The Intersection of Animal Health and Ecosystem Conservation in Pakistan

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Abstract

The health of animals and the conservation of ecosystem are deeply interconnected, forming a critical nexus tat impacts biodiversity, ecosystem functions, and human well-being. In Pakistan, a country rich in diverse ecosystems ranging from the Indus river plains to the Himalayan mountains, this relationship is particularly vital. Healthy animal populations, both wild and domestic, are indispensable for ecosystem balance. Stable ecosystem plays a crucial role in maintaining animal health. However, this balance is increasingly threatened by habitat degradation, climate change, anthropogenic activities, weak governance, and lack of funds and spread of zoonotic diseases. By understanding and encouraging community involvement, and establishing laws associated with animal monitoring and habitat preservation and strengthening policy implementation, Pakistan can achieve a sustainable balance between animal health an ecosystem conservation which is necessary in maintaining this dynamic relationship. A comprehensive understanding of how animal health influences ecosystems and vice versa is essential to address the growing challenges.

Keywords: Animal health, Wildlife, Conservative, Ecosystem, Threats, Challenges, Policy Recommendation

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Introduction

The word "HEALTH" can be reimagined as an acronym symbolizing

- Humans
- Ecosystems
- Animals
- Living
- Together

Harmoniously (Evans & Leighton, 2014).

The interconnectedness of humans, animals, and the environment recognizing their mutual dependence for well-being has been acknowledged for centuries (Depledge & Galloway, 2005). A healthy ecosystem requires that its constituent animals, plants, and microbes are, collectively, in good health (Van Helden et al., 2013). The ecosystems represent complex networks of living organisms and their physical environments, functioning as dynamic and interdependent systems. A thriving ecosystem is defined by its capacity to maintain structure, functionality, and resilience amidst disturbances. It fosters biodiversity, ensures the availability of essential resources, and upholds ecological stability (Woodroffe & Ginsberg, 1998). Wildlife plays a complex and vital role at the central level of ecological health. Wildlife, which includes a wide variety of species, is essential in determining how ecosystems function. Every creature, from tiniest invertebrates to massive predators, makes a distinct contribution to the general well-being and equilibrium of the ecosystem. Effective conservation and sustainable management strategies depend on an understanding of the relationships and effects of animals throughout ecosystems (Fahrig, 2003).

Pakistan is among the few nations with a wide variety of wild creatures and environments. Pakistan lies at the intersection between Central Asia and the Middle East, in two geographical regions: the Palearctic and the Oriental (Aslam et al., 2022). The Indus Plains, foothills, and mountain ranges are Pakistan's three ecological zones. Pakistan is home to a wide variety of habitats, such as valleys, glaciers, massive coastal belts, sandy regions, mangroves, and lagoons (Khan, 1999).

There are many different types of ecosystems in Pakistan, such as freshwater, marine, riverine, dry tropical thorn, tropical deciduous, subtropical broad leaf evergreen, sub-tropical pine, dry temperate, moist temperate, sub-alpine, alpine pastures, glaciers with permanent snow fields, plateaus, natural and artificial wetlands, and the Indus delta. The Himalayan Alps, Hindu Kush, and Karakoram ranges are home to seven robust brown bear populations. There are 198 mammal species, 700 bird species, 177 reptilian species, 22 amphibian species, and 198 freshwater fish species in the vertebrate biodiversity. Additionally, eight freshwater turtle species and five marine turtle species were identified. Pakistan's biodiversity also includes a number of internationally significant endangered species, including the Indus River dolphin, Astor Markhor, Balochistan Black Bear, Brown Bear, Snow Leopard, and Common Leopard. The Arabian Sea, Rocky Mountains, desert, river, estuary, and wide plains are among the six habitats that make up the distinctive Hingol National Park. Pakistan is home to numerous indigenous species, such as the Chiltan markhor, Balochistan black bear, Indus dolphin, and wholly flying squirrels (Aslam et al., 2022).

1. Relationship Between Animal Health and Ecosystem Conservation

1.1. Wildlife and Ecosystem Health and stability

Wildlife includes a wide variety of species, from insects and birds to mammals and reptiles, and is defined as undomesticated animals that live in their natural environments. According to Estes et al. (2011), these organisms are essential to ecosystems because they support biodiversity, ecological balance, and the planet's general health. Furthermore, a large number of wildlife species are keystone or indicator species, which means that their existence or nonexistence can have a major effect on an ecosystem's structure and function or act as markers of the health of the environment (Terborgh et al., 2001). Wildlife participates in a wide range of beneficial interactions within ecosystems that support the general well-being and functionality of the environment. For plant species to reproduce and spread, mutualistic relationships like pollination and seed dispersion by insects and birds are essential. On the other hand, interactions with wildlife can also have detrimental effects on ecosystem dynamics and stability. The adverse interactions that influence population dynamics include territorial disputes, competing over resources, and predation. The distribution and abundance of species within ecosystems can be significantly impacted by these relationships. To appreciate the complex weave of biodiversity, one must comprehend how ecosystems and creatures interact. A web of relationships that improves ecological resilience is fostered by positive interactions, which frequently add to the diversity of species within a particular area. In contrast, when balanced, adverse effects support a diverse and stable population by preventing the superiority of a single species. This section examines how wildlife interactions impact the complex web of life within ecosystems and emphasizes the significance of biodiversity in preserving ecosystem health (Ruikar, 2024). It is commonly known that emerging diseases are playing an increasingly significant role in the reduction of wildlife populations and the loss of biodiversity (Scheele et al., 2019). Furthermore, invasive species, pollution, climate change, and resource overexploitation are just a few of the many anthropogenic stressors that ecosystems are facing. These factors all have a harmful effect on wildlife health and raise the risk of disease (Barnosky et al., 2011; Ceballos et al., 2015; Tompkins et al., 2015). Stressors that have pessimistic consequences on wildlife populations' health have also been shown to interfere with wildlife's ecological roles, which hinders ecosystem functioning and conservation efforts in general (Deem et al., 2001). The health of ecosystems is drastically declining as a result of human intervention, endangering economic activity, the life-sustaining system, and the wellness of humans as well as animals. In this regard, assessing management interventions and figuring out ecological dynamics depend heavily on monitoring the health of animal populations and ecosystems (Ribas et al., 2023).

2.2. Livestock Health and Its Role in Ecosystems

The livestock sector is a vital component of Pakistan's agricultural industry. The Livestock & Dairy Development Department was established as an independent entity in 1973 Punjab, in particular, plays a significant role in Pakistan's economy due to its thriving agricultural sector, which contributes approximately 28% to the province's GDP and employs 44% of its population. However, several challenges in animal production persist, which can be mitigated through the effective implementation of policies and strategies. Key constraints in Pakistan include inadequate nutrition, poor animal health, low productivity, genetic limitations, and insufficient financial support for livestock farmers, and inefficiencies in livestock extension and marketing services (Khan, 2021).

Climate change poses a substantial threat to humans, livestock, and ecosystems globally. Studies by Howden et al. (2008) reveal that global temperatures are rising by 3.7°C annually. The climatic fluctuations significantly impact livestock production metrics such as egg, meat, and milk yield, as well as health, weight, and reproductive performance (Nardone et al., 2010; Henry et al., 2012). Global warming exacerbates the spread of diseases, reducing livestock immunity and increasing susceptibility to infections like nematode infestations and avian influenza. Additionally, it accelerates the prevalence of diseases such as babesiosis caused by ticks. Vaghela & Mangal (2017) highlighted the close association between climate change, animal health, and ecosystem health, noting that high temperatures can shorten the incubation periods of pathogens (Van den Bossche & Coetzer, 2008). Various factors drive the changing dynamics of livestock diseases, including climate change, habitat loss, deforestation, wildlife conservation challenges, biodiversity loss, human migration, land acquisition by foreigners, irrigation practices, poverty, inequality, conflicts, land use changes, overpopulation, wildlife encroachments, and trade in animal products like milk, meat, eggs, and wool. Among these, climate change stands out as the most significant driver (Grace et al., 2015).

2.3. Zoonotic Diseases: Bridging Animal and Human Health

The genesis and spread of several infectious diseases are significantly influenced by human beings, animals, and the environment (Thompson & Kutz, 2019). The Greek words "zoon," which means animal, and "nosos," which means illness, are the roots of the phrase "zoonoses" (Rahman et al., 2020). Because of their close ties to people, domesticated animals, and the environment, wild animals directly contribute to the spread and upkeep of several infectious diseases (Thompson & Polley, 2014). The ecological relationships between the one-health components are being upset by globalization, habitat degradation, climate change, and the extinction of species and biodiversity. This eventually leads to the introduction of zoonotic infections and changes in the ways in which they spread (Thompson, 2013; Aguirre, 2017; Akter et al., 2020). Pathogens transported by wild organisms can cause disturbances in wildlife, lower agricultural productivity, and affect both human and animal health (Bengis et al., 2004). Wildlife reservoirs are home to a variety of diseases, many of which do not significantly impair or kill the reservoir species. There is a greater chance of pathogen spillover into human populations as human development encroaches on wildlife habitats and people continue to interact with wildlife through hunting or trading in wild animals (Daszak et al., 2000). A key biological element of any zoonosis is the habitat that the reservoir host or hosts occupy. Force of infection (FOI) typically rises in domestic ecosystems due to an increase in microbe abundance, which is frequently brought on by mechanical vectors and/or reservoir hosts moving around a lot, as well as by system failures in abattoirs. Furthermore, immunogenetics may be compromised when animals are bred for specific desirable features. Exposure to *Homo sapiens* is less common in sylvatic ecosystems, although increases in human incursion and possibly habitat degradation may cause FOI to rise or fall (McMahon et al., 2018).

3. Key Threats to Animal Health and Ecosystems in Pakistan

The nation's biological diversity is incredibly rich, but there are still substantial obstacles. Excessive grazing, overharvesting, salinization, water-logging, deforestation, soil deterioration, land conversion, foreign invasive species, chemical pollution, and desertification are some of the factors that can lead to biodiversity loss (Baig & Al-Subaiee, 2009).

3.1. Habitat loss and Fragmentation

When the landscape's composition shifts and fewer individuals are present, this is referred as pure habitat loss. Destruction of habitat may have a disruptive impact on species richness dynamics (Horváth et al., 2019). Animal populations suffer greatly from habitat fragmentation. Due to the fact that it denies animals their natural environment (Svenning & Sandel, 2013). One of the main environmental factors contributing to a decline in bird diversity at the local, regional, and global levels is habitat loss (Frick et al., 2020). Swans, ducks, flamingos, and Siberian cranes are among the winter visitors and passage migrants in Pakistan. The number of these birds has decreased due to the destruction and degradation of vegetated wetland habitats (Umar et al., 2018). Because of natural territory degradation and disintegration, mountain ungulate populations have either significantly decreased or became locally extinct (Baig & Al-Subaiee, 2009; Arshad et al., 2012).

3.2. Illegal Hunting

Pakistan has a long history of hunting, which has grown with the use of contemporary weapons and increasing mobility. Pakistan now faces threats to 10 reptilian, 25 avian, and 37 mammalian species. Marsh crocodiles and freshwater turtles are going extinct due to overhunting. While *Chitra indica* is endangered and *Kachuga smithii* is near threatened, three of the nation's eight freshwater turtle species such as *Geoclemys hamiltonii*, *Hardella thurjii*, and *Aspideretes gangeticus* are vulnerable (Baillie et al., 1996).

3.3. Human Activity

Birds are important markers of an efficient ecosystem and environment. Because of human meddling and environmental deterioration, bird diversity has been declining. Overexploitation, hunting, and construction projects pose the biggest threats to the declining trend of birds (Shah et al., 2022). Over the past four years, both natural and man-made activities have harmed the biodiversity of Margallah Hills National Park (MHNP). The flora and animals and their environment were impacted by wildfire, tourism, and solid waste produced by eateries, cottages, and residential developments in the center of the national park. The primary causes of fires are cooking, smoking, and backyard barbecue by both locals and visitors. The majority of tourists are unaware of sustainable tourism, and many are also unaware of whether MHNP is a protected area (PA). Wildlife is disturbed by noise pollution, garbage pollution, and other undesired activities, particularly during the breeding seasons. Grey goral and barking deer, which were overly abundant in the previous five to six years, have vanished as a result, and many of them have moved to higher areas. The way that animals like wild boar and monkeys eat has been altered by solid waste. Instead of eating their natural diet, they have begun to consume the trash that is thrown by humans, homes, and restaurants (Sanjrani et al., 2019).

3.4. Climate Change

Species extinction and declining diversity of flora and fauna are caused by climate change (Batool & Hussain, 2016). Where certain plant and animal species may survive, thrive, and reproduce is largely determined by temperature and rainfall. The physiology of organisms is known to be directly impacted by temperature (Qureshi and Ali, 2011). The climate change influences some creatures, such as the giant panda, polar bear, tiger, green sea turtle, and snow leopard. Global warming is threatening approximately 23 percent of bird species and 47% of mammal species. Since the impacts of climate crises are anticipated to vary greatly, it is difficult to forecast how it will impact the spread of illness in a particular location. Particularly in the aquatic environment, this might be the case. Organisms that exploit weather variations for their own benefit are the source of wildlife diseases (Ashraf Hussain et al., 2022).

4. Case Studies

Case study I: Winter Bird Survey at Keti Bunder, Thatta District, Pakistan

Keti Bunder, located in the Indus Delta within the Thatta district of Sindh, was the focus of a study on avian diversity and the threats faced by the local bird population. The survey, conducted during the winter season (November 2015 to February 2016), involved both direct and indirect methods at dawn and dusk. A total of 49 bird species were recorded, belonging to 33 genera and 21 families, with 4,280 individual birds observed. The study also measured numerous biodiversity indices, including Dominance (D), Shannon-Wiener Diversity Index (H'), Simpson Index (S), Evenness (E), and Margalef (R), with values of 0.06, 3.23, 0.94, 0.52, and 5.74, respectively. The most generous species in the area included the little egret, cattle egret, greater flamingo, greater egret, and common coot. The findings suggested a decrease in bird species over time, particularly when compared to previous research, which could be ascribed to anthropogenic factors, primarily pollution (Ali et al., 2016).

Case study II: "Freshwater Turtles of Pakistan: Survival Threats and Conservation Challenges"

Freshwater turtles in the country face a range of serious threats, leading to an important decline in their populations. Illegal hunting, in particular, has had a devastating effect on already vulnerable turtle species. The short-term exploitation of these limited resources, which recover slowly, has proven unsustainable, especially as local collectors receive least financial gain from selling them, thereby restricting the potential for substitute, sustainable development opportunities like eco-tourism or wildlife ranching. Ecologically, the role of Asian turtles has remained largely unrecognized, and as species have vanished from the wild, restoring this crucial knowledge has become nearly impossible. Turtles have become a central focus in conservation awareness initiatives, spotlighted on television and integrated into global marketing and

donor programs. They are now viewed as a conservation priority, valued for their role in maintaining ecological balance rather than as commodities for exploitation. To protect the remaining turtle populations, strict law enforcement is vital. Additionally, research on turtle ecology and monitoring of wildlife trade are critical for effective management. Organizations like provincial wildlife departments, federal wildlife agencies, WWF Pakistan, and IUCN have been instrumental in conservation efforts. Community-based conservation programs and alternative livelihood initiatives have also played a pivotal role in decreasing pressure on the natural turtle population (Saeed et al., 2011).

5. Challenges in Management

Wildlife, fisheries, forestry, and agriculture are some of the important aspects that make up Pakistan's biodiversity domain. Sectoral policies have been created for these areas, but management and administration are still lacking. Despite the development of biodiversity governance and a central pivot in Pakistan, execution of policies remains an issue and mostly depends on foreign organizations and timely partnership. Limitations to country's biological variability preservation and management include weak institutional frameworks and governance, low literacy rates, inadequate infrastructure, tight budgets, little political influence, and a lack of tools for strategic or policy execution (Lashari et al., 2021). When it comes to species protection, the law prioritizes varieties of animals over threatened and endangered plant species. The majority of current legislation prohibiting the killing of game animals cannot be implemented. Building Capacity Provincial wildlife administrations lack the necessary manpower and resources to carry out their responsibilities. There is no funding available for conservation in an underdeveloped country like Pakistan (Khan et al., 2022).

Pakistan's PA divisions are antiquated. The majority of remaining areas with significant biodiversity are used and managed by local communities. Pakistan's wildlife law lacks a provision for protected areas with community involvement and long-term use (Mufti and Hassan, 2005).

Below are a number of shortcomings in administration of Protected Areas (PAs) in Pakistan (Anwar et al., 2008).

i. Current wildlife laws do not offer a sufficient framework for effective management, lacking provisions that enable wildlife departments to oversee surrounding areas.
ii. Most PAs in Pakistan either have inadequate management plans or fail to implement them effectively.
iii. Provincial wildlife departments are not adequately staffed with trained personnel to manage the PAs effectively.
iv. There has been limited progress in establishing collaborative management frameworks, and local communities seldom play a role in the management of Protected Areas.

6. Policy Recommendations

It is recommended that some preventive measures should be taken immediately to halt the loss of biodiversity. Some of them given below:

6.1. Boost Vegetation Growth

The practices of plantation, seed broadcasting, and the sustainable management of forest resources retain significant potential to boost vegetation cover. These approaches not only aid to the restoration and growth of forested areas but also enhance the overall quality of habitats. By creating more varied and stable ecosystems, these efforts can support a wider variety of wildlife species, encouraging both higher species diversity and larger populations. In turn, this promotes healthier and stronger ecosystems capable of sustaining a broader range of wildlife. Sustainable forest management ensures that these efforts are long-term, balancing ecological restoration with the protection of resources for forthcoming generations (Rajpar et al., 2022)

6.2. Establish Protected Forest Areas

This approach will play a vital role in ceasing deforestation and preventing the loss of forests' ability to isolate carbon. Forests act as vital carbon sinks, absorbing significant amounts of CO_2 from the atmosphere, which helps reduce the effects of climate change. By protecting and expanding forested areas, we can maintain and enhance this natural process, reducing the amount of carbon dioxide in the air. As CO_2 emissions continue to be a primary cause of global warming, strengthening forest conservation and restoration efforts is essential for both fighting climate change and securing a sustainable future (Rajpar et al., 2022)

6.3. Create Biodiversity and Climate Change Resource Hubs

These centers should be established nationwide to offer education and raise awareness about strategies for reducing climate change and protecting biodiversity. They could serve as hubs for sharing pivotal information on different aspects of biodiversity, particularly focusing on forestry and wildlife conservation. Additionally, these centers can emphasize the impacts of biodiversity loss on ecosystems and communities, as well as the underlying causes of climate change. By offering reachable resources and educational programs, these centers will enable individuals and communities to take action toward a more sustainable and resilient future (Rajpar et al., 2022)

6.4. Conserve Wildlife Fauna and Their Habitats

Wild fauna and flora are important for the well-being and survival of humanity, providing vital ecosystem services such as pollination, air and water purification, and climate regulation. However, these species are under major threat due to human activities and the effects of climate change, including habitat destruction, food shortages, illegal poaching, and unchecked hunting. As a result, wildlife populations have been quickly declining across the wide. To counteract these threats, it is necessary to establish protected areas such as national parks, wildlife refuges, game reserves, biodiversity reserves, and natural parks. These protected zones can help restore habitats, promote the recovery of wildlife populations, and ensure that ecosystems continue to function effectively for future generations (Rajpar et al., 2022).

6.5. Promote Public Awareness

Launch campaigns in educational institutions, local communities and tourists to promote the importance of biodiversity conservation. Promote eco-tourism as sustainable economic activity, ensuring it does not disrupt local ecosystems and wildlife (Rajpar et al., 2022).

Conclusion

Pakistan, with its rich biodiversity plays an important role in maintaining global environment health. The interconnection of human, animals and ecosystem is essential to sustaining life, as demonstrated in the concept of "health," which emphasizes living cooperatively with the environment. However, the country's wildlife and ecosystems face a number of threats, including habitat loss, illegal hunting, human interference, and climate change, all of which have resulted in significant declines in biodiversity. Case studies, such as Keti Bunder winter bird survey and Freshwater turtle conservation efforts, demonstrate the dire need for effective management and conservation strategies. Weak governance, insufficient resources, and outdated wildlife laws exacerbate the challenges in managing protected areas and conserving biodiversity. To safeguard Pakistan's natural heritage and ensure the long-term survival of its diverse species, it is necessary to strengthen conservation efforts, enhance public awareness, and implement efficient policies. By recognizing the interconnectedness of all living systems and promoting a deeper understanding of ecological balance, Pakistan can work towards a future where humans, wildlife, and ecosystems thrive together harmoniously.

References

Aguirre, A. A. (2017). Changing patterns of emerging zoonotic diseases in wildlife, domestic animals, and humans linked to biodiversity loss and globalization. *ILAR Journal*, *58*(3), 315-318.

Akter, M., Islam, M. S., Islam, M. A., Sobur, M. A., Jahan, M. S., Rahman, S., & Rahman, M. T. (2020). Migratory birds as the potential source for the transmission of Aspergillus and other fungus to Bangladesh. *Journal of Advanced Veterinary and Animal Research*, *7*(2), 338-344. https://doi.org/10.5455/javar.2020.g427

Ali, A., Altaf, M., & Khan, M. S. H. (2016). Winter survey of birds at Keti Bunder, district Thatha, Pakistan. *Punjab University Journal of Zoology*, 31, 203-208. https://pu.edu.pk/images/journal/zology/PDF-FILES/12-31_2_16.pdf

Anwar, M., Jasra, A. W., & Ahmad, I. (2008). Biodiversity conservation status in Pakistan-a review. *The Pakistan Journal of Forestry*, *58*(1), 39.

Arshad, M., Qamer, F. M., Saleem, R., & Malik, R. N. (2012). Prediction of Kashmir markhor habitat suitability in Chitral Gol National Park, Pakistan. *Biodiversity*, *13*(2), 78-87.

Ashraf Hussain, D. M. N. C., Jafri, S. Z. H., Malik, S., & Ali, N. (2022). Climate Change and Its Impacts on Pakistan. *Journal of Positive School Psychology*, *6*(8), 9195-9217.

Aslam, S., Siddiqui, S., Ullah, U., Manzoor, U., Lateef, T., Samreen, N., & Ghalib, S. A. (2022). Vertebrate wildlife of Pakistan: A review. *Canadian Journal of Pure and Applied Sciences*, *16*(2), 5483-95.

Baig, M. B., & Al-Subaiee, F. S. (2009). Biodiversity in Pakistan: key issues. *Biodiversity*, *10*(4), 20-29.

Baillie, J., Gärdenfors, U., Groombridge, B., Rabb, G., & Stattersfield, A. J. (1996). 1996 IUCN Red List of threatened animals. Retrieved from https://coilink.org/20.500.12592/k6vqcc on 18 Feb 2025. COI: 20.500.12592/k6vqcc.

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O., Swartz, B., Quental, T. B., & Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived?. *Nature*, *471*(7336), 51-57.

Batool, S., & Hussain, M. (2016). Wildlife in the perspective of environmental degradation: A review. *Journal of Entomology and Zoology Studies*, *4*(5), 508-511.

Bengis, R. G., Leighton, F. A., Fischer, J. R., Artois, M., Morner, T., & Tate, C. M. (2004). The role of wildlife in emerging and re-emerging zoonoses. *Revue Scientifique et Technique-office International des Epizooties*, *23*(2), 497-512.

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015). Accelerated modern human–induced species losses: Entering the sixth mass extinction. *Science Advances*, *1*(5), e1400253.

Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife--threats to biodiversity and human health. *Science*, *287*(5452), 443-449.

Deem, S. L., Karesh, W. B., & Weisman, W. (2001). Putting theory into practice: wildlife health in conservation. *Conservation Biology*, *15*(5), 1224-1233.

Depledge, M. H., & Galloway, T. S. (2005). Healthy animals, healthy ecosystems. *Frontiers in Ecology and the Environment*, *3*(5), 251-258.

Estes, J. A., Terborgh, J., Brashares, J. S., Power, M. E., Berger, J., Bond, W. J., & Wardle, D. A. (2011). Trophic downgrading of planet Earth. *Science*, *333*(6040), 301-306.

Evans, B. R., & Leighton, F. A. (2014). A history of One Health. *Review Science Technology*, *33*(2), 413-420.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, *34*(1), 487-515.

Frick, W. F., Kingston, T., & Flanders, J. (2020). A review of the major threats and challenges to global bat conservation. *Annals of the new York Academy of Sciences*, *1469*(1), 5-25.

Grace D, Bett BK, Lindahl JF, Robinson TP (2015). Climate and livestock disease: assessing the vulnerability of agricultural systems to livestock pests under climate change scenarios. *CCAFS Working Paper*. https://www.farm-d.org/app/uploads/2015/07/Formatted-livestock-FINAL.pdf

Henry, B., Charmley, E., Eckard, R., Gaughan, J. B., & Hegarty, R. (2012). Livestock production in a changing climate: adaptation and mitigation research in Australia. *Crop and Pasture Science*, *63*(3), 191-202.

Horváth, Z., Ptacnik, R., Vad, C. F., & Chase, J. M. (2019). Habitat loss over six decades accelerates regional and local biodiversity loss via changing landscape connectance. *Ecology Letters*, *22*(6), 1019-1027.

Howden, S. M., Crimp, S. J., & Stokes, C. J. (2008). Climate change and Australian livestock systems: impacts, research and policy issues. *Australian Journal of Experimental Agriculture, 48*(7), 780-788.

Khan, A. N., Khan, H. A., & Ammar, E. E. S. I. (2022). A Review: Protected Areas of Pakistan Management and Current Issues. *American Journal of Biological and Environmental Statistics*, *8*(4), 112-116.

Khan, M. S. (1999). Herpetology of habitat types of Pakistan. *Pakistan Journal of Zoology*, *31*(3), 275-289.

Khan, Z. U. (2021). The Legal Structure and Role of Livestock in Pakistan's Economy. *Pakistan Vision*, *22*(2), 59.

Lashari, A. H., Li, W., Hassan, M., Nabi, G., Mabey, P. T., Islam, M. M., & Memon, K. H. (2021). Biodiversity governance and management in Pakistan: a way forward through the China-Pakistan Economic Corridor. *Polish Journal of Environmental Studies*, *30*(3), 2589-2596.

McMahon, B. J., Morand, S., & Gray, J. S. (2018). Ecosystem change and zoonoses in the Anthropocene. *Zoonoses and Public Health*, *65*(7), 755-765.

Mufti, S. A., & Hassan, S. A. (2005). Biodiversity and sustainable development: Pakistani perspective. *Science Vision, 11*(1–4), 149–160.

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M. S., & Bernabucci, U. (2010). Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science*, *130*(1-3), 57-69. Qureshi, N. A., & Ali, Z. (2011). Climate change, biodiversity Pakistan's scenario. *Journal of Animal and Plant Sciences*, *21*(2 Suppl), 358-363.

Rahman, M. T., Sobur, M. A., Islam, M. S., Ievy, S., Hossain, M. J., El Zowalaty, M. E., & Ashour, H. M. (2020). Zoonotic diseases: etiology, impact, and control. *Microorganisms*, *8*(9), 1405.

Rajpar, M. N., Baig, M. B., Behnassi, M., & Reed, M. R. (2022). Impacts of climate change on biodiversity resources, especially forests and wildlife distribution. In *The Food Security, Biodiversity, and Climate Nexus* (pp. 55-85). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-12586-7_4

Ribas, M. P., García-Ulloa, M., Espunyes, J., & Cabezón, O. (2023). Improving the assessment of ecosystem and wildlife health: microbiome as an early indicator. *Current Opinion in Biotechnology*, *81*, 102923. https://doi.org/10.1016/j.copbio.2023.102923

Ruikar, S. (2024). The Role of Wildlife in Ecosystem Health: Interactions and Impacts. *Revista Electronica de Veterinaria*, *25*(1), 275-295.

Saeed, K., Azam, M. M., & Wahab, A. (2011). Freshwater turtles of Pakistan: Threats to survival and conservation challenges. *Records of the Zoological Survey of Pakistan, 20*, 68–77.

Sanjrani, A., Khaskheli, N. A., & Chandio, S. H. (2019). Impact of Natural Events and Anthropogenic Activities on the Biodiversity of Margallah Hills National Park Islamabad (MHNP). *North American Academic Research*, *2*(3), 20-32

Scheele, B. C., Legge, S., Blanchard, W., Garnett, S., Geyle, H., Gillespie, G., & Woinarski, J. (2019). Continental-scale assessment reveals inadequate monitoring for threatened vertebrates in a megadiverse country. *Biological Conservation*, *235*, 273-278. https://doi.org/10.1016/j.biocon.2019.04.023

Shah, S. A. H., Bilal, A., Ahmad, M. M., & Bukhari, S. S. (2022). Deforestation is causing a great loss in avian diversity in Pakistan. *American Journal of Zoology*, *5*(3), 24-29.

Svenning, J. C., & Sandel, B. (2013). Disequilibrium vegetation dynamics under future climate change. *American Journal of Botany*, *100*(7), 1266-1286.

Terborgh, J., Lopez, L., Nuñez, P., Rao, M., Shahabuddin, G., Orihuela, G., & Balbas, L. (2001). Ecological meltdown in predator-free forest fragments. *Science*, *294*(5548), 1923-1926.

Thompson, A., & Kutz, S. (2019). Introduction to the special issue on 'Emerging Zoonoses and Wildlife'. *International Journal for Parasitology: Parasites and Wildlife*, *9*, 322. https://doi.org/10.1016/j.ijppaw.2019.07.002

Thompson, R. A. (2013). Parasite zoonoses and wildlife: one health, spillover and human activity. *International Journal for Parasitology*, *43*(12-13), 1079-1088.

Thompson, R. A., & Polley, L. (2014). Parasitology and one health. *International Journal for Parasitology: Parasites and Wildlife*, *3*(3), A1.

Tompkins, D. M., Carver, S., Jones, M. E., Krkošek, M., & Skerratt, L. F. (2015). Emerging infectious diseases of wildlife: a critical perspective. *Trends in Parasitology*, *31*(4), 149-159.

Umar, M., Hussain, M., Murtaza, G., Shaheen, F. A., & Zafar, F. (2018). Ecological concerns of migratory birds in Pakistan: a review. *Punjab University Journal of Zoology*, *33*(1), 69-76.

Vaghela, J. F., & Mangal, A. (2017). Climate Change and its effects on Vector Borne Diseases in India. *International Journal of Preventive, Curative & Community Medicine, 3*(4), 4.

Van den Bossche, P., & Coetzer, J. A. (2008). Climate change and animal health in Africa. *Revue Scientifique et Technique*, *27*(2), 551-562.

Van Helden, P. D., Van Helden, L. S., & Hoal, E. G. (2013). One world, one health: Humans, animals and the environment are inextricably linked—A fact that needs to be remembered and exploited in our modern approach to health. *EMBO Reports*, *14*(6), 497-501.

Woodroffe, R., & Ginsberg, J. R. (1998). Edge effects and the extinction of populations inside protected areas. *Science*, *280*(5372), 2126-2128.