, S., Shinde, O., Awandkar, S. and Gaikwad, N. (2023). Molecular characterization of multidrug-resistant avian pathogenic *Escherichia coli* isolated from poultry and poultry products. *Indian Journal of Animal Sciences*. **93:** 431-436.

Forastiere, F. (2010). Climate change and health: A challenge for epidemiology and public health. *International Journal of Public Health*. **55(2):** 83-84.

Frank, H.K. (1991). Risk estimation for ochratoxin A in European countries. *IARC Scientific Publications*. **(115):** 321-325.

Gaughan, J., Lacetera, N., Valtorta, S. E., Khalifa, H.H., Hahn, L. and Mader, T. (2009). Response of domestic animals to climate challenges. Heidelberg (Germany): Springer-Verlag. *Biometeorology for adaptation to climate variability and change*. pp. 131-170.

GoI, (2004). Disaster Management in India - A Status Report. National Disaster Management Division, Ministry of Home Affairs, Government of India, MHA/GOI/28/06/2004, Jun 2004.

Hahn, G.L. and Mader, T.L. (1997). Heat Waves in Relation to Thermoregulation, Feeding Behaviour and Nortality of Feedlot Cattle. In: Proceedings of the 5th International Symposium. St Joseph (MI): ASAE. pp. 563-571.

Hahn, G.L., Mader, T.L., Harrington, J.A., Nienaber, J.A. and Frank, K.L. (2002). Living with Climatic Variability and Potential Global Change: Climatological Analyses of Impacts on livestock performance. In Proceedings of the 16th international congress on biometeorology, Kansas City. pp. 45-49.

IPCC (2007), Fourth Assessment Report on Climate Change, Cambridge University Press, New York. IPCC (2007), Report of Inter-governmental Penal on Climate Change, World Meteorological Organization and UNEP, Geneva.

IUCN Red List. (2019). IUCN Red List of Threatened Species. www.iucnredlist.org. Last accessed March, 2024.

Kleiboeker, S.B. and Scoles, G.A. (2001). Pathogenesis of African swine fever virus in Ornithodoros ticks. *Animal Health Research Reviews*. **2(2):** 121-128.

Kumar, K.R., Sahai, A.K., Kumar, K.K., Patwardhan, S.K., Mishra, P.K., Revadekar, J.V., Kamala, K. and Pant, G.B. (2006). High-resolution climate change scenarios for India for the 21st century. *Current Science*. **90(3):** 334-345.

Lacetera, N. (2012). Effect of Environment on Immune Functions. In: Environmental physiology of livestock. Chichester (England): Wiley-Blackwell. pp. 165-179.

Lacetera, N., Bernabucci, U., Ronchi, B. and Nardone, A. (1996). Body condition score, metabolic status and milk production of early lactating dairy cows exposed to warm environment. *Riv. Agric. Subtrop. Trop*. **90(1):** 43-55.

Lacetera, N., Bernabucci, U., Scalia, D., Ronchi, B., Kuzminsky, G. and Nardone, A. (2005). Lymphocyte functions in dairy cows in hot environment. *International Journal of Biometeorology*. **50:** 105-110.

Lacetera, N., Segnalini, M., Bernabucci, U., Ronchi, B., Vitali, A., Tran, A., Guis, H., Caminade, C., Calvete, C., Morse, A. and Baylis, M. (2013). Climate induced effects on livestock population and productivity in the mediterranean area. Regional assessment of climate change in the mediterranean: Agriculture, Forests and Ecosystem Services and People. **2:** 135-156.

Lecchi, C., Rota, N., Vitali, A., Ceciliani, F. and Lacetera, N. (2016). *In vitro* assessment of the effects of temperature on phagocytosis, reactive oxygen species production and apoptosis in bovine polymorphonuclear cells. *Veterinary Immunology and Immunopathology*. **182:** 89-94.

Lowen, A.C., Mubareka, S., Steel, J. and Palese, P. (2007). Influenza virus transmission is dependent on relative humidity and temperature. *PLoS Pathogens*. **3(10):** e151.

Lykkesfeldt, J. and Svendsen, O. (2007). Oxidants and antioxidants in disease: Oxidative stress in farm animals. *The Veterinary Journal*. **173(3):** 502-511.

Manjeet, Anurag, Niwas, R., Khichar, M.L. and Kumar, A. (2023). Study of climate change impact on crops and soil health in India: A review. *Agricultural Reviews*. **44(3):** 357-363. doi: 10.18805/ag.R-2200.

Mirzad, A.N., Tada, T., Ano, H., Kobayashi, I., Yamauchi, T. and Katamoto H. (2018). Seasonal changes in serum oxidative stress biomarkers in dairy and beef cows in a daytime grazing system. *Journal of Veterinary Medical Science*. **80:** 20-27.

Mondet, B., Diaïté, A., Ndione, J.A., Fall, A.G., Chevalier, V., Lancelot, R., Ndiaye, M. and Ponçon, N. (2005). Rainfall patterns and population dynamics of Aedes (Aedimorphus) vexans arabiensis, Patton 1905 (Diptera: Culicidae), a potential vector of Rift Valley Fever virus in Senegal.

Morse, D., DeLorenzo, M.A., Wilcox, C.J., Collier, R.J., Natzke, R.P. and Bray, D.R. (1988). Climatic effects on occurrence of clinical mastitis. *Journal of Dairy Science*. **71(3):** 848-853.

Nardone, A., Lacetera, N., Bernabucci, U. and Ronchi, B. (1997). Composition of colostrum from dairy heifers exposed to high air temperatures during late pregnancy and the early postpartum period. *Journal of Dairy Science*. **80:** 838-844.

Patz, J.A., Campbell-Lendrum, D., Holloway, T. and Foley, J.A. (2005). Impact of regional climate change on human health. *Nature*. **438(7066):** 310-317.

Purusothaman, M.R., Thiruvenkadan, A.K. and Karunanithi, K. (2008). Seasonal variation in body weight and mortality rate in Mecheri adult sheep. *Livestock Research for Rural Development*. **20(9).**

Rabinowitz, P. and Conti, L. (2013). Links among human health, animal health and ecosystem health. *Annual Review of Public Health*. **34:** 189-204.

Regnier, J.A. and Kelley, K.W. (1981). Heat-and cold-stress suppresses *in vivo* and *in vitro* cellular immune responses of chickens. *American Journal of Veterinary Research*. **42(2):** 294-299.

Ronchi, B., Bernabucci, U., Lacetera, N., Verini Supplizi, A. and Nardone, A. (1999). Distinct and common effects of heat stress and restricted feeding on metabolic status of Holstein heifers. *Zootecnica e Nutrizione Animale*. **25(1):** 11-20.

Rose, H., Wang, T., van Dijk, J. and Morgan, E.R. (2015). GLOWORM-FL: A simulation model of the effects of climate and climate change on the free-living stages of gastro-intestinal nematode parasites of ruminants. *Ecological Modelling*. **297:** 232-245.

Sharma, S.K., Rathore, G. and Joshi, M. (2024). Impact of Climate Change on Animal Health and Mitigation Strategies: A Review. *Indian Journal of Animal Research*. doi: 10.18805/IJAR.B-5303.

Shearer, J.K. (1999). Foot health from a veterinarian's perspective. *Proceedings of Feed and Nutritional Management Cow College, Virginia Tech*. pp. 33-43.

Shukla, M., Jangid, B.L., Khandelwal, V. Keerthika, A. and Shukla, A.K. (2023). Climate change and agriculture: An Indian perspective: A review. *Agricultural Reviews*. **44(2):** 223-230. doi: 10.18805/ag.R-2190.

Solomon, S., Qin, D., Manning, M., Alley, R.B., Berntsen, T., Bindoff, N.L., Chen, Z., Chidthaisong, A., Gregory, J.M., *et al.* (2007). Technical Summary. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (eds.)].

Stephenson, D.B., Diaz, H.F. and Murnane, R.J. (2008). Definition, diagnosis and origin of extreme weather and climate events. *Climate Extremes and Society*. **340:** 11-23.

Suryawanshi, R., Bhosale, A., Deshmukh, O., Jogdand, A., Shinde, O., Hatwar, N. and Kamat, H. (2024). The Occurrence, Antibiotic susceptibility pattern and multiple drug resistance index studies of *E. coli* from fresh meats in Marathwada region of Maharashtra. *Indian Journal of Animal Research*. doi: 10.18805/IJAR.B-5257.

UNFCCC. Definitions of climate change (1992). [accessed March 2024] 7 Available *via* http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.

Visschers, V. H. (2018). Public perception of uncertainties within climate change science. *Risk Analysis*. **38(1):** 43-55.

Vitali, A., Bernabucci, U., Nardone, A. and Lacetera, N. (2016). Effect of season, month and temperature humidity index on the occurrence of clinical mastitis in dairy heifers. *Advances in Animal Biosciences*. **7(3):** 250-252.

Vitali, A., Felici, A., Esposito, S.I.L.V.I.A., Bernabucci, U., Bertocchi, L., Maresca, C., Nardone, A. and Lacetera, N. (2015). The effect of heat waves on dairy cow mortality. *Journal Of Dairy Science*. **98(7):** 4572-4579.

Vitali, A., Lana, E., Amadori, M., Bernabucci, U., Nardone, A. and Lacetera, N. (2014). Analysis of factors associated with mortality of heavy slaughter pigs during transport and lairage. *Journal of Animal Science*. **92(11):** 5134-5141.

Vitali, A., Segnalini, M., Bertocchi, L., Bernabucci, U., Nardone, A. and Lacetera, N. (2009). Seasonal pattern of mortality and relationships between mortality and temperature-humidity index in dairy cows. *Journal of Dairy Science*. **92(8):** 3781-3790.

Waage, S., Sviland, S. and Odegaard, S.A. (1998). Identification of risk factors for clinical mastitis in dairy heifers. *Journal of Dairy Science*. **81:** 1275-1284.

Wittmann, E.J., Mellor, P.S. and Baylis, M. (2001). Using climate data to map the potential distribution of *Culicoides imicola* (Diptera: Ceratopogonidae) in Europe. *Revue Scientifique et Technique-Office International des Epizooties*. **20(3):** 731-740.