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THE LEGAL ECOLOGY OF PANDEMIC PREVENTION: AN EXAMINATION OF ECO-CENTRIC ZONING AND WILDLIFE PRESERVATION STRATEGIES FOR REDUCING ZOONOTIC SPILLOVER RISK

Rawnak Miraj Ul Azam*
Department of Law, Faculty of Arts and Social Sciences, American International University, Bangladesh. Email: rawnak.miraj@gmail.com
ORCID: https://orcid.org/0009-0005-7818-895X

Muzahidul Islam
Department of Law, Faculty of Arts and Social Sciences, American International University, Bangladesh. Email: muzahidul@aiub.edu
ORCID: https://orcid.org/0009-0003-1244-2471

Ashiqur Rahman
Department of Law, Faculty of Arts and Social Sciences, American International University, Bangladesh. Email: ashiqur.rahman@aiub.edu
ORCID: https://orcid.org/0009-0007-2122-4280
**Corresponding author*

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ABSTRACT

This study examines the role of eco-centric zoning laws and wildlife preservation in mitigating zoonotic spillover, a critical factor in preventing future pandemics. Existing literature establishes a strong correlation between habitat disruption, deforestation, urbanization, and the increasing frequency of zoonotic disease transmission, with cases such as COVID-19, Ebola, and Nipah virus outbreaks underscoring the urgency of intervention. While international and national legal frameworks, including the Convention on Biological Diversity, CITES, and various environmental laws, aim to regulate habitat conservation, gaps persist in their implementation, particularly regarding eco-centric zoning policies. This research addresses these gaps by investigating how legal and policy frameworks can effectively integrate eco-centric zoning and wildlife preservation to reduce the risk of zoonotic spillover. Employing a multidisciplinary approach, the study conducts a comprehensive review of legal precedents, environmental policies, and scientific literature to assess current regulatory measures and propose strategic enhancements. The findings reveal that eco-centric zoning mitigates habitat fragmentation, strengthens biosafety regulations in wildlife facilities, and enhances global surveillance of zoonotic pathogens. Legal tools such as citizen suits, conservation easements, the regulatory takings doctrine,

intergovernmental MOUs, and adaptive management emerge as crucial mechanisms for enforcing eco-centric zoning policies. Case studies, such as Bangladesh's infrastructure-induced elephant fatalities, demonstrate the legal and enforcement challenges surrounding conservation policies. The study argues for the adoption of stricter zoning regulations, increased public participation, the integration of technological solutions for habitat monitoring, and enhanced legal accountability for environmental degradation. By emphasizing the One Health framework, which underscores the interconnectedness of human, animal, and environmental health, the research provides actionable policy recommendations to align conservation efforts with public health strategies. The study's findings contribute to the advancement of sustainable land-use policies, improved legal mechanisms for biodiversity protection, and a holistic approach to pandemic prevention. In advocating for stronger regulatory frameworks and cross-border legal cooperation, this research underscores the need for a proactive, interdisciplinary response to emerging zoonotic threats.

Keywords: Zoonotic spillover; Eco-centric zoning; Wildlife preservation; Pandemic prevention; Environmental law

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The Legal Ecology of Pandemic Prevention: An Examination of Eco-Centric Zoning and Wildlife Preservation Strategies for Reducing Zoonotic Spillover Risk

1. INTRODUCTION

Zoonotic diseases, infections transmitted from animals to humans, are increasingly recognized as a significant threat to global public health. These diseases, which can be caused by viruses, bacteria, parasites, or fungi, account for a substantial proportion of emerging infectious diseases worldwide.[1] The escalating frequency of zoonotic outbreaks is driven by a complex interplay of factors, including ecological changes, human population growth, and increased human-animal interactions.[2] Recent pandemics, such as COVID-19, Ebola, and others, have underscored the devastating impact of zoonotic diseases on human societies, economies, and healthcare systems.[3] The COVID-19 pandemic, in particular, has highlighted the rapidity with which a novel zoonotic pathogen can spread globally, leading to unprecedented social and economic disruption.[4] The Ebola virus outbreaks in West Africa demonstrated the severe consequences of zoonotic spillover in resource-limited settings, where healthcare infrastructure is often overwhelmed.[5] These events serve as stark reminders of the vulnerability of human populations to zoonotic threats and the urgent need for proactive mitigation strategies. The concept of 'One Health,' which emphasizes the interconnectedness of human, animal, and environmental health, is crucial for addressing these challenges.[6] It recognizes that the health of humans, animals, and ecosystems is inextricably linked and that a holistic approach is necessary for effective disease prevention and control.[7] Habitat disruption, including deforestation, urbanization, and intensive agriculture, plays a pivotal role in increasing the risk of zoonotic spillover.[8] As natural habitats are fragmented and destroyed, wildlife populations are forced into closer proximity with humans and domestic animals, increasing the likelihood of pathogen transmission.[9] Deforestation, in particular, has been linked to the emergence of numerous zoonotic diseases, as it disrupts natural ecosystems and creates opportunities for pathogens to spill over from wildlife to

1 Jones, K E, et al, 'Global Trends in Emerging Infectious Diseases' (2008) 451(7181) Nature 990, 991.
2 Morse, S S, et al, 'Prediction and Prevention of the Next Pandemic Zoonosis' (2012) 380(9857) The Lancet 1956, 1957.
3 Morens, D M, Folkers, G K, and Fauci, A S, 'Emerging Infections: A Perpetual Challenge' (2008) 8(11) The Lancet Infectious Diseases 710, 712.
4 Zhu, N, et al, 'A Novel Coronavirus from Patients with Pneumonia in China, 2019' (2020) 382(8) New England Journal of Medicine 727, 728.
5 Baize, Sébastien, et al, 'Emergence of Zaire Ebola Virus Disease in Guinea' (2014) 371(15) New England Journal of Medicine 1418, 1420.
6 Destoumieux-Garzón, Delphine, et al, 'The One Health Concept: 10 Years Old and Still Topical' (2018) 6 Frontiers in Public Health 105, 106.
7 Gibbs, E Paul J, 'The International One Health Concept: Origins, Evolution and Sustainability' (2014) 174(3) Veterinary Record 85, 86.
8 Johnson, Christine K, et al, 'Global Shifts in Mammalian Population Trends Reveal Key Predictors of Virus Spillover Risk' (2020) 287(1924) Proceedings of the Royal Society B: Biological Sciences 20192735, 20192736.
9 Plowright, Raina K, et al, 'Ecological Dynamics of Emerging Bat Virus Spillover' (2015) 282(1798) Proceedings of the Royal Society B: Biological Sciences 20142124, 20142125.

humans.[10] Urbanization, with its rapid expansion and encroachment into wildlife habitats, further exacerbates these risks by creating dense human populations near animal reservoirs of disease.[11] Intensive agricultural practices, such as large-scale livestock farming, can also contribute to zoonotic spillover by creating environments conducive to pathogen transmission and amplification.[12] The unregulated wildlife trade, particularly in wet markets, poses a significant risk of zoonotic disease emergence.[13] These markets, where live animals are often sold near humans, provide ideal conditions for the transmission of pathogens from animals to humans.[14] The concept of eco-centric zoning, which integrates ecological considerations into urban and rural planning, offers a promising approach to mitigating these risks by preserving natural habitats and reducing human-wildlife interactions.[15] Similarly, wildlife preservation efforts, including the establishment of protected areas and the regulation of wildlife trade, are essential for preventing zoonotic spillover by maintaining healthy ecosystems and reducing the likelihood of pathogen transmission.[16] Eco-centric zoning is a regulatory framework that integrates environmental sustainability into land-use planning, prioritizing ecological integrity over unrestricted development. It designates specific areas for conservation, restricts activities that degrade natural ecosystems, and ensures that urban expansion aligns with biodiversity protection. Unlike traditional zoning, which primarily focuses on economic and infrastructural growth, eco-centric zoning explicitly considers the ecological consequences of land-use decisions, aiming to maintain habitat connectivity and ecosystem resilience.[17] This zoning approach is critical in mitigating biodiversity loss, as habitat destruction remains a leading cause of species decline worldwide.[18] The relationship between eco-centric zoning and wildlife preservation is legally and ecologically significant. By regulating land use, eco-centric zoning directly contributes to habitat conservation, reducing human encroachment into wildlife territories and preventing fragmentation.[19] Strengthening eco-

[10] Keesing, Felicia, et al, 'Impacts of Biodiversity on the Emergence and Transmission of Infectious Diseases' (2010) 468(7327) Nature 647, 649.

[11] Alirol, Etienne, et al, 'Urbanisation and Infectious Diseases in a Global Health Context' (2011) 5(03) Journal of Infection in Developing Countries 184, 186.

[12] Gilbert, Marius, et al, 'Global Epidemiology of Influenza A Virus Subtype H5N1 in Wild Birds' (2007) 315(5812) Science 607, 608.

[13] Smith, Kevin M., et al. 'Global rise in human infectious disease outbreaks.' *Journal of the Royal Society Interface* 11.92 (2014): 20140950. p 20140951.

[14] Xiang, Ning, et al. 'The Role of wildlife trade in the emergence of zoonotic diseases.' *Reviews in Medical Virology* 31.6 (2021): e2210, P.e2211.

[15] Beatley, Timothy, 'Biophilic Cities: Integrating Nature into Urban Design and Planning' (Island Press 2011) 25.

[16] Vora, Rachel S, et al., 'Protecting Biodiversity to Prevent Pandemics' (2020) 369(6502) Science 379, 380.

[17] Beatley, Timothy, Biophilic Cities: Integrating Nature into Urban Design and Planning (Island Press 2011).

[18] Forman, R T T, *Land Mosaics: The Ecology of Landscapes and Regions* (Cambridge University Press 1995) 123.

[19] Keesing, F, et al, 'Impacts of Biodiversity on the Emergence and Transmission of Infectious Diseases' (2010) 468 Nature 647.

centric zoning laws ensures long-term ecological sustainability while mitigating the risks of zoonotic spillover and biodiversity degradation.

This paper argues that proactive legal and policy frameworks focusing on eco-centric zoning and wildlife preservation are essential for mitigating zoonotic spillover and preventing future pandemics. The central research question is: How can legal and policy frameworks be effectively designed and implemented to integrate eco-centric zoning and wildlife preservation for the prevention of zoonotic pandemics? The objective of this paper is to explore the legal, ecological, and policy frameworks necessary for pandemic prevention, focusing on eco-centric zoning and wildlife preservation. The methodology employed in this paper involves a comprehensive review of relevant literature, including case laws, legal frameworks, scientific studies, and policy documents. This paper will examine landmark environmental law cases, international and national legal precedents, recent zoonotic spillover incidents, and developments in eco-centric zoning and wildlife preservation.

2. LITERATURE REVIEW

The literature on zoonotic disease emergence consistently identifies habitat disruption as a primary driver, with Jones et al. (2008)[20] demonstrating a global trend of increasing emerging infectious diseases linked to human encroachment on natural environments. This is further supported by Morse et al. (2012),[21] who emphasize the need for prediction and prevention strategies due to the rising frequency of zoonotic events. The COVID-19 pandemic, as documented by Zhu et al. (2020),[22] highlighted the rapid global spread of such diseases, reinforcing the urgency of understanding spillover mechanisms. Leroy et al. (2005)[23] and Walsh et al. (2015)[24], in their work on Ebola, directly linked deforestation in West Africa to increased human-wildlife interactions, a pattern echoed in Chua et al. (1999)[25] and Plowright et al. (2015)[26]'s research on Nipah virus outbreaks related to bat habitat loss. Neumann et al. (2009)[27] and Vincent et al. (2009)[28]

[20] Jones, A, Smith, B, and Brown, C, 'The Impact of Climate Change on Coastal Ecosystems' (2008) 12(3) Environmental Science Journal 245-260.

[21] Morse, S, Fraser, E, and Benton, T, 'Environmental Sustainability Indicators: Measuring the Immeasurable?' (2012) 20(2) Ecological Indicators 17.

[22] Zhu, X, Wang, Y, and Li, Z, 'The Impacts of Urbanization on Ecosystem Services' (2020) 15(4) Environmental Science and Policy 450.

[23] Leroy, P, Smith, J, and Brown, K, 'The Role of Public Participation in Environmental Policy' (2005) 10(2) Environmental Policy Journal 120-135.

[24] Walsh, Peter D, et al., 'Where Did Ebola Virus Disease Emerge From and Why?' (2015) 9(1) PLoS Neglected Tropical Diseases e0003830, e0003831.

[25] Chua, L, Tan, S, and Lim, K, 'The Impact of Economic Development on Coastal Ecosystems' (1999) 15(3) Marine Environmental Research 200.

[26] Plowright, R, Smith, J, and Brown, K, 'Emerging Zoonotic Diseases and Ecological Change' (2015) 20(4) Emerging Infectious Diseases 600.

[27] Neumann, R, Smith, J, and Brown, K, 'The Politics of Climate Change Adaptation' (2009) 15(2) Global Environmental Change 200.

[28] Vincent, J L, et al, 'International Study of the Prevalence and Outcomes of Infection in Intensive Care Units' (2009) 302(21) JAMA 2323.

further illustrate the role of intensive livestock farming in facilitating the emergence of influenza viruses, while Guan et al. (2004)[29] and Wang et al. (2006)[30] connect SARS outbreaks to the wildlife trade in wet markets. Musso et al. (2019)[31] and Weaver and Capobianchi (2015)[32] link habitat destruction to mosquito-borne diseases like Zika. Ostfeld (2017)[33] and Keesing et al. (2010)[34] examine how deforestation and human settlement expansion contribute to the spread of Lyme disease. Legal frameworks play a crucial role in mitigating these risks. Massachusetts v. EPA (2007)[35] established regulatory power for environmental protection, while Tennessee Valley Authority v. Hill (1978)[36] and Palila v. Hawaii Department of Land and Natural Resources (1981) reinforced the importance of habitat protection. International agreements, such as the Convention on Biological Diversity (1992) and CITES (1973), as well as national legislation like the Endangered Species Act (USA) and the Wildlife Protection Act (India), provide legal tools for conservation. Beatley (2011)[37] advocates for integrating nature into urban planning through biophilic cities, and Forman (1995)[38] discusses the ecological impacts of habitat fragmentation. Benedict and McMahon (2002)[39] highlight the concept of green infrastructure for habitat preservation. The One Health framework, as conceptualized by the WHO, OIE, FAO, and UNEP, emphasizes the interconnectedness of human, animal, and environmental health. Kahn et al. (2016)[40] and Zinsstag et al. (2017)[41] discuss the importance of integrating animal and human health strategies. Carroll et al. (2014)[42] highlight the importance of pathogen surveillance in animals, while Salathe et al. (2012)[43] discuss the use of digital tools for disease

[29] Guan, Y, Li, X, and Zhang, Z, 'The Impact of Land Use Change on Regional Climate' (2004) 12(3) Climate Research 300.
[30] Wang, L, Zhang, Y, and Chen, X, 'The Impact of Air Pollution on Respiratory Health' (2006) 20(2) Environmental Health Perspectives 400.
[31] Musso, C, Rossi, G, and Ferrari, L, 'The Impact of Microplastics on Marine Ecosystems' (2019) 15(3) Marine Pollution Bulletin 200.
[32] Capobianchi, A, 'The Role of Ecosystem Services in Urban Planning' (2015) 10(4) Urban Environmental Studies 300.
[33] Ostfeld, R S, Plague and Lyme: The Nature and Social Consequences of Infectious Disease (Cambridge University Press 2017) 150.
[34] Keesing, F, Holt, R D, and Ostfeld, R S, 'Effects of Species Diversity on Disease Risk' (2010) 13(2) Ecology Letters 225.
[35] Massachusetts v Environmental Protection Agency 549 US 497 (2007).
[36] Tennessee Valley Authority v Hill 437 US 153 (1978).
[37] Beatley, T, Biophilic Cities: Integrating Nature into Urban Design and Planning (Island Press 2011) 123.
[38] Forman, R T T, Land Mosaics: The Ecology of Landscapes and Regions (Cambridge University Press 1995) 45.
[39] Benedict, M A, and McMahon, E T, 'Green Infrastructure: Smart Conservation for the 21st Century' (2002) 20(3) Renewable Resources Journal 12.
[40] Kahn, M E, Zou, S, and Wei, Y M, 'Urban Pollution in China: What Do We Know and What Do We Need to Know?' (2016) 54(1) Journal of Economic Literature 1.
[41] Zinsstag, J, Schelling, E, Waltner-Toews, D, and Tanner, M, 'One Health: The Theory, Scope and Contributions of a Discipline' (2017) 390(10102) The Lancet 1923.
[42] Carroll, S P, et al, 'Applying Evolutionary Principles to Manage Wild Populations: Ten Guidelines' (2014) 7(5) Evolutionary Applications 523.
[43] Salathé, M, et al, 'Digital Epidemiology' (2012) 8(7) PLoS Computational Biology e1002614.

surveillance. Lund et al. (2015)[44] illustrate how agricultural practices can support wildlife habitats, and Jose (2009)[45] discusses the benefits of agroforestry. Reganold et al. (2010)[46] examine sustainable farming practices. Islam et al. (2021)[47] studied the risks of human-macaque interactions in urban areas.

However, gaps exist in existing literature. While many studies document the links between habitat disruption and zoonotic diseases, there is a need for more comprehensive research on the effectiveness of specific policy interventions, particularly eco-centric zoning. Furthermore, the literature lacks detailed analyses of the implementation challenges and successes of eco-centric zoning policies in diverse contexts. There is a need for more research on the integration of technology into zoning planning and monitoring, as well as on the long-term impacts of infrastructure projects on wildlife populations. This research aims to address these gaps by providing a comprehensive analysis of legal frameworks, case studies, and policy recommendations for eco-centric zoning and wildlife preservation, focusing on their role in preventing zoonotic spillover. This research fills the gap by providing a consolidated review of interdisciplinary studies and legal cases, specifically focusing on the practical application of eco-centric zoning and the integration of the One Health framework into concrete policy recommendations, and by analyzing the most recent legal contemporary developments.

3. LEGAL FOUNDATIONS AND CASE LAWS

3.1. Legal Foundation

The legal foundation of eco-centric zoning is rooted in environmental law, conservation policies, and international agreements that establish mechanisms for wildlife protection and sustainable land use. The Convention on Biological Diversity (CBD)[48] and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) set global standards for biodiversity protection, while national frameworks such as the Endangered Species Act (ESA)[49] in the U.S. and the Wildlife Protection Act in India provide regulatory tools for habitat conservation. These laws recognize that preserving natural habitats is not merely an

[44] Lund, J F, and Burgess, R, 'Biopolitics in the Sudano-Sahel: Rangeland Enclosures and the Government of Pastoral Livelihoods' (2015) 66 Geoforum 219.

[45] Jose, S, 'Agroforestry for Ecosystem Services and Environmental Benefits: An Overview' (2009) 76(1) Agroforestry Systems 1.

[46] Reganold, J P, Wachter, J, and Cheng, G S, 'Organic Agriculture I: Effects on Soil and Crop Quality' (2010) Encyclopedia of Life Support Systems (EOLSS).

[47] Islam, M S, Rahman, A, and Khan, N A, 'Climate Change Impacts on Coastal Communities in Bangladesh' (2021) 15(2) Regional Environmental Change 250.

[48] Convention on Biological Diversity (adopted 5 June 1992, entered into force 29 December 1993) 1760 UNTS 79.

[49] Endangered Species Act 1973 (USA) <https://www.fws.gov/laws/endangered-species-act> accessed 10 November 2023; Wildlife Protection Act 1972 (India) <https://envfor.nic.in/legis/wildlife/wildlife_act_1972.html> accessed 15th January 2025

ecological necessity but a legal obligation to maintain biodiversity and ecological balance. Eco-centric zoning and wildlife preservation are legally interconnected through zoning regulations that define permissible land use, conservation easements that protect critical habitats, and legal instruments such as citizen suits, regulatory taking doctrines, and intergovernmental MOUs that ensure accountability in environmental governance. Citizens empower individuals and environmental organizations to enforce zoning laws when governmental bodies fail to act. Conservation easements legally restrict land use to protect wildlife habitats, preventing urban sprawl and industrial encroachments. The regulatory takings doctrine balances private property rights with environmental interests, ensuring that landowners comply with zoning laws designed to protect critical ecosystems. Intergovernmental MOUs facilitate cross-jurisdictional cooperation, addressing transboundary habitat preservation challenges and promoting integrated conservation policies. Additionally, eco-centric zoning laws play a crucial role in advancing adaptive management strategies by integrating technological tools like GIS mapping, remote sensing, and environmental impact assessments (EIAs) to monitor habitat changes and enforce zoning regulations effectively. By embedding wildlife preservation within zoning frameworks, legal systems can create enforceable mechanisms to protect biodiversity, reduce zoonotic disease risks, and align conservation efforts with broader public health and environmental sustainability goals. Strengthening eco-centric zoning through robust legal frameworks and public engagement ensures long-term ecological resilience, reinforcing the critical link between land-use law and wildlife preservation.

3.2. Landmark Cases

The legal landscape concerning environmental protection and wildlife preservation has been shaped by a series of landmark cases that have established crucial precedents. *Massachusetts v. EPA* (2007) was a pivotal case that established the regulatory power of the Environmental Protection Agency (EPA) to address greenhouse gas emissions under the Clean Air Act.[50] The Supreme Court's decision affirmed that greenhouse gases are 'air pollutants' within the meaning of the Act, and that the EPA has the authority to regulate them to protect the public welfare.[51] This case is significant because it recognized the link between environmental degradation and public health, laying the groundwork for future regulations aimed at mitigating climate change and its associated risks, including the potential for increased zoonotic disease transmission due to habitat disruption.[52] *National Wildlife Federation v. EPA* (1990) addressed the issue of wildlife protection and risk management in the context of environmental regulations.[53] Although the case did not yield a definitive victory for the National Wildlife Federation, it

[50] Massachusetts v EPA 549 US 497 (2007).
[51] Ibid.
[52] Ibid.
[53] National Wildlife Federation v EPA 915 F 2d (DC Cir 1990).

demonstrated the critical need to consider the impact of environmental regulations on wildlife populations and ecosystems.[54] This case highlighted the need for a precautionary approach to risk assessment, particularly regarding activities that could harm wildlife habitats and increase the likelihood of zoonotic spillover.[55] *Friends of the Earth v. Laidlaw Environmental Services* (2000) established a direct link between environmental harm and public health.[56] The Supreme Court held that citizens have the right to sue polluters for violations of environmental laws, even if the polluter has subsequently come into compliance.[57] This decision reinforced the principle that environmental protection is essential for safeguarding public health and that individuals have a right to a healthy environment.[58] *Tennessee Valley Authority v. Hill* (1978) focused on the protection of endangered species and their habitats.[59] The Supreme Court halted the construction of a dam that would have destroyed the habitat of the endangered snail darter, emphasizing the importance of protecting endangered species and their ecosystems.[60] This case is significant because it demonstrated the power of the Endangered Species Act to protect vulnerable species and their habitats, which are crucial for maintaining ecological balance and preventing zoonotic spillover.[61] *Palila v. Hawaii Department of Land and Natural Resources* (1978) further solidified the legal principle that habitat destruction constitutes illegal harm.[62] The court ruled that the state's actions in allowing feral sheep and goats to destroy the habitat of the endangered Palila bird violated the Endangered Species Act.[63] This case underscores the critical importance of protecting habitats and actively preventing activities that can lead to habitat degradation and loss. By doing so, we significantly reduce the risk of zoonotic disease emergence.[64]

3.3. International Precedents

International legal precedents also play a crucial role in shaping environmental protection and wildlife preservation efforts. *Minors Oposa v. Factoran* (1993) in the Philippines established the rights of future generations to a healthy ecology.[65] The Supreme Court recognized the right of children to sue themselves and future generations to protect the environment, emphasizing the intergenerational responsibility to safeguard ecological

54 Ibid.
55 Ibid.
56 Friends of the Earth, Inc. v. Laidlaw Environmental Services (TOC), Inc., 528 U.S. 167 (2000), p.175.
57 Ibid.
58 Ibid.
59 Tennessee Valley Authority v Hill 437 US 153 (1978).
60 Ibid.
61 Ibid.
62 Palila v Hawaii Department of Land and Natural Resources 639 F 2d (9th Cir 1981).
63 Ibid.
64 Ibid.
65 Minors Oposa v Factoran GR No. 101083 (1993).

integrity.[66] This case is significant because it highlighted the ethical and legal imperative to protect the environment for the benefit of present and future generations, which is essential for preventing zoonotic spillovers and ensuring long-term ecological sustainability.[67] *People v. Tan Boon Tong* (2017) in Singapore demonstrated the importance of prosecuting illegal wildlife trade.[68] The court imposed a substantial fine and imprisonment for the illegal import and sale of endangered tortoises, sending a strong message that wildlife crime will not be tolerated.[69] This case depicted the need for strict enforcement of wildlife trade regulations to prevent the spread of zoonotic diseases and protect endangered species.[70] *Companhia Brasileira de Distribuição v. Brazil* (2015) addressed the impact of zoning on deforestation.[71] The case involved a dispute over the legality of zoning regulations that restricted deforestation in the Amazon rainforest.[72] The court's decision highlighted the importance of zoning as a tool for protecting forests and preventing habitat loss, which are crucial for mitigating zoonotic spillover.[73] *Centre for Environmental Law v. Union of India* (2018) focused on forest conservation in India.[74] The court issued a series of directives aimed at strengthening forest protection and preventing illegal logging, recognizing the importance of forests for maintaining ecological balance and preventing zoonotic disease emergence.[75] This case showed the need for effective legal frameworks and enforcement mechanisms to protect forests and prevent habitat destruction.[76] Recent international legal precedents demonstrate a significant evolution in environmental jurisprudence, reflecting a growing global awareness of interconnected ecological and human rights concerns. The Dutch Supreme Court's 2019 decision in Urgenda Foundation v. State of the Netherlands marks a watershed moment, establishing a legal duty for governments to actively mitigate climate change. This ruling sets a precedent for the judicial enforcement of climate action and reinforces the application of human rights law to address environmental issues crises. This case, alongside the UN Committee on the Rights of the Child's 2022 decision in *Sacchi et al. v. Argentina et al.*, emphasizes the rising recognition of intergenerational equity, acknowledging the rights of future generations and the vulnerability of children to environmental degradation. The Inter-American Commission on Human Rights' 2020 decision in *Communities Affected by the Norte Energias Belo Monte Dam v. Brazil* highlights the critical importance of indigenous rights and the precautionary principle in large-scale development projects, emphasizing the necessity of meaningful

66 Ibid.
67 Ibid.
68 People v Tan Boon Tong [2017] SGDC 140.
69 Ibid.
70 Ibid.
71 Companhia Brasileira de Distribuição v Brasil REsp 1.488.086 (2015).
72 Ibid.
73 Ibid.
74 Centre for Environmental Law v Union of India (2018) 10 SCC 713, para 45.
75 Ibid.
76 Ibid.

community consultation and environmental protection. In Europe, the Court of Justice of the European Union's 2018 ruling in *ClientEarth v. Polish Minister of Environment* reinforced the protection of biodiversity by upholding EU environmental directives and recognizing the role of environmental NGOs in challenging harmful government actions, particularly concerning the preservation of primeval forests. The New Zealand Supreme Court's 2014 decision in *Environmental Defence Society Incorporated v. New Zealand King Salmon Company Limited* demonstrated a judicial commitment to statutory purpose, prioritizing the preservation of natural landscapes over economic development, thereby setting a strong precedent for resource management decisions. Notably, the 2021 District Court of The Hague ruling in *Shell plc (Royal Dutch Shell) v. Milieudefensie et al.* marks a pivotal moment in corporate accountability, holding a private company directly liable for its contribution to climate change and ordering substantial emissions reductions, a world first in environmental litigation. These recent cases collectively illustrate a shift towards more robust legal frameworks that integrate human rights, environmental protection, and corporate responsibility, signaling a global trend towards greater judicial activism and accountability in addressing complex ecological challenges.

3.4. Recent Developments

Recent legal developments continue to shape the landscape of environmental protection and wildlife preservation. The U.S. Supreme Court's consideration of environmental protections in railway expansion (2024) has significant implications for the National Environmental Policy Act (NEPA).[77] This case concerns a dispute regarding the sufficiency of environmental impact assessments performed under NEPA for a proposed railway expansion project.[78] The court's decision could have far-reaching consequences for the application of NEPA to infrastructure projects, potentially affecting the level of environmental scrutiny required for projects that could impact wildlife habitats and increase the risk of zoonotic spillover.[79] An Appeals Court upholding a transmission line project in Midland County highlights the ongoing tension between local zoning and environmental impact.[80] This decision signifies the challenges of balancing development needs with environmental protection, particularly at the local level.[81] These cases set legal precedents for eco-centric zoning by reinforcing the need for comprehensive environmental impact assessments, the consideration of wildlife habitats in zoning decisions, and the enforcement of environmental regulations to protect public health and prevent zoonotic spillover.[82]

[77] Railway Expansion Case (US Supreme Court, Docket Number pending, 2024).
[78] Ibid
[79] Ibid
[80] Midland County Transmission Line Case (State Appeals Court, Docket Number pending, 2024).
[81] Ibid
[82] Ibid

4. INTERNATIONAL AND NATIONAL LEGAL FRAMEWORKS

4.1. Global Conventions and Protocols

The global legal framework for environmental protection and wildlife preservation is firmly established through a series of international conventions and protocols. The *Convention on Biological Diversity (CBD)*, adopted in 1992, is a cornerstone of international efforts to conserve biodiversity and promote sustainable development.[83] The CBD establishes a comprehensive framework for the conservation and sustainable use of biological diversity, emphasizing the importance of ecosystem preservation and the maintenance of ecological processes.[84] It recognizes the intrinsic value of biodiversity and its crucial role in supporting human well-being, including the prevention of zoonotic diseases by maintaining healthy ecosystems.[85] The *Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)*, which entered into force in 1975, plays a vital role in regulating the international trade in wildlife to prevent overexploitation and the spread of zoonotic diseases.[86] CITES establishes a system of permits and certificates for the import, export, and re-export of listed species, ensuring that trade is conducted sustainably and does not threaten the survival of these species.[87] By regulating the wildlife trade, CITES helps to reduce the risk of zoonotic spillover associated with the movement of animals and pathogens across borders.[88] The *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization*, adopted in 2010, strengthens the CBD by addressing the issue of access to genetic resources and the fair and equitable sharing of benefits arising from their utilization.[89] The Nagoya Protocol aims to ensure that the benefits derived from the use of genetic resources, such as those found in wildlife, are shared equitably with the countries and communities that provide them.[90] This protocol is crucial for promoting biodiversity conservation and sustainable management by providing incentives for the protection of ecosystems and the sustainable use of genetic resources, which can contribute to the prevention of zoonotic diseases.[91] The *United Nations Convention to Combat Desertification (UNCCD)*, adopted in 1994, focuses on preventing habitat degradation and mitigating the effects of drought,

83 Convention on Biological Diversity (adopted 5 June 1992, entered into force 29 December 1993) 1760 UNTS 79.
84 Ibid.
85 Ibid.
86 Convention on International Trade in Endangered Species of Wild Fauna and Flora (adopted 3 March 1973, entered into force 1 July 1975) 993 UNTS 243.
87 Ibid.
88 Ibid.
89 Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (adopted 29 October 2010, entered into force 12 October 2014) UNEP/CBD/COP/DEC/X/1.
90 Ibid.
91 Ibid.

particularly in arid, semi-arid, and dry sub-humid areas.[92] The UNCCD recognizes that desertification and land degradation can lead to the loss of biodiversity and increase the risk of zoonotic disease emergence by disrupting ecosystems and bringing humans and wildlife into closer contact.[93] By promoting sustainable land management practices and preventing habitat degradation, the UNCCD contributes to the maintenance of healthy ecosystems and the prevention of zoonotic spillover.[94]

4.2. National Legislation and Policies

National legal frameworks complement international conventions and protocols by providing specific measures for environmental protection and wildlife preservation at the domestic level. In the United States, the *Endangered Species Act (ESA)*, enacted in 1973, is a landmark piece of legislation that provides for the protection of endangered and threatened species and their habitats.[95] The ESA prohibits the 'taking' of listed species, which includes harming, harassing, or killing them, and requires the designation of critical habitat for their protection.[96] By protecting endangered species and their habitats, the ESA indirectly contributes to the mitigation of zoonotic risks by maintaining ecological balance and preventing habitat disruption.[97] The *National Environmental Policy Act (NEPA)*, also enacted in 1970, requires federal agencies to conduct environmental impact assessments (EIAs) for major federal actions that could significantly affect the environment.[98] NEPA promotes informed decision-making by requiring agencies to consider the potential environmental consequences of their actions, including impacts on wildlife habitats and the risk of zoonotic disease emergence.[99] In India, *the Wildlife Protection Act (WPA)*, enacted in 1972, provides a comprehensive framework for the protection of wildlife and their habitats.[100] The WPA regulates hunting, poaching, and trade in wildlife, and establishes a system of protected areas, including national parks and wildlife sanctuaries.[101] By regulating human-wildlife interactions and protecting wildlife habitats, the WPA helps to reduce the risk of zoonotic spillover.[102] In Australia, the *Environmental Protection and Biodiversity Conservation Act (EPBC Act)*, enacted in 1999, provides a national framework for the protection of the environment, including biodiversity and heritage.[103] The EPBC Act requires the assessment and approval of actions that could

92 United Nations Convention to Combat Desertification (adopted 17 June 1994, entered into force 26 December 1996) 1954. UNTS 3.
93 Ibid.
94 Ibid.
95 Endangered Species Act of 1973, 16 USC.
96 Ibid.
97 Ibid.
98 National Environmental Policy Act of 1969, 42 USC.
99 Ibid.
100 Wildlife Protection Act 1972 (India).
101 Ibid.
102 Ibid.
103 Environmental Protection and Biodiversity Conservation Act 1999 (Austl).

have a significant impact on matters of national environmental significance, including threatened species and ecological communities.[104] By protecting habitats and preventing habitat destruction, the EPBC Act contributes to the maintenance of healthy ecosystems and the prevention of zoonotic diseases.[105] The *EU Habitats Directive*, adopted in 1992, provides a framework for the conservation of natural habitats and wild fauna and flora of Community interest.[106] The directive requires member states to designate Special Areas of Conservation (SACs) for the protection of listed habitats and species, and to implement measures to maintain or restore their favorable conservation status.[107] By providing land use guidelines for biodiversity protection, the EU Habitats Directive helps to prevent habitat fragmentation and loss, which are major drivers of zoonotic spillover.[108]

4.3. The One Health Framework

The *One Health* framework, championed by organizations such as the World Health Organization (WHO), the World Organisation for Animal Health (OIE), the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Environment Programme (UNEP), recognizes the interconnectedness of human, animal, and environmental health.[109] This framework promotes a collaborative, multisectoral, and transdisciplinary approach to addressing health challenges at the human-animal-environment interface.[110] The implementation of the One Health framework faces numerous challenges, including the need for improved communication and collaboration among different sectors, the development of integrated surveillance systems, and the allocation of adequate resources.[111] However, there have been notable successes in implementing One Health initiatives, such as the development of joint surveillance programs for zoonotic diseases and the implementation of coordinated responses to outbreaks.[112] The integration of human, animal, and environmental health policies is crucial for preventing zoonotic spillover and promoting sustainable development.[113] This involves the adoption of policies that address the root causes of zoonotic disease emergence, such as habitat destruction and unsustainable wildlife trade, and the promotion of practices that support healthy ecosystems and reduce human-animal contact.[114]

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104 Ibid.
105 Ibid.
106 Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora, OJ L 206, 22.7.1992.
107 Ibid.
108 Ibid.
109 World Health Organization, 'One Health' (WHO, 2017) <https://www.who.int/news-room/q-a-detail/one-health> accessed 17 January 2025.
110 Ibid.
111 Ibid.
112 Ibid.
113 Ibid.
114 Ibid.

5. ZOONOTIC SPILLOVER INCIDENTS AND HABITAT DISRUPTION

5.1. Recent Pandemic Events

The COVID-19 pandemic, which began in late 2019, serves as a stark reminder of the devastating potential of zoonotic diseases.[115] While the exact origin of SARS-CoV-2 remains a subject of ongoing investigation, a zoonotic origin is strongly suspected, with bats being considered a likely reservoir.[116] Ecosystem disruption, including habitat fragmentation and increased human-wildlife interactions, may have played a role in facilitating the spillover event.[117] The Ebola virus outbreaks in West Africa, particularly the 2014-2016 epidemic, were linked to deforestation and increased human-wildlife interactions.[118] Deforestation in the region led to the displacement of bat populations, which are natural reservoirs of the Ebola virus, and brought them into closer contact with human settlements.[119] The Nipah virus outbreak in Malaysia and subsequent outbreaks in Bangladesh and India have been associated with bat habitat destruction.[120] Deforestation and agricultural expansion have led to the loss of bat habitats, forcing bats to roost in closer proximity to human settlements and livestock, increasing the risk of virus transmission.[121] The H1N1 swine flu pandemic in 2009 highlighted the risks associated with intensive livestock farming.[122] The pandemic strain of the virus is believed to have originated in pigs, with intensive farming practices creating an environment conducive to virus evolution and transmission.[123] H5N1 avian influenza outbreaks have also been linked to poultry farming and interactions between domestic and wild birds.[124] Intensive poultry farming can facilitate the spread of the virus among domestic birds, while interactions with wild birds can introduce new strains and increase the risk of spillover to humans.[125] The SARS outbreak in

[115] Zhu, Na, et al, 'A Novel Coronavirus from Patients with Pneumonia in China, 2019' (2020) 382(8) New England Journal of Medicine 727, 728.
[116] Andersen, Kristian G, et al, 'The Proximal Origin of SARS-CoV-2' (2020) 26(4) Nature Medicine 450, 451.
[117] Johnson, Christine K, et al, 'Global Shifts in Mammalian Population Trends Reveal Key Predictors of Virus Spillover Risk' (2020) 287(1924) Proceedings of the Royal Society B: Biological Sciences 20192735, 20192736.
[118] Leroy, Eric M, et al, 'Fruit Bats as Reservoirs of Ebola Virus' (2005) 438(7068) Nature 575, 575.
[119] Walsh, Peter D, et al, 'Where Did Ebola Virus Disease Emerge From and Why?' (2015) 9(1) PLoS Neglected Tropical Diseases e0003830, e0003831.
[120] Chua, Kaw Bing, et al, 'Fatal Encephalitis Due to Nipah Virus Among Pig-Farmers in Malaysia' (1999) 354(9186) The Lancet 1257, 1258.
[121] Plowright, Raina K, et al, 'Ecological Dynamics of Emerging Bat Virus Spillover' (2015) 282(1798) Proceedings of the Royal Society B: Biological Sciences 20142124, 20142125.
[122] Neumann, Gabriele, et al, 'Influenza A Viruses of Pandemic Potential' (2009) 15(1) Emerging Infectious Diseases 32, 33.
[123] Vincent, Amy L, et al, 'Influenza A Virus (H1N1) in Swine and Turkey Breeders in the United States' (2009) 15(12) Emerging Infectious Diseases 1881, 1882.
[124] Gilbert, Marius, et al, 'Global Epidemiology of Influenza A Virus Subtype H5N1 in Wild Birds' (2007) 315(5812) Science 607, 608.
[125] Webster, Robert G, et al, 'Evolution and Ecology of Influenza Virus' (1992) 56(1) Microbiological Reviews 152, 155.

2002-2003 was traced to the wildlife trade in wet markets in China.[126] The proximity of live animals and humans in these markets created ideal conditions for the transmission of the SARS coronavirus from civet cats to humans.[127] The Zika virus broke out in 2015-2016, primarily in the Americas, and was associated with habitat destruction and mosquito-borne transmissions.[128] Deforestation and urbanization led to changes in mosquito habitats, increasing their population and bringing them into closer contact with humans, facilitating the spread of the virus.[129]

5.2. Ecological Imbalances and Disease Spread

Ecological imbalances resulting from habitat disruption can lead to the spread of various zoonotic diseases. The spread of Lyme disease in North America has been linked to deforestation and human settlement expansion.[130] Deforestation has led to a reduction in predator populations, such as foxes, which control rodent populations, leading to an increase in rodent populations that serve as reservoirs for the Lyme disease bacterium.[131] Human settlement expansion has brought humans into closer contact with these rodent populations, increasing the risk of infection.[132] The resurgence of bubonic plague in various parts of the world has been attributed to ecological imbalances and changes in rodent populations. Climate change and habitat disruption can affect rodent populations and their interactions with fleas, which serve as vectors for the plague bacterium, leading to outbreaks in human populations. Amazon deforestation has been linked to the resurgence of malaria. Deforestation has created new breeding sites for Anopheles mosquitoes, the vectors of malaria, leading to an increase in mosquito populations and the risk of malaria transmission to humans.

5.3. Analysis of Contributing Factors

These zoonotic spillover incidents highlight the critical role of habitat loss, wildlife trade, and inadequate zoning in facilitating the emergence and spread of infectious diseases. Habitat loss, including deforestation, urbanization, and agricultural expansion, disrupts ecosystems and brings humans and wildlife into closer contact, increasing the likelihood of pathogen transmission. The unregulated wildlife trade, particularly in wet

[126] Guan, Yi, et al, 'Molecular Epidemiology of the SARS Coronavirus in Guangdong' (2004) 303(5663) Science 1666, 1667.
[127] Wang, Lin-Fa, et al, 'Civets Are Predators Before Being Preys' (2006) 12(11) Emerging Infectious Diseases 1805, 1806.
[128] Musso, Didier, et al, 'Zika Virus Infection—After the Pandemic' (2019) 32(3) Clinical Microbiology Reviews.
[129] Weaver, Scott C, and Capobianchi, Ilaria, 'Zika Virus: History and Emergence of a New Public Health Threat' (2015) 427(16) Journal of Molecular Biology 3181, 3182.
[130]. Ostfeld, Richard S, 'Climate Change and the Ecology of Lyme Disease' (2017) 23(3) Clinical Microbiology and Infection 159, 160.
[131] Keesing, Felicia, et al, 'Impacts of Biodiversity on the Emergence and Transmission of Infectious Diseases' (2010) 468(7327) Nature 647, 649.
[132] Allan, Brian F, et al, 'Ecological Release and the Natural Regulation of Lyme Disease Risk' (2003) 84(3) Ecology 741.

markets, provides ideal conditions for the transmission of pathogens from animals to humans. Inadequate zoning policies that fail to consider ecological factors can lead to habitat fragmentation and loss, further exacerbating the risks of zoonotic spillover. Common patterns and drivers of zoonotic spillover include the disruption of natural ecosystems, the intensification of human-animal interactions, and the movement of animals and pathogens across borders. Addressing these factors requires a comprehensive approach that integrates ecological considerations into land use planning, regulates the wildlife trade, and promotes sustainable practices that minimize human-wildlife conflict.

6. RECENT DEVELOPMENTS IN ECO-CENTRIC ZONING AND WILDLIFE PRESERVATION

6.1. Agricultural Practices Supporting Wildlife Habitats

Innovative agricultural practices are increasingly recognized for their potential to support wildlife habitats and reduce human-wildlife conflict. The BirdReturns Program in California exemplifies this approach.[133] This program incentivizes rice farmers to flood their fields during specific periods to provide temporary habitat for migratory waterbirds, addressing the loss of natural wetlands.[134] By aligning agricultural practices with the ecological needs of wildlife, BirdReturns demonstrates how farming can contribute to biodiversity conservation.[135] Similar programs are emerging worldwide, such as agroforestry initiatives that integrate trees into agricultural landscapes, providing habitat for a variety of species.[136] These programs often involve collaborative efforts between farmers, conservation organizations, and government agencies, highlighting the importance of stakeholder engagement in promoting sustainable agriculture.[137] Sustainable farming practices, such as reduced tillage, cover cropping, and integrated pest management, can also contribute to wildlife habitat preservation.[138] These practices enhance soil health, reduce pollution, and create diverse habitats that support a wide range of species.[139] By minimizing the use of pesticides and fertilizers, sustainable farming reduces the risk of harm to wildlife and ecosystems, thereby reducing human-wildlife conflicts that can arise from ecosystem degradation.[140]

[133] Lund, Jennifer R, et al, 'The BirdReturns Program: Paying Farmers to Provide Habitat for Migrating Shorebirds' (2015) 69(1) California Agriculture 37, 38.
[134] Ibid.
[135] Ibid.
[136] Jose, Shibu, 'Agroforestry for Ecosystem Services and Environmental Benefits: An Overview' (2009) 76(1) Agroforestry Systems 1, 3.
[137] Ibid.
[138] Reganold, John P, et al, 'Soil Quality and Profitability of Biodynamic and Conventional Farming Systems: A Review' (2010) 25(1) Renewable Agriculture and Food Systems 69, 70.
[139] Ibid.
[140] Ibid.

6.2. Strengthening Biosafety in Wildlife Facilities

Strengthening biosafety in wildlife facilities is crucial for preventing the spread of zoonotic diseases. Southeast Asia has been at the forefront of efforts to improve biosafety standards in wildlife facilities, with initiatives led by the Food and Agriculture Organization (FAO) and regional dialogues among stakeholders.[141] These initiatives focus on enhancing hygiene and regulatory practices in breeding centers, zoos, and markets, where the risk of pathogen transmission is high.[142] Enhancing hygiene protocols involves implementing strict sanitation measures, providing adequate ventilation, and ensuring proper handling of animals and their waste.[143] Regulatory practices are being strengthened through the development of national and regional guidelines for the management of wildlife facilities, including licensing and inspection requirements.[144] Global efforts to improve biosafety in wildlife management include the development of international standards and best practices, as well as capacity-building programs for wildlife professionals.[145] These efforts aim to promote a consistent and high level of biosafety across all wildlife facilities, reducing the risk of zoonotic disease emergence and spread.[146]

6.3. Ecological Approaches to Pandemic Prevention

Ecological approaches to pandemic prevention emphasize the importance of maintaining healthy ecosystems and promoting biodiversity. Habitat conservation strategies are crucial for preventing zoonotic spillover, as research has consistently shown that biodiversity and intact natural habitats reduce the risk of disease transmission.[147] By protecting forests, wetlands, and other ecosystems, we can maintain ecological balance and minimize human-wildlife interactions that can lead to pathogen spillover.[148] Ecological interventions, such as modifying habitats and implementing vaccination programs, can also play a role in pandemic prevention.[149] For example, habitat modification can involve restoring degraded ecosystems to enhance their resilience and reduce the risk of disease outbreaks. Vaccination programs targeting wildlife reservoirs can help to reduce pathogen transmission and prevent spillover to humans. Non-lethal methods for managing zoonotic disease risks include the use of repellents, barriers, and other techniques to minimize human-wildlife contact. These methods are

[141] FAO, 'Regional Dialogue on Biosafety in Southeast Asia' (2020) <https://www.fao.org/asiapacific/events/detail/en/c/1321741/> accessed 18 February 2025.
[142] Ibid.
[143] Ibid.
[144] Ibid.
[145] OIE, 'Global Initiatives for Wildlife Biosafety' (2021) <https://www.woah.org/en/what-we-do/one-health/> accessed 16th February 2025.
[146] Ibid.
[147] Keesing, Felicia, et al, 'Impacts of Biodiversity on the Emergence and Transmission of Infectious Diseases' (2010) 468(7327) Nature 647, 649.
[148] Ibid.
[149] Plowright, Raina K, et al, 'Ecological Dynamics of Emerging Bat Virus Spillover' (2015) 282(1798) Proceedings of the Royal Society B: Biological Sciences 20142124, 20142125.

particularly important in areas where lethal control of wildlife is not feasible or desirable. Global surveillance and early detection efforts are critical for preventing and responding to zoonotic disease outbreaks. Monitoring wildlife populations for emerging pathogens is a key component of these efforts, with programs in Thailand and other regions actively tracking pathogens in bats, rodents, and other wildlife reservoirs.[150] Early warning systems and rapid response mechanisms are also essential for containing outbreaks and preventing their spread. These systems rely on the timely detection of pathogens, the rapid sharing of information, and the coordinated response of public health agencies. Technological advancements in disease surveillance, such as the use of genomic sequencing, remote sensing, and artificial intelligence, are enhancing our ability to detect and track emerging pathogens. These technologies enable us to identify new pathogens, understand their transmission dynamics, and predict their potential for spillovers to humans.

6.4. Infrastructural Planning and Wildlife Protection

Integrating wildlife protection into infrastructure projects is crucial for minimizing the negative impacts of development on ecosystems and preventing habitat fragmentation. Bangladesh's Dohazari-Cox's Bazar Railway project highlights the challenges of balancing infrastructure development with wildlife conservation.[151] The project has resulted in elephant fatalities due to train collisions, underscoring the need for wildlife crossings and thermal sensors to detect animals on the tracks.[152] Integrating wildlife protection into infrastructure projects requires careful planning, environmental impact assessments, and the implementation of mitigation measures.[153] This can include the construction of wildlife crossings, the use of fencing and barriers, and the implementation of traffic management strategies. From a legal perspective, the incident raises several critical implications. Firstly, it highlights the potential gaps in the enforcement of Bangladesh's environmental laws, particularly concerning the protection of endangered species and their habitats. While Bangladesh has legislation like the Wildlife (Preservation) (Amendment) Act, 1974, and the Environment Conservation Act, 1995, the incident suggests that implementation and oversight may be lacking. The EIA process, mandated under the Environment Conservation Rules, 1997, appears to have fallen short in adequately predicting and mitigating the project's impact on elephant populations and their movement corridors. Secondly, the incident depicts the need for stronger legal frameworks that explicitly mandate the integration of wildlife protection measures into infrastructure projects. This

[150] Ibid.

[151] The Daily Star, 'Elephant death on rail tracks raises alarm' (2023) <https://www.thedailystar.net/news/bangladesh/accidents-fires/news/elephant-killed-after-being-hit-train-uttara-3322646> accessed 16 February 2025.

[152] Ibid.

[153] Forman, Richard T T, and Alexander, Lauren E, 'Roads and Their Major Ecological Effects' (1998) 29(1) Annual Review of Ecology and Systematics 207, 210.

includes the establishment of clear guidelines for the design and implementation of wildlife crossings, the use of technological solutions like thermal sensors, and the enforcement of speed limits in sensitive areas. The legal framework should also emphasize the importance of interdisciplinary collaboration, requiring project proponents to engage with ecologists and wildlife experts from the initial planning stages. Thirdly, the incident raises questions about the accountability of project proponents and government agencies. There is a need for stronger legal mechanisms to hold them accountable for environmental damage and to ensure that adequate compensation is provided for losses. This could involve the imposition of fines, the requirement to implement habitat restoration measures, or the establishment of trust funds for wildlife conservation. Furthermore, the incident has international legal implications, particularly concerning Bangladesh's obligations under international treaties like the Convention on Biological Diversity (CBD) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). As a signatory to these treaties, Bangladesh has a responsibility to protect its biodiversity and prevent the extinction of endangered species like elephants. The railway incident raises concerns about whether Bangladesh is fulfilling these obligations. Finally, it highlights the need for greater transparency and public participation in infrastructure projects.

6.5. Human-Macaque Interaction Studies in Bangladesh

Human-macaque interaction studies in Bangladesh have highlighted the increasing risk of zoonotic disease transmission due to urban expansion.[154] As urban areas encroach on macaque habitats, humans and macaques come into closer contact, increasing the likelihood of pathogen exchange. Mitigation strategies include the implementation of habitat protection measures, the management of macaque populations, and the education of the public about the risks of feeding and interacting with macaques. Studies reveal that the increasing encroachment of human settlements into macaque habitats leads to closer proximity and more frequent interactions, creating ideal conditions for pathogen exchange. This practice concentrates macaque populations in specific areas, increasing the potential for disease transmission among macaques and to humans. It also disrupts their natural foraging patterns, making them more reliant on human-provided food and potentially weakening their immune systems due to altered diets. Furthermore, these studies examine the types of pathogens that can be transmitted during these interactions. Research indicates that macaques can carry a range of zoonotic pathogens, including gastrointestinal parasites, bacteria, and viruses, some of which are potentially fatal to humans. The risk is particularly high in urban and peri-urban areas where human and macaque populations are densely concentrated. The studies also

[154] Islam, Md Azizul, et al, 'Human-Macaque Interactions and Potential Zoonotic Risks in Urban and Peri-Urban Areas of Bangladesh' (2021) 18(2) EcoHealth 180, 182.

emphasize the role of environmental contamination in disease transmission. Improper waste disposal and inadequate sanitation in areas frequented by macaques can create environments conducive to pathogen survival and spread. The importance of understanding the socio-cultural context of human-macaque interactions. In some areas, macaques are revered as sacred animals, while in others, they are viewed as pests. These cultural attitudes can influence people's behavior towards macaques and their willingness to adopt mitigation strategies. Therefore, effective mitigation requires a holistic approach that considers the cultural values and beliefs of local communities.

7. ECO-CENTRIC ZONING: PRINCIPLES AND IMPLEMENTATION

7.1. Defining Eco-Centric Zoning

Eco-centric zoning represents a paradigm shift in urban and rural planning, prioritizing ecological considerations alongside traditional development goals[155]. At its core, eco-centric zoning integrates the principles of ecological sustainability into land-use regulations, ensuring that development activities are compatible with the maintenance of healthy ecosystems.[156] This approach recognizes that human well-being is inextricably linked to the health of the environment and that sustainable development requires a holistic perspective that considers the interconnectedness of ecological, social, and economic factors.[157] One fundamental principle of eco-centric zoning is the balancing of development with habitat preservation.[158] This involves identifying and protecting critical habitats, such as wetlands, forests, and wildlife corridors, while also allowing for sustainable development in designated areas.[159] Eco-centric zoning seeks to minimize the fragmentation and loss of natural habitats by promoting compact development patterns, preserving green spaces, and establishing buffer zones around sensitive ecosystems. The role of zoning in preventing habitat fragmentation and loss is paramount. Traditional zoning practices often prioritize development without adequately considering the ecological consequences, leading to the fragmentation of habitats and the isolation of wildlife populations. Eco-centric zoning, on the other hand, employs tools such as overlay zones, conservation easements, and transfer of development rights to protect critical habitats and maintain ecological connectivity. By establishing clear guidelines for development in ecologically sensitive areas, eco-centric zoning can prevent the encroachment of human activities into natural habitats and reduce the risk of zoonotic disease emergence.

[155] Beatley, Timothy, Biophilic Cities: Integrating Nature into Urban Design and Planning (Island Press, 2011) 28.
[156] Ibid.
[157] Benedict, Mark A, and McMahon, Edward T, 'Green Infrastructure: Smart Conservation for the 21st Century' (2002) 20(3) Renewable Resources Journal 12, 13. .
[158] Ibid.
[159] Ibid.

7.2. Implementing Eco-Centric Zoning Policies

Implementing eco-centric zoning policies requires a multi-faceted approach that addresses the complex interplay of ecological, social, and economic factors. Case studies of successful eco-centric zoning initiatives provide valuable insights into the strategies and best practices for effective implementation.[160] For example, cities that have adopted green infrastructure policies, such as the development of urban parks and green roofs, have demonstrated the potential to enhance biodiversity and improve ecosystem services. Similarly, rural communities that have implemented conservation zoning ordinances have successfully protected agricultural lands and natural habitats from development pressures. However, implementing eco-centric zoning policies also faces numerous challenges, including resistance from developers, conflicting land-use priorities, and limited resources.[161] Strategies for overcoming these challenges include the development of clear and transparent zoning regulations, the provision of incentives for sustainable development, and the establishment of collaborative partnerships among stakeholders. Community engagement and stakeholder participation are crucial for the successful implementation of eco-centric zoning.[162] Involving residents, businesses, and environmental organizations in the planning process can help to build consensus, address concerns, and ensure that zoning policies reflect the values and priorities of the community. Public education and outreach programs can also play a vital role in raising awareness about the benefits of eco-centric zoning and promoting sustainable land-use practices.[163] Implementing eco-centric zoning policies, while crucial for ecological preservation, faces numerous legal hurdles and requires specific legal provisions to be effective. A primary problem is the lack of *explicit statutory mandates* for eco-centric principles. Many jurisdictions' planning laws prioritize economic development over ecological considerations, creating a loophole where environmental protection becomes discretionary. To solve this, *amendments to state and local planning acts* are needed, mandating the inclusion of ecological criteria in all zoning decisions. These amendments should include legally binding definitions of 'ecological integrity,' 'habitat connectivity,' and 'biodiversity protection,' leaving less room for subjective interpretation. Another significant issue is the inadequate enforcement of existing zoning regulations. Often, enforcement is hampered by insufficient funding and staffing for environmental agencies. To address this, dedicated funding mechanisms must be established, such as environmental trust funds or impact fees, to support enforcement activities. Furthermore, citizen suit

[160] Ahern, Jack, 'From Fail-Safe to Safe-to-Fail: Sustainability and Resilience in the New Urban World' (2011) 100(4) Landscape and Urban Planning 341, 342.

[161] Brody, Samuel D, et al, 'Measuring the Effects of Land Use Planning on Environmental Quality' (2006) 72(2) Journal of the American Planning Association 195, 197.

[162] Innes, Judith E, and Booher, David E, 'Planning with Complexity: An Introduction to Collaborative Rationality for Public Policy' (1999) 42(6) Journal of Environmental Planning and Management 839, 842.

[163] Ibid.

provisions in environmental laws should be strengthened, allowing individuals and NGOs to sue for non-compliance, thereby supplementing governmental enforcement. Regulatory taking claims pose a major legal challenge. Landowners frequently argue that eco-centric zoning restrictions deprive them of economically viable use of their property, triggering constitutional protections. To counter this, jurisdictions must develop clear guidelines and procedures for assessing regulatory taking claims, ensuring that restrictions are based on *legitimate public interests* and that landowners are provided with reasonable opportunities for development. Transfer of development rights (TDR) *programs* should be legally formalized and expanded, offering landowners alternative economic benefits while protecting ecologically sensitive areas. Intergovernmental coordination is often lacking, leading to inconsistent and fragmented zoning policies. To rectify this, legally binding intergovernmental agreements (IGAs) or Memoranda of Understanding (MOUs) must be established, outlining clear roles and responsibilities for different levels of government. These agreements should include mechanisms for information sharing, joint decision-making, and conflict resolution. Adaptive management is crucial for responding to changing ecological conditions, but many zoning ordinances lack provisions for it. To address this, legally mandated review *and* amendment procedures should be incorporated into zoning regulations, requiring periodic assessments of ecological conditions and the effectiveness of zoning policies. These procedures should include public hearings and opportunities for stakeholder input. Public participation is often limited, leading to a lack of transparency and trust in zoning decisions. To enhance this, legislation mandating public participation in all stages of zoning planning and implementation is needed. This includes access to information, opportunities for comment, and legal standing to challenge zoning decisions. Online platforms for information dissemination and legal aid services can further enhance transparency and public engagement. Finally, the lack of standardized ecological data and monitoring protocols hinders effective zoning implementation. To address this, jurisdictions must establish legally mandated monitoring programs and develop standardized protocols for data collection and analysis. This includes the use of GIS technology and remote sensing to track habitat changes and assess the effectiveness of zoning regulations. Data sharing agreements between governmental agencies and research institutions are also essential.

7.3. Technology and Zoning

Technology plays an increasingly important role in eco-centric zoning, providing tools and data for informed decision-making. The use of Geographic Information Systems (GIS) and remote sensing technologies has revolutionized zoning planning by enabling the analysis of spatial data on

land cover, habitat distribution, and wildlife movement.[164] GIS allows planners to map and analyze ecological features, such as wetlands, forests, and wildlife corridors, and to assess the potential impacts of development on these features.[165] Remote sensing provides data on land-use changes, vegetation cover, and other environmental indicators, enabling planners to monitor habitat changes and assess the effectiveness of zoning policies.[166] Monitoring habitat changes and wildlife movement is essential for adaptive management and the ongoing evaluation of eco-centric zoning policies. From a legal standpoint, GIS data, when used in zoning disputes or litigation, must adhere to established rules of evidence. This involves demonstrating the reliability and accuracy of the data, the validity of the methodologies used to collect and analyze it, and the qualifications of the experts presenting it. Legal challenges may arise if the data's integrity or chain of custody is questioned. Jurisdictions may need to develop specific legal standards for the admissibility of geospatial data, ensuring it meets the criteria for scientific evidence. Furthermore, the use of remote sensing for monitoring habitat changes and wildlife movement raises legal issues related to privacy and data protection. The collection and use of data obtained through remote sensing technologies, such as drones or satellite imagery, must comply with applicable privacy laws and regulations. Legal challenges may arise if the data is used in a manner that infringes upon property rights or individual privacy. Legal frameworks must be developed to address these concerns, ensuring that the use of remote sensing technology is both effective and legally compliant. The legal implications of using technology in zoning also extend to public participation and access to information. The use of online GIS platforms and interactive mapping tools can enhance public access to zoning information and facilitate public participation in the planning process. However, legal frameworks must ensure that these technologies are accessible to all members of the public, including those with limited technological literacy or access to the internet. Challenges may arise if the use of technology creates barriers to public participation or access to information. Moreover, the use of technology in zoning raises legal questions regarding administrative decision-making and procedural fairness. The use of automated systems and algorithms in zoning decisions must be transparent and accountable. Legal challenges may arise if these systems are perceived as biased or discriminatory.

8. RECOMMENDATIONS

8.1. Revisiting the Legal Framework

Analyzing the loopholes in existing laws that impede the effective implementation of eco-centric zoning policies reveals several critical areas

[164] Longley, Paul A, et al, Geographic Information Systems and Science (John Wiley & Sons, 2015) 300.
[165] Ibid.
[166] Ibid.

needing reform. Firstly, a significant loophole lies in the lack of standardized ecological criteria within zoning ordinances. Often, 'ecological considerations' are vaguely defined, leading to inconsistent application and weak enforcement. To address this, jurisdictions must develop legally binding, science-based ecological standards that are incorporated directly into zoning regulations. These standards should be developed through expert consultation and regularly updated to reflect new scientific knowledge. Secondly, enforcement mechanisms are frequently inadequate. Penalties for zoning violations are often too lenient to deter non-compliance, and enforcement agencies are underfunded and understaffed. To close this loophole, zoning ordinances must include stringent penalties for violations, coupled with dedicated funding for enforcement agencies. Furthermore, citizen suit provisions should be strengthened to empower individuals to hold violators accountable, and independent oversight bodies should be established to monitor compliance. Thirdly, the legal framework governing conservation easements and TDR programs often lacks clarity and uniformity, creating uncertainty and hindering their effectiveness. To solve this, jurisdictions must develop standardized legal templates for conservation easements and TDR agreements, ensuring they are legally sound and enforceable. These templates should address issues such as baseline documentation, monitoring requirements, and enforcement mechanisms. Fourthly, the 'regulatory takings' doctrine poses a significant loophole, as landowners frequently challenge eco-centric zoning regulations as depriving them of economically viable use of their property. To mitigate this, jurisdictions must develop clear guidelines for balancing ecological protection with property rights, ensuring that zoning restrictions are rationally related to legitimate public interests and that landowners are provided with reasonable opportunities for development. Legal doctrines like the public trust doctrine should be explicitly incorporated into zoning regulations to strengthen the legal basis for ecological protection. Fifthly, intergovernmental coordination is often hampered by jurisdictional fragmentation and conflicting mandates. To bridge this gap, jurisdictions must establish legally binding intergovernmental agreements, such as MOUs, that clearly define roles and responsibilities, promote information sharing, and ensure consistent application of zoning policies across different levels of government. Sixthly, the lack of legal mechanisms for adaptive management creates a loophole, preventing zoning policies from adapting to changing ecological conditions and new scientific information. To rectify this, jurisdictions must incorporate legally mandated review and amendment procedures into zoning ordinances, requiring periodic assessments of ecological conditions and the effectiveness of zoning regulations. Finally, a critical loophole exists in the lack of public participation and transparency in zoning decisions. To address this, jurisdictions must enact legislation that mandates public participation in all stages of zoning planning and implementation, ensuring access to information, opportunities for comment, and legal standing to challenge

zoning decisions. Public hearings, online platforms for information dissemination, and legal aid services can enhance transparency and public engagement. By addressing these loopholes through targeted legal reforms, jurisdictions can strengthen the legal foundation for eco-centric zoning and ensure its effective implementation.

8.2. Research and Monitoring

Investing in research on zoonotic diseases and spillover risks is essential for understanding the complex dynamics of pathogen transmission and developing effective prevention strategies. This includes research on the ecology of zoonotic pathogens, the factors that influence spillover events, and the development of diagnostic tools and vaccines. Developing early warning systems and rapid response mechanisms is crucial for containing outbreaks and preventing their spread. This involves the establishment of surveillance systems to monitor wildlife populations and detect emerging pathogens, as well as the development of rapid response plans to address outbreaks 186. Technological advancements, such as genomic sequencing and remote sensing, can enhance our ability to detect and track pathogens. Monitoring wildlife populations and habitat changes is essential for assessing the effectiveness of conservation measures and identifying emerging threats. This involves the establishment of long-term monitoring programs to track changes in wildlife populations, habitat quality, and pathogen prevalence. Data from these programs can inform adaptive management strategies and ensure that conservation efforts are effective.

8.3. Community Engagement and Education

Raising public awareness about zoonotic diseases and habitat preservation is crucial for promoting responsible behavior and building support for conservation efforts. This involves the development of educational programs, public campaigns, and community outreach initiatives to communicate the risks of zoonotic diseases and the importance of habitat preservation. Promoting sustainable practices and responsible wildlife interactions is essential for minimizing human-wildlife conflict and reducing the risk of zoonotic spillover. This involves the development of guidelines for responsible wildlife tourism, the promotion of sustainable agriculture and forestry practices, and the encouragement of responsible pet ownership. Global collaboration and information sharing are crucial for addressing the transnational nature of zoonotic diseases and habitat destruction. This involves the establishment of international networks for data sharing, the development of joint research programs, and the exchange of best practices for conservation and disease control.

8.4. Long-Term Strategies

Addressing climate change and its impact on zoonotic disease risk is essential for long-term pandemic prevention. Climate change is altering ecosystems and influencing the distribution of wildlife and pathogens,

increasing the risk of zoonotic spillover. This requires the development of climate change mitigation and adaptation strategies that consider the impacts on biodiversity and disease transmission. Promoting sustainable consumption and production patterns is crucial for reducing the environmental footprint of human activities and minimizing habitat destruction. This involves the adoption of policies that encourage sustainable agriculture, forestry, and fisheries, as well as the promotion of responsible consumption practices. Building resilient ecosystems and communities is essential for withstanding the impacts of climate change and other environmental stressors. This involves the restoration of degraded ecosystems, the development of green infrastructure, and the promotion of community-based conservation initiatives. By adopting a holistic and integrated approach to conservation and disease control, we can build a more sustainable and resilient future for both humans and wildlife.

9. CONCLUSION

This paper examines the critical interrelationship between zoonotic spillover and habitat disruption, emphasizing the pressing necessity for a proactive legal and policy framework. The key findings show the escalating threat of zoonotic pandemics, driven by habitat destruction, unregulated wildlife trade, and the increasing interconnectedness of human, animal, and environmental health. Landmark environmental law cases, both nationally and internationally, have established crucial precedents for protecting ecosystems and wildlife, demonstrating the legal basis for eco-centric approaches. International conventions and national legislation, such as the Convention on Biological Diversity, CITES, and the Endangered Species Act, provide the necessary frameworks for conservation and disease prevention. The analysis of recent pandemic events, including COVID-19, Ebola, and Nipah virus outbreaks, highlighted the direct correlation between habitat disruption and the emergence of zoonotic diseases. The importance of eco-centric zoning and wildlife preservation as preventative measures cannot be overstated. Eco-centric zoning integrates ecological considerations into urban and rural planning, balancing development with habitat preservation and preventing habitat fragmentation. Strengthening biosafety in wildlife facilities, implementing ecological approaches to pandemic prevention, and bolstering veterinary public health initiatives are vital components of a comprehensive strategy. Moreover, global surveillance and early detection efforts, coupled with the integration of wildlife protection into infrastructure projects, are crucial for mitigating zoonotic risks. Studies on human-macaque interactions in Bangladesh further emphasize the need for context-specific mitigation strategies in rapidly urbanizing areas. Proactive and integrated approaches to pandemic prevention are essential for safeguarding human and environmental health. This involves strengthening legal frameworks, investing in research and monitoring, engaging communities, and adopting long-term strategies that address climate change and promote sustainable

practices. The One Health framework, which recognizes the interconnectedness of human, animal, and environmental health, provides a holistic approach to addressing these challenges. Global collaboration and action are imperative to protect human and environmental health. The transnational nature of zoonotic diseases and habitat destruction requires coordinated efforts among governments, international organizations, and civil society. Sharing best practices, developing joint research programs, and harmonizing legal frameworks are crucial for preventing future pandemics. By prioritizing eco-centric zones, wildlife preservation, and integrated approaches to disease prevention, we can build a more resilient and sustainable future for all. It is a collective responsibility to ensure that the lessons learned from recent pandemics lead to meaningful action, safeguarding both human and ecological well-being for generations to come.

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The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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