Biodiversity Loss and Emerging Zoonoses: The Role of Wildlife Conservation in Preventing Disease Outbreaks

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Abstract

The increasing frequency of zoonotic diseases such as Nipah virus, COVID-19, and Ebola highlights the crucial link between the loss of biodiversity and newly emerging infectious diseases. Zoonoses originate from animals, which often involve complex spillover processes influenced by ecological, human, and environmental processes. Cross-species transmission is favored by increased human-wildlife contact caused by habitat destruction, agricultural encroachment, and urbanization. Recent studies substantiate the "dilution effect," diversified ecosystems can slow down the spreading of viruses, as opposed to previous assumptions where high biodiversity contributes to health dangers. Wildlife trade, deforestation and climate change are significant causes of biodiversity loss and enable the spillover of disease. Prevention of disease requires conservation actions such as conservation of natural habitats and control of wildlife markets. One Health calls for inter-disciplinary and stresses interlinkage between human, animal, and environmental health. Recent technologies such as AI, DNA barcoding, and convergent wildlife monitoring systems also contribute towards surveillance and management. Public participation, education, and policy implementation are key to sustainable coexistence and worldwide pandemic preparedness. Preventative measures are less expensive than reactive measures, highlighting the need for convergent conservation and health interventions.

Keywords: Biodiversity loss, Zoonotic diseases, Spillover events, Convergent conservation, Health interventions.

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Introduction

Zoonoses, also known as zoonotic diseases, are illnesses that humans have gotten from animals. An infectious pathogen is first housed in the animal population, also referred to as a "reservoir host," and subsequently transferred to humans. This cross-species transmission event is frequently called a "spillover event." In around half of these cases, the disease's progression can progress to human-to-human transmission after this species barrier is broken. Ebola, COVID-19, influenza, and the human immunodeficiency virus (HIV) are notable instances of contemporary zoonotic illnesses (Bedenham et al., 2022). Human infectious diseases known as zoonotic diseases are brought on by pathogens that humans and other vertebrates share. In the past, it was thought that great biodiversity in pure natural environments would certainly give rise to new zoonotic infections, implying that biodiversity would be harmful to human health. However, it has also been acknowledged that biodiversity may improve human health by slowing the spread of certain viruses that have already been established in human populations. It may now be possible to reconcile these seemingly incompatible impacts of biodiversity on human health (Keesing et al., 2021).

A huge reservoir of infections can be found in wild animals. Mammals, for instance, are home to at least 320,000 unknown viruses. In a similar vein, scientists still do not fully understand between 88 and 98% of fungal species. Therefore, it is not surprising that areas with high biodiversity and anthropogenic perturbations have a higher risk of zoonotic emerging infectious diseases. Thus, there are many chances for pathogen transfer if contact conditions are suitable. Several of these are spread by arthropod vectors, such as the invasive Aedes mosquitoes that caused the Zika virus to recently expand far beyond Africa. Major reservoir hosts include rodents, livestock, carnivores, non-human primates, and bats (Schmeller et al., 2020; White & Razgour, 2020). The primary drivers of biodiversity loss as of 2019 were intensification and extension of agriculture. Previously intact ecosystems were both cleared biodiversity also releases pesticides, fertilizers, and antimicrobial compounds into the environment, homogenizes landscapes to decrease the availability of natural resources for wildlife, and creates edge habitats that increase human encroachment on wildlife. Similar to this, urbanization—which is defined by the existence of built environments—cleaves intact ecosystems while increasing pollution of the air, water, light, and land. Furthermore, by 2050, 70% of the world's population is predicted to reside in urban regions, a considerable rise in human density brought about by urbanization. All of these elements may affect the dynamics of infectious diseases that have a significant environmental component in their cycle of transmission, and they all contribute to species population decreases or even local extinctions (Glidden et al., 2021). The impact of One Health viewpoints on global health is increasing.

It is said that One Health is intrinsically integrative and transdisciplinary, bringing together environmental, animal, and human health under one roof. However, following closer examination, it becomes clear that this depiction of entanglement relies on an apolitical comprehension of three distinct conceptual realms that are brought together (Davis & Sharp, 2020).

Factors of Zoonotic Spillover

Rising temperatures, shifting precipitation patterns, and habitat degradation are some of the effects of climate change that are becoming a major factor in changes to the migratory and population dynamics of different wildlife species. As a result, there are more opportunities for zoonotic pathogens to spread into human populations. Human exposure to zoonotic diseases can be increased by customs such as eating bushmeat or utilizing traditional medicines made from animals. The origin and spread of zoonotic infections have been intimately associated with agricultural activities, especially intensive farming. The 1998–1999 Nipah virus outbreak in Malaysia is one prominent example.The virus was able to spread from bats to pigs and then to humans because of the intense pig farming methods near fruit orchards that bats visit. Over a million pigs were culled as a result of the pandemic, which also caused over 100 human deaths and large financial losses (Bhatia et al., 2024).

The Link between Biodiversity Loss and Emerging Zoonoses

There is competition for increased food and supply production as a result of population growth as well as industrialization. Consequently, there is an increase in the occupation including population of forest regions, contact with animals and the parasites and vectors that accompany it, wildlife trafficking and consumption, water source degradation, and garbage accumulation. At the same time, the production of animals and crops for human use has increased, frequently in an unruly manner, which has resulted in the destruction of forests that are vital to the planet's ecological and climatic equilibrium. The contamination of this habitat and the decrease in the availability of fish along with other animals, which leads to the migration of the coastal population to the continent, are examples of the equally severe harm caused by human activities on other ecosystems, such as the marine ecology. These populations become neglected and more susceptible to the consequences of global warming as well as the appearance of new and re-emerging diseases as a result of the accumulation of these variables, which raises demands for things like housing, basic sanitation, and medical aid (Tazerji et al.,2022). Animal populations may migrate as a result of habitat loss and climate change, which could aid in the transmission of any diseases that are introduced from other countries. An illustra tion of this is the anticipated outbreak of the Zika virus, which is brought on by mosquito population migration aided by global warming in other parts of the world. The pathogen's journey from a reservoir host to humans is naturally complex, relying on a variety of variables related to the dynamics of the reservoir host population, human contact with sick animals, and the pathogen's properties. Despite the seeming impossibility of such spillover occurrences, infectious disease outbreaks in humans are on the rise, with over 70% of them thought to be zoonotic (Bedenham et al., 2022).

The Role of Wildlife Conservation in Preventing Disease Outbreaks

A dramatic and exponential increase in human activity worldwide, including the growth of the human population and the expansion of wildlife habitat, the increasing change in land use and deforestation, the increasing demand for food systems based on animal consumption, and the globalization of travel and trade, has been connected to the rise in zoonotic spillover via wildlife reservoir. A viable way to stop future zoonotic spillover from the animal trade may be to implement conservation strategies. The protection of biodiversity and animal welfare are directly improved by conservation measures, which also help to ensure the security of human health worldwide.The vast scope and significance of the wildlife sector as a whole are demonstrated by estimates of 350 million exotic fish, 4 million birds, 640,000 reptiles, and 40,000 primates handled annually. The wildlife trade facilitates zoonotic spillover by bringing wild animals and people close together. Along the trade route, wildlife is exposed to consumers, hunters, and marketers in addition to other wild and domesticated animal species that may act as vectors. An estimated one billion interactions between humans and wildlife occur each year as a result of this exposure, creating the possibility of zoonotic spillover (Hilderink et al., 2021).

Protecting Natural Habitats: A Key Strategy for Preventing Zoonotic Spillover

The onset and dissemination of infectious illnesses are linked to biodiversity loss. On the other hand, zoonotic spillovers from wildlife to humans are less likely in forests along with other natural landscapes with a high animal species abundance because they are better able to "maintain" diseases in the wild environment. The lower incidence of Lyme disease was linked to the preservation of vertebrate biodiversity. The "dilution effect" explains why biodiversity is so important for promoting health. To put it briefly, a wide diversity of host species lowers, or "dilutes," the prevalence of infection in highly competent reservoir hosts, lowering the possibility of human infection and spillover occurrences. Additionally, a variety of species found in biodiverse landscapes reduce the risk of human infection by interfering with pathogen transmission through a variety of ways. The loss of biodiversity and environmental degradation encourage the movement of infections and animal vectors to new locations, which makes it easier for diseases to spread from one species to another. In this way, building roads, homes, and hydroelectric power plants in forested areas, along with other activities linked to deforestation, exposes people to wild species and their diseases, so establishing the prerequisites for zoonotic transmission (Ellwanger & Chies, 2021).

To guarantee alignment with the prioritizing of activities and resources, it is crucial to define "prevention of spillover" in the context of preventing outbreaks, prevalence of diseases, epidemics, and pandemics. The word "prevention" is currently employed in a variety of applications. In the field of public health, for instance, it refers to either primary prevention, which aims to prevent human disease from ever arising, or downstream/secondary prevention, which aims to stop minor, localized disease outbreaks from spreading and becoming an epidemic or pandemic. Interventions like early detection, vaccinations, better health systems, medication therapy, health promotion, social and behavioral change, and the adoption of hygienic practices are frequently used to accomplish secondary prevention. Since "containment of infection" more accurately captures the goal of these actions and avoids any confusion with spillover prevention, it would be a better term to use for secondary prevention (Markotter et al., 2023).

Conservation Efforts and Disease Risk Reduction, Case Studies

Over the past century, the number of fatalities and financial losses resulting from viral zoonotic pandemics has consistently climbed. Prominent policymakers have advocated programs that contend "detecting and containing emerging zoonotic threats" should be the primary strategy for dealing with future pandemic disasters. To put it another way, we ought to intervene only when people become ill. We are diametrically opposed. Humans frequently come into contact with animals, which are known to carry a large number of viruses, many of which have not yet infected people. We calculate the yearly damage caused by newly discovered viral zoonoses. We examine three doable strategies to lessen the effects of upcoming pandemics: improved management of the wildlife trade, significant reduction of deforestation, and improved surveillance of pathogen spillover and the creation of worldwide databases of virus genomes and serology. We discover that these key pandemic preventive measures offer significant cobenefits and cost less than one-twentieth of the annual number of fatalities caused by newly developing viral zoonoses (Bernstein et al., 2022).

The capacity of zoonotic infections to produce persistent human-to-human transmissibility is closely related to their potential for pandemics. This is the case with SARS-CoV-2, the virus that causes COVID-19 [WHO Coronavirus Disease (COVID-19)]. The virus caused a global pandemic that affected more than 200 countries and territories in less than 100 days, resulting in over 175 million recognized infections along with 3811561 assigned human deaths by June 15, 2021. COVID-19 appears to have been the consequence of zoonotic transmission from an original wildlife host, maybe via an intermediate animal host, after close contact with humans, notwithstanding disagreements over its precise origins and infection mechanism (Andersen *et al.*, 2020; Wu *et al.*, 2020). The close proximity of various wild as well as domestic animal species in a wildlife trade setting (often confused with a "wet market," which may or may not have wildlife and simply indicates the existence of fresh produce) may allow recombination within more distant coronaviruses and a rise of recombinants with novel phenotypes, even though the direct reservoir of SARS-CoV-2 may never be identified (Li *et al.*, 2020). This is especially important because wildlife species in southern China and Southeast Asia carry several relatives of SARS-CoV-2 and SARS-CoV, which caused the 2003 SARS outbreak (Zhou *et al.*, 2021). Reducing direct human interaction with wild animals and avoiding such circumstances seem to be essential for avoiding the spread of novel coronavirus zoonoses (Petrovan et al., 2021).

In terms of land-clearing and deforestation, Australia remains one of the worst nations. The encroachment of urban populations into wildlife habitats, land clearing and deforestation, unsustainable agricultural practices, the development of new mining sites, and the resulting changes in the management of ordinarily owned or ancestral Indigenous lands—the majority of which are managed by non-Indigenous individuals or businesses for mining and/or agriculture—are some of the factors that contribute to land-use change. In Australia, changes in native vegetation and land usage have been linked to about 22% of infectious illnesses, including Hendra virus (Woolaston et al., 2022).

The Importance of Community Engagement and Education in Wildlife Conservation

The timing and content of conservation research, management, and public involvement in protected areas worldwide have been thrown off by the COVID-19 epidemic. This disruption is noticeable in US national parks, which are essential for both providing the public with outdoor experiences and safeguarding cultural and natural resources. In addition to protecting 34 million hectares, US national parks welcome over 300 million visitors a year and are among the biggest informal education institutions in the world. In many ways, the pandemic has changed park operations and circumstances. Managers have had to make tough trade-offs between conflicting priorities as a result of changes in operating conditions brought on by safety concerns, personnel shortages, and declining park income. Long-term studies and observations of wildlife populations' and ecosystems' health have been disrupted. Time-sensitive management procedures have been postponed, including invasive plant eradication and habitat restoration (Miller-Rushing et al., 2021). Wildlife managers, who deal with free-ranging, non-domestic animals, must make increasingly difficult judgments. This is particularly relevant in light of the current ecological crisis, which involves widespread and growing threats to wildlife populations from a variety of causes. Recent analysis by UN agency (IPBES) shows nearly a million plants and animals will be extinct in the future. For already complicated wildlife management and conservation, the cumulative and interrelated causes of these changes—such as pollution, climate change, invasion of foreign species, and organism exploitation—present a unique challenge (Kadykalo et al., 2021).

Balancing Human Needs and Wildlife Conservation: The Challenge of Coexistence

To conserve biodiversity over the long run, human and wildlife requirements must be balanced. Human-wildlife conflict mitigation necessitates a thorough grasp of ecological, social, and economic dynamics and will mostly depend on an awareness of conflict patterns, processes, and trends. Although there will likely be an increase in human-wildlife interactions, conflict patterns will become more intricate in dynamic landscapes due to changing land use and cover, varying human activity intensities, increased resource demand, and climate change. To find similarities, support management choices, and direct funding toward mitigation, it is necessary to highlight patterns, mechanisms, and trends in human–wildlife conflict that are backed by scientific data **(**Ilse Storch et al., 2024). The intricate, dynamic, and varied ties that exist between people and wildlife are a pressing concern of our day. On the one hand, the primary cause of biodiversity loss and environmental degradation is the expanding human population and the corresponding rise in demand for a finite and unequally distributed pool of natural resources. Unquestionably, the social sciences have improved our comprehension of the so-called "human dimension of wildlife," which may be viewed from a variety of angles, such as political, cultural, and temporal ones. Since "coexistence" has a more positive meaning than "conflict," the argument over whether it is a better term is indicative of the anthropocentric nature of such issues. The extinction of wildlife species as a result of human activity is a particularly noticeable form of conflict. Examples of these include the Tasmanian tiger (*Thylacinus cynocephalus*), the blue antelope (*Hippotragus leucophaeus*). The dodo (*Raphus cucullatus*), the moas (*Dinor nithiformes*) the giant tortoises (*Cylindraspis spp.*). Though they are referred to as "modern era extinctions" or "extinctions in the Anthropocene", these human-caused wildlife species extinctions are hardly ever included in the HWC framework (Thomas Göttert & Nicole Starik 2022).

The Challenge of Coexistence

Humans and wildlife coadapt to coexist in shared landscapes in a dynamic yet sustainable state known as coexistence, where human-wildlife interactions are regulated by efficient institutions that guarantee the long-term survival of wildlife populations, social legitimacy, and acceptable risk levels (König et al., 2020). In areas where coexistence is expensive, ensuring that the money gained by wildlife serves local residents remains a continuing problem to address coexistence inequality. For instance, local populations' cooperation with wildlife is frequently necessary for wildlife tourism, yet foreign control of industry can occasionally result in little local tourism earnings and no changes to residents' standard of living. More income must be kept close to and associated with its source (Pooley et al., 2022).

"The Role of Policy and Governance in Supporting Wildlife Conservation and Disease Prevention

Certain nations have wildlife farming sectors designed to satisfy market demands for protein and appeal to cultural customs while preventing overhunting of wild species. About 15 million people are employed in China's wildlife farming sector, which is worth about $20 billion. Discussions over phase-out of this industry are underway since the Standing Committee of the National People's Congress said in February 2020 that wildlife consumption for food and related trade in China would be prohibited. It is justified by the fact that it increases the likelihood of illness emergence and Utilizing ecology and economics to avert pandemics, in order to guard against future zoonotic disease outbreaks, investments should be made to stop tropical deforestation and restrict the trade in animals, that there are frequently insufficient health and safety laws pertaining to raising wild animals. To avoid zoonotic disease, laws prohibiting the trade of high-risk disease reservoir species both domestically and internationally must be implemented, and their enforcement must be maintained. Rules must prevent rodents, primates, bats, pangolins, and civets from being sold (Dobson et al., 2020). Among the primary causes of biodiversity loss, new infectious illnesses in wildlife continue to be one of the most difficult to combat. Eradication of a pathogen is usually impossible once it has spread to a new location. On the other hand, increased knowledge of the effects of disease is creating new opportunities for prompt action. For instance, broad species losses had been caused by the fungus Batrachochytrium dendrobatidis (Bd) since the 1970s, when it was identified in 1998 as the cause of amphibian chytridiomycosis. Strategic plans for prevention and response were developed in Europe when a second similar pathogen appeared in the early 2010s. The threat posed by this pathogen was identified earlier than that of Bd. The following characteristics define a zoonotic hotspot: direct human-animal contact, mixing of non-endemic wildlife species, and inadequate health and safety regulations. Although many wildlife markets worldwide satisfy these requirements, there is typically little disease surveillance there. More generally, there are no international regulations on pathogen screening related to the international trade in wildlife, and only a small number of nations employ stringent veterinary import controls, despite the fact that the Convention on the International Trade in Endangered Species (CITES) governs the international wildlife trade based on the endangered status of species (Watsa et al., 2020).

Emerging Technologies and Innovative Solutions for Wildlife Conservation and Disease Risk Reduction

Because of collisions with other vehicles, transportation poses a serious threat to biodiversity. Vehicle collisions are thought to kill hundreds of millions of vertebrates every year in the United States alone. The same patterns are expected to occur on European roadways, where 29 million animals and over 194 million birds are killed each year.

The most obvious consequence of linear infrastructure is the loss of billions of pollinating insects annually, the second-largest source of anthropogenic mortality for many vertebrate species, and wildlife–vehicle collisions (WVCs). Roads have had moderate to severe negative effects on the majority of vertebrate taxa, but there haven't been many studies on invertebrates in the scientific literature (Silva et al., 2024). The use of digitalization in natural resources and bio-conservation management has become essential for sustainable development and biodiversity preservation in this age of rapid technological innovation.

With their creative answers to some of the most urgent environmental problems, emerging digital technologies are becoming more and more important in the management of biodiversity and natural resources.

These technologies include the following:

Artificial Intelligence (AI) and Machine Learning (ML)

The capacity of artificial intelligence (AI) and machine learning (ML) to handle and analyze enormous volumes of environmental data with previously unheard-of speed and accuracy makes them stand out. For example, AI uses in wildlife conservation are transforming efforts to monitor and conserve species. More effective population surveys and behavioral research are being made possible by algorithms that have been trained to identify individual animals from camera trap photographs.

DNA Barcoding and Molecular Ecology

DNA barcoding and molecular ecology make it possible to precisely analyze an organism's genetic makeup, they are revolutionizing species identification and biodiversity protection. This technology makes it easier to identify species, even from very small samples, which helps with biodiversity monitoring and the identification of illegal wildlife trading. DNA barcoding, a technique for quick species identification first presented by has since been used in a number of disciplines, such as conservation biology, ecosystem monitoring, and the investigation of species interactions. Molecular ecology offers a potent tool for biodiversity conservation and natural resource management by shedding light on the genetic diversity and evolutionary processes of species through the use of DNA barcoding and other genetic techniques (Akindele et al., 2024)

Transmissible pathogens that are maintained by at least one host species from either compartment are the cause of shared infections at the wild-domestic interface. These infections may have an impact on biodiversity conservation, wildlife management, public health, animal health, and the economy. Although WHM systems still require significant development, wildlife is crucial to the epidemiology of shared diseases, making Wildlife Health Monitoring (WHM) crucial for identifying shifts in disease prevalence and pathogen emergence.

In order to successfully accomplish Integrated Wildlife Monitoring (IWM) from a One Health perspective, wildlife population monitoring is necessary, even if the majority of WHM programs now primarily depend on general and targeted disease surveillance. Understanding the epidemiology of pathogens and their emergence as endemic in host communities is crucial to regulate shared diseases, and IWM's long-term, large-scale data gathering helps achieve this goal. Therefore, to identify emerging pathogens and changes in pathogen dynamics, estimate wildlife disease risks and the effects of treatments, and gain a deeper understanding of intricate multi-host and multi-pathogen networks, a balanced IWM system that includes wildlife abundance monitoring is crucial (Barroso et al., 2023).

Conclusion

The health of humans, animals, and the environment is inextricably linked, requiring a holistic, interdisciplinary approach to wildlife conservation and disease prevention. The emergence of zoonotic diseases, such as COVID-19, Ebola, and avian influenza, has shown the disastrous effects of ecosystem imbalances and uncontrolled human encroachment on wildlife habitats. Greater contact between wildlife, livestock, and humans due to deforestation, climate change, and urbanization can potentially destroy the existing ecosystems and increase the likelihood of spillover events of pathogens. Anticipatory action that increases biodiversity and reduces the possibilities of public health risk is therefore needed. Public education and awareness are also crucial to facilitate behavior change for coexisting with wildlife. Public education and awareness campaigns can help in convincing local communities to adopt conservation friendly practices and appreciate the economic and health benefits of maintaining ecological integrity. Policy actions and global cooperation are also needed to address transboundary health risks. The COVID-19 pandemic has highlighted the necessity of better global governance in the preparation against disease, such as funding research into wildlife-borne pathogens and investment in early warning systems. The human and environmental health paradigm should change to incorporate sustainability, resilience, and interdisciplinary. Through a focus on wildlife conservation, where public health programs are merged into environmental policy, we will minimize the threat of emerging infectious diseases while ensuring that the world retains its biodiversity. A harmonized global response will be key to ensuring that a healthy future exists for all beings. Time is now by embracing the holistic approach, we can make human development sustainable in relationship with the natural world.

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