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Human Wildlife Interaction and the Risk of Emerging Zoonoses

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Abstract: *Interactions between humans and wildlife are becoming more widely acknowledged as a major factor in the emergence of zoonotic illnesses, which represent major risks to ecological stability and public health worldwide. Growing human populations, urbanization, deforestation, intensified agriculture, and wildlife exploitation put people in close proximity to a variety of animal species, which increases the risk of viruses spreading from wildlife to people. The distribution and behavior of wildlife and their associated infections are further altered by environmental changes, such as habitat fragmentation, biodiversity loss, and temperature fluctuations, increasing the likelihood of disease transmission. The rise of zoonoses, which include bacterial, parasitic, and viral infections, highlights the intricate relationship between environmental, animal, and human health. A comprehensive One Health strategy is necessary for effective management, including habitat preservation, wildlife trade legislation, sustainable farming methods, and integrated monitoring systems to track disease in both human and wildlife populations. To stop outbreaks, lessen the worldwide burden of zoonotic illnesses, and protect ecosystem integrity and public health, it is crucial to comprehend the dynamics of interactions between humans and wildlife.*

Keywords*: humans and wildlife*

I. INTRODUCTION

Infectious diseases that have spread from animals to people are known as zoonoses. Infectious diseases that have previously occurred but have lately exhibited an increase in incidence or spread into a new geographic, host, or vector range are known as emerging or re-emerging zoonoses. As medical researchers recorded and attempted to explain the seemingly sudden increase in the number of novel and significant infectious diseases over the previous 20 years, the idea of "emerging diseases" emerged. The processes and factors that may have contributed to the emergence or reemergence of infectious and zoonotic diseases that originated in wildlife include growing human populations and increased contact with wild animals or their products; ecosystem changes of natural or man-made origin, with climatic and geographic influences on pathogens and vectors; increased human-assisted movement of animals and animal products; wildlife-associated microbes entering intensive livestock-based agricultural systems; intensive farming of formerly wild species; changes in the microbes themselves or their host spectrum (crossing the species barrier); improved technical diagnostic and epidemiological techniques that have led to the discovery of a disease agen1. . It would be helpful to remember that zoonoses typically fit into one of the two groups listed below: a) diseases of animal origin in which the actual transmission to humans is a rare event but, once it has occurred, human-to-human transmission perpetuates the infection cycle for some amount of time. Human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS), certain influenza A strains, Ebola virus, and severe acute respiratory syndrome (SARS) are a few examples. b) animal-borne illnesses that typically infect humans by direct or vector-mediated animal-to-human transmission. The pathogen's primary reservoir is animal populations, and human horizontal infection is uncommon. Lyssavirus infections, Lyme borreliosis, plague, tularemia, leptospirosis, ehrlichiosis, Nipah virus, West Nile virus (WNV), and hantavirus infections are a few instances that fall under this category. It is not surprising that many of these relatively new viruses can also be linked to animals, as about 60% of known human pathogens are zoonotic. There is a wildlife source for about 75% of the diseases that have surfaced in the last 20 years.2

Scope

It is necessary to synthesize the current evaluative evidence in order to offer insights into how to use policy to successfully reduce zoonotic spillover incidents. A One Health viewpoint enables this evidence synthesis to suggest strategies for effectively implementing and assessing policies in this intricate, multisectoral setting, as well as to encompass a wide range of policy instruments and actors. In the medical literature, strategies for controlling infectious diseases that have spread to human populations during epidemics and pandemics have been methodically compiled 3,4. Hand washing, face masks, school closures, contact tracing, immunization, and case isolation are some of these precautions. Further upstream, systematic reviews of interventions aimed at the spillover pathway have mostly concentrated on programs rather than policies. These reviews have been limited by a number of characteristics, such as geographic region 5 or pathogen type 6, or they have concentrated on programs that explicitly support a One Health approach 7. As a result, there is a lack of thorough knowledge regarding the policies that have been assessed to prevent zoonotic spillover, the actors involved, and the best ways to implement and assess them. To address these research gaps, our objective was to synthesise the existing evaluative evi dence around policies that target the determinants of zoonotic spillover. A One Health viewpoint, which acknowledges the interdependence of human, animal, and environmental health, served as the basis for our search and evaluation of this material. Methods Based on a previously published approach, we carried out a thorough scoping review of assessments of policies intended to reduce zoonotic spillover incidents 8. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews are followed for reporting the results 9. The scoping review was carried out in accordance with recommendations developed by Levac and colleagues10–11 and published by Arksey and O'Malley, which emphasize an iterative method appropriate for an exploratory research issue. The review approach was developed with the One Health perspective in mind. This included the research questions, which aim to describe the policies and the variety of sectors involved in implementation, and the search strategy and inclusion criteria, which permit the inclusion of policies focused on human, animal, or environmental mental health (or any combination of these areas) and with leadership from one or more of these sectors . We specifically looked for environment-focused policies (e.g., protection of wetlands and other wildlife habitats) that might have been evaluated from this perspective, even though our focus on the spillover pathway meant that we only included policies that had been evaluated in terms of their impacts on animal and human population distributions, health, and interactions. By evaluating the degree to which cross-sectoral collaboration—a fundamental component of One Health practice12 emerged as a reason for policy success, we also sought to examine the One Health approach to governance.

II. RECENT EMERGING ZOONOSES

2.1 Viral zoonoses

Simian immunodeficiency viruses and human immunodeficiency virus/acquired immune deficiency syndrome –Two of the 26 simian immunodeficiency virus (SIV) strains that are known to exist in African primates are responsible for human immunodeficiency virus/AIDS. A chimpanzee (Pan troglodytes) strain and a Sooty mangabey (Cercocebus torquatus) strain are the ancestors of the HIV- 1 and HIV-2 viruses, respectively 13–14. These SIV strains have been transmitted to humans on at least seven different occasions during the past century, according to the evidence that is currently available and genetic study. Hunting and eating apes seems to be connected to these early transmissions in equatorial Africa. From these transmission episodes, virus strains which were both highly adapted to humans and communicable among humans emerged as HIV-1 and HIV-2, and these are currently maintained and transmitted in human populations, independent of their simian origin. The advent of HIV-AIDS in the twentieth century appears to be the result of a complex series of mostly ecological and socioeconomic changes in Africa, including the following:

I. growing numbers of people

II. deforestation

III. People who relocate from rural to urban regions in search of work, education, or new social connections are known as rural displacement.

IV. Urbanization and the poverty it causes

V. Sexual conduct

VI. Usage of parenteral drugs

VII. increasing travel, both domestically and abroad.15,16

One of the largest zoonotic pandemics in recent human history is most likely the HIV infection. The United Nations (UN) reported that 40 million people were infected globally at the end of 2003, and that year 17 saw more than three million HIV-related fatalities. The most badly impacted region was Sub-Saharan Africa. The entire impact of this zoonosis on human well-being, economies, and security has not yet been felt; its prevalence and geographic dispersion are increasing globally, and international public health interventions have not yet been successful in lessening its effects.

2.2 Ebola virus

Ebola virus infection of humans was first described in Central Africa in 1976, in the southwestern Sudan and the northern region of the Democratic Republic of the Congo with high mortality 18. Additional deadly outbreaks were reported in Gabon, the Republic of the Congo, and the Democratic Republic of the Congo between 1992 and 1999. In 1994, the virus was isolated from a chimpanzee 19 and human infections were connected to excessive mortality in chimpanzee colonies in Côte d'Ivoire. Over the past four years, Gabon and the Republic of the Congo have seenmultiple outbreaks of Ebola in humans and animals. The human outbreaks included several concurrent epidemics brought on by various virus subtypes20. The handling of a specific gorilla (Gorilla sp.), chimpanzee, or duiker (Sylvicapra grimmia) carcass—all of which were unintentionally infected—has been connected to every human outbreak. It is crucial to note that populations of these animals dropped dramatically throughout the period of human Ebola epidemics, possibly also as a result of Ebola infection. Numerous Ebola strains were found in recovered carcasses, indicating that multiple virus imports from an unidentified animal maintenance host of these viruses cause Ebola outbreaks in great apes. It has not been ruled out that arthropod vectors may have had a role in the initial infection. Following then, a number of well-known and extensively researched gorilla and chimpanzee groups have vanished due to apparent horizontal transfer from ape to ape. The majority of human Ebola outbreaks in Gabon and the Republic of the Congo were caused by hunters or villagers handling dead animals, which was followed by horizontal human-to-human transmission. Animal mortality surveillance may be useful in identifying high-risk times for Ebola outbreaks.

2.3 Hantavirus

Hantaviruses cause hantavirus pulmonary syndrome (HPS) in the Americas and hemorrhagic fever with renal syndrome (HFRS) in Europe and Asia. Hantaan, Seoul, Dobrava, and Puumala hantaviruses are the microorganisms that cause HFRS, while the Sin Nombre group of hantaviruses causes HPS. All of these viruses are sustained in wild rodent reservoirs, and aerosolization of rodent excrement causes respiratory illnesses in humans. In these natural maintenance hosts, the infection is persistent and seems to be asymptomatic21. El Niño Southern Oscillation (ENSO)-driven weather events have been linked to peaks in the incidence of HPS in the United States of America (USA). (In general, the effects of the ENSO are opposite in the northern and southern hemispheres; for example, when precipitation increases in the northern hemisphere, droughts occur in the southern hemisphere, and vice versa.) The documented increase in precipitation in the USA often led to environmental conditions that supported denser rodent populations. Human activities that have been linked to the occurrence of hantavirus disease include farming, hunting, camping, cleaning rodent-infested areas, and rat trapping. While the average mortality rate for HPS is 45%, it ranges from 0.1% to 10% for HFRS 22. There is no evidence of human-to-human transmission.

2.4 Hendra virus

Two outbreaks of a new, frequently lethal viral disease that affected both humans and horses happened in Queensland, Australia, in 1994. Hendra virus 23, a hitherto unidentified paramyxovirus, was the cause of the epidemics. Both the parenteral and oronasal routes could be used to experimentally infect horses; cats and guinea pigs were also infected.24. Human instances were associated with very close exposure, including an equine necropsy, and the virus does not seem to be directly communicable between humans and horses. According to virological and serological testing, the virus 25 is naturally found in bats belonging to the Megachiroptera family (Pteropus spp.). Although the exact mode of transmission from bats to horses is uncertain, the presence of large levels of the virus in bat pee may indicate that feed or water has been contaminated by bat urine.

III. SPREAD

3.1 Land-Use Change and Spillover Risk

a. According to a systematic analysis, there is a clear correlation between increasing zoonotic spillover risk from mammals and anthropogenic land-use changes (deforestation, urbanization, and agricultural intensification).

b. Mechanisms: Wildlife, particularly rats and bats, must adjust to habitat fragmentation, often relocating closer to human settlements; changing host behavior might alter the dynamics of pathogens.

c. The authors point out that as links between humans and animals, livestock are frequently linked to intensification of agriculture, carnivores to urbanization,
etc.26

3.2 Wildlife–Livestock Interface

a. The International Livestock Research Institute (ILRI) compiled data on zoonotic transmission at the wildlife–livestock interface in a systematic review.

b. Important factors include vectors, environmental overlap, indirect transmission, and direct contact (common grazing or water supplies).

c. Promising intervention techniques, such controlling shared landscapes to lessen dangerous interaction, are also covered in the review.27

3.3 One Health Approach & Gaps in Research

a. A comprehensive analysis looked at how the One Health approach is applied in wildlife zoonotic risk investigations.

b. Key finding: environmental health is underrepresented and only a tiny percentage of studies properly integrate all three categories (human, animal, and environmental health).

c. Additionally, because few research include non-academic stakeholders
(community, policymakers), interventions may overlook real-world issues.28

3.4 Emerging Diseases via Wildlife-Livestock System

a. Development of Zoonotic Diseases at the Convergence of Wildlife-Livestock System examines how climate change, habitat loss, and globalization affect zoonoses at this interface.

b. It highlights intricate networks of transmission, including viral and bacterial zoonoses, and suggests One Health mitigation techniques.29

3.5 Zoonotic Emergence Risk from Wildlife & Environmental Change

a.In the Animal board invited review: Risks of zoonotic disease emergence at the interface of wildlife and livestock systems, authors note how environmental change (such land-use change) enhances wildlife–livestock and wildlife–human contact.

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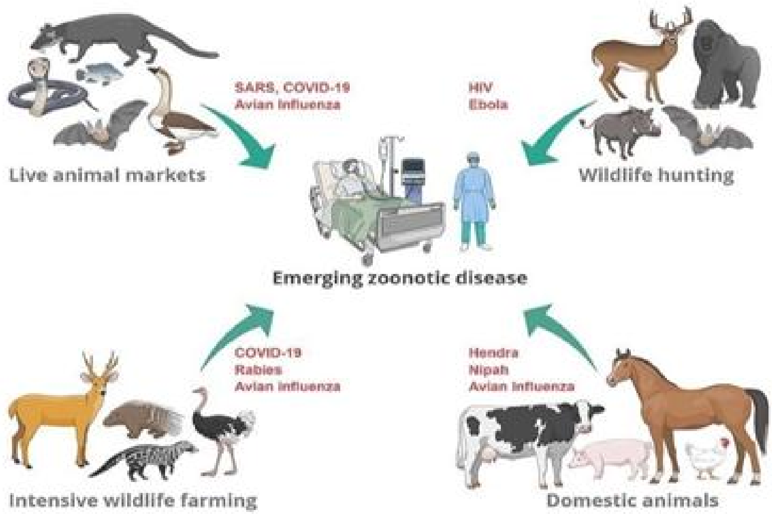

Environment al / Indirect Transmission

Pathogens shed into and maintained in the environment (soil, water, surfaces), from where humans pick them up.

Contaminated water (from wildlife feces), soil contaminated by wild animal excreta, surfaces in markets. Indirect exposure: humans ingest or touch contaminated water/food or environment. The Southeast Asia systematic review identified "exposure through contaminated water/food/soil" as a key risk factor for zoonotic pathogen transmission from wildlife. 34

3. Vector-Media ted Transmission

Arthropods (ticks, mosquitoes, fleas etc.) transmit pathogens from wild reservoirs to humans (or via intermediate hosts).

Vectors bite wildlife, acquire infection, then transmit to humans. In the Animal board invited review (Yon et al.), vector- mediated transmission is identified as one of the "usual" sources of human infection from wildlife.35

4. Aerosol / Respiratory Transmission

Pathogens are transmitted via inhalation of droplets, dust, or aerosols contaminated by wildlife.

Inhalation of aerosolized excreta (e.g., rodent urine/feces), respiratory viruses. Humans breathe in contaminated particles. The Veterinary World review describes aerosol or inhalation as possible in the human–animal interface: e.g., handling animals, plus environmental contamination.36

• Wildlife markets, often known as "wet markets," are hotspots for face-to-face interaction. Animals are either captured in the wild or kept in captivity, are frequently under stress, and interact closely with people (traders, butchers, and consumers).

• Humans may come into contact with blood and tissues during butchering or slaughter in these markets, which raises the possibility of virus transmission (e.g., coronaviruses, filoviruses).

b.Ecotourism and Research Settings:

• Increased human-wildlife interaction through ecotourism is emphasized in the review. Because monkeys and humans share many infections and are genetically similar, tourists and researchers may come into contact with or be near primates.

• Bites, scrapes, and unintentional contact with bodily fluids all pose a risk.

c.Bites and Injuries:

• According to earlier assessments of zoonosis, traditional routes of infection include direct skin contact, animal bites, and other traumas (needle sticks, for veterinarians who work with wild animals).

• For diseases like rabies, herpes B virus (in macaques), and others, such exposures are crucial.

4.1.3Risk Factors Associated with Direct Contact

• Wildlife trade: Humans come into frequent, frequently unprotected contact with potentially pathogenic animals during the capture, transportation, and sale of wild animals.

• Poor biosafety: People may be exposed to high-risk tissues due to handling procedures, a lack of protective gear, and inadequate hygiene in markets or unofficial slaughterhouses.

• High-risk species: Because they harbor several zoonotic viruses and have direct interaction with humans, some wildlife taxa—such as bats, non-human primates, and rodents—are particularly significant.

• Behavioral practices: Because bushmeat hunting, slaughtering, and consumption are deeply ingrained in many communities' cultures and economies, "direct contact" is a frequent and frequent occurrence.

4.1.4Implications for Public Health

• Direct contact can be highly effective in spreading the disease, thus surveillance and control measures include controlling the wildlife trade, enhancing market hygiene, educating hunters and butchers, and enforcing biosafety.

• Interventions must take cultural sensitivity into account. For example, risk reduction (proper butchering, protective gear) is frequently more effective than prohibition because simply outlawing bushmeat may not be practical in many regions.38

4.2Environmental / Indirect Transmission in Human–Wildlife Zoonoses

4.2.1Definition & Mechanism:

• When viruses from wildlife are released into the environment (soil, water, surfaces, aerosols, fomites), humans become infected through contact with this contaminated environment rather than through direct contact with living animals. This process is known as indirect transmission.

• Contaminated water, dirt, dust, feces, urine, or animal excrement are examples of important environmental media. Depending on their biology and the environment, pathogens can survive in these medium for hours, days, or even longer.

• Although we concentrate mainly on non-vector environmental persistence here, this approach also involves transmission through vectors (such as ticks and mosquitoes) that acquire diseases from wildlife reservoirs and subsequently infect people.

4.2.2Examples & Case Studies

a.Chlamydia abortus

• The bacterium Chlamydia abortus, which can infect animals and linger in the environment, is covered in a review published in Veterinary Research. The review indicates that environmental exposure (e.g., contaminated soil, surfaces, animal birthing materials) plays a crucial role in zoonotic risk.

• The infection can remain viable in the environment after infected animals shedC. abortus, particularly during childbirth, according to the scientists. This poses a risk to humans who come into touch with contaminated materials, particularly pregnant women or immunocompromised individuals.

• They also highlight important knowledge gaps, such as how long it can persist in various environmental substrates, how it transfers between species, and what mitigation or disinfection techniques would work.

b.General Wildlife-to-Human Environmental Contamination

•Many zoonotic infections are spread to humans by environmental contamination, according to the author of the review "Animals and Mechanisms of Disease Transmission.":

i. fecal-oral pathway via tainted food or water (for example, water sources contaminated by wildlife excrement).

ii. Inhalational infections can result from exposure to aerosols from dried animal excreta, such as dust from rodent urine or excrement.

iii. Pathogens can also be spread indirectly through instruments or through contact with contaminated surfaces or fomites, such as animal droppings on soil.

•Although these environmental channels are crucial in many situations, Fong contends that they are frequently overlooked in zoonosis risk assessments.

c.Modeling of Environmentally Persistent Pathogens

• Diseases whose pathogens linger in the environment for longer than 48 hours were examined in a systematic evaluation of transmission dynamic models. It offers significant insight into environmental and indirect transmission, albeit being more modeling than a strictly ecological analysis.

• They observed that many zoonotic infections (viral, bacterial) can survive in environmental reservoirs (soil, water) and that many disease models do not appropriately incorporate realistic environmental persistence data.

• The authors emphasize the necessity for One Health modeling frameworks that take into account the animal-human-environment link in order to more accurately forecast and stop environmental spillover.

4.2.3Risks & Public Health Implications

• Persistence and Amplification: Even when there is little direct contact, pathogens that thrive in the environment might serve as a "reservoir" for infection, increasing the likelihood of spillover.

• High‑risk Human Behaviors: People may be exposed to contaminated soil or water if they live near wildlife habitats, gather water from streams, or work in agriculture.

• Occupational Risk: Unaware of the risk, farm workers, wildlife handlers, and veterinarians may come into touch with environmental contamination (such as pathogen-laden birthing materials).

• Surveillance Challenges: Compared to animal surveillance, environmental surveillance is more challenging because monitoring soil, water, dust, etc. calls for specific techniques and consistent work.

• Prevention & Control: Safe water sources, environmental decontamination, and environmental hygiene (such as cleaning birthing areas and handling animal waste) are all necessary components of control measures. Ecological, veterinary, and human health interventions must be integrated in comprehensive "One Health" approaches.39,40,41

4.3 Vector‑Mediated Transmission in Human–Wildlife Zoonoses

4.3.1Definition & Mechanism

• Vector-mediated transmission occurs when arthropod vectors—such as ticks, mosquitoes, sandflies, and biting midges—feed on pathogen-carrying wildlife hosts before attacking humans or other animals.

• In many zoonotic cycles, the disease is kept in a sylvatic (wildlife) reservoir and spreads among wild animals through vectors; when people join or reside close to these cycles, they become inadvertent (or "spillover") hosts.

4.3.2Examples & Key Points

a.Arboviruses (Mosquito‑Borne Viruses)

• Numerous newly discovered arthropod-borne viruses, or "arboviruses," are maintained in nature by mosquito or tick vectors, according to review research on vector-borne viral illnesses.

• Dengue, yellow fever, and Zika are a few examples that are mainly spread by mosquitoes.

• Vector biology (distribution, biting habit) and environmental changes (land usage, climate change, etc.) that affect vector populations have a significant impact on the ecology of these viruses.

b.Tick‑Borne Zoonoses

• Numerous zoonotic diseases with wildlife reservoirs are mostly spread by ticks. The authors of the review Zoonotic aspects of vector-borne diseases explain how pathogens are maintained by "wild" cycles (non-human mammals + ticks), which can occasionally spread to humans.

• Examples: Borrelia spp. (Lyme disease), Anaplasma, Rickettsia, Babesia, etc.

• Human encroachment into natural habitats, such as forests, raises the possibility of contracting an infection from tick bites, hence increasing the chance of spillover.

c.Other Arthropods

• Additionally, biting midges and sandflies (Leishmania) are vectors. The function of these vectors in zoonoses and the challenge of interrupting transmission cycles in sylvatic (wildlife) settings are covered in reviews on vector management.

• The overview of the Biology, Control and Zoonotic Role of Disease Vectors goes into detail about how certain hematophagous (blood-feeding) insects spread illnesses from wildlife to people.

d. One Health Perspective

• A One Health strategy is necessary for the effective control of vector-mediated zoonoses because preventing transmission affects not only human health but also wildlife ecology, vector ecology, and environmental issues.

• For instance, compared to urban/regional vector control, vector-management techniques in sylvatic cycles—where vectors and wildlife interact—are more intricate.

4.3.3 Public Health Implications

• Surveillance: Early detection of zoonotic danger requires monitoring both wildlife reservoirs and vector populations.

• Vector Control: The dynamics of wildlife reservoirs must be taken into account while developing strategies (insecticides, biological control, environmental management).

• Land-Use Planning: Zoonotic risk mitigation must take into account habitat changes (deforestation, urbanization) that promote human-vector-wildlife contact.

• One Health Collaboration: It is crucial that environmental scientists, entomologists, wildlife biologists, and public health professionals work
together.42,43

4.4Aerosol / Respiratory Transmission in Human–Wildlife Zoonoses

4.4.1Definition & Mechanism:

• Pathogens that are conveyed by tiny respiratory particles (droplets or droplet nuclei) released by animals are known as aerosol (airborne) transmission. These can linger in the atmosphere for a considerable amount of time and enter the human respiratory system by inhalation.

• Humans can contract respiratory viruses from wildlife by inhaling these infectious aerosols or by being exposed to "close-range droplets" in confined spaces with inadequate ventilation.

• Because aerosols can travel through numerous physical barriers and have a high potential for respiratory system infection, this pathway is especially crucial for viruses.

4.4.2Examples & Key Insights

a.Coronaviruses and Influenza Viruses of Animal Origin

• A thorough overview titled "Aerosol Transmission of Coronavirus and Influenza Virus of Animal Origin" explains how aerosols can spread avian influenza viruses and zoonotic coronaviruses like SARS, MERS, and SARS-CoV-2.

• The authors point out that aerosol particles are an extremely effective means of infection since they are tiny, may stay in the air for a long time, and can penetrate deeply into the lungs.

• They also go over how viruses spread and infect new hosts, as well as how viral aerosols are created—that is, how infected animals or intermediate hosts release virus-laden particles.

• Changes in human-animal interactions, such as wildlife markets and habitat encroachment, may raise the risk of aerosol-mediated zoonotic spillover, according to the review.

• To reduce aerosol transmission, they suggest control strategies include improved ventilation, suitable personal protective equipment (PPE), environmental cleaning, and isolation.

b.Reverse Zoonosis / Spillback

• A review examines SARS-CoV-2 zoonotic and reverse zoonotic transmission. They talk about the possibility that respiratory viruses, such as SARS-CoV-2, could spread from humans to wildlife and vice versa.

• This demonstrates a two-way risk: humans can infect wildlife by airborne droplets, particularly in situations of close contact, in addition to contracting the disease from wildlife through aerosols.

c.Broader Zoonosis Risk Framework

• The review published in the International Journal of One Health emphasizes that respiratory transmission (via aerosols) is a crucial route for zoonotic development, particularly for coronaviruses, and advocates for a One Health strategy to address it.

• This review connects growing human-animal contact, habitat loss, and wildlife commerce to the likelihood of aerosol transfer.

4.4.3 Public Health Implications

• Surveillance: Keeping an eye on the potential of aerosol transfer in high-contact environments such as bat caves, wildlife markets, or rehabilitation facilities

• Preventive Measures: In areas where people might be exposed to aerosols from wildlife, mask use, better ventilation, and air disinfection are recommended.

• One Health Approach: collaborating in environmental science, human public health, and wildlife biology to comprehend and reduce airborne danger.

• Risk Communication: teaching anyone who deal with wildlife, such as hunters and traders, of the possibility of airborne transmission and self-defense measures.44

4.5 Reverse Zoonosis (Zooanthroponosis) in Human– Wildlife Interactions

4.5.1 Definition & Mechanism

• The spread of infections from humans to animals is known as reverse zoonosis, or zooanthroponosis. In contrast to traditional zoonoses (animal → human), humans are the source in this case.

• Direct contact (touch, bites), indirect exposure (human-contaminated environment), or shared settings (zoos, animal sanctuaries, farms) are some of the ways that this might happen.

• The likelihood of such transmission is increased by the growing overlap between human and wildlife environments (caused by urbanization, tourism, international trade, etc.).

4.5.2 Key Findings from Review Articles

a. Global Prevalence & Types of Pathogens

•Human-to-animal disease transmission from bacterial, viral, parasitic, and fungal diseases was documented in 56 research spanning more than 30 years, according to a comprehensive analysis.

a. In their review:

i. 21 (38%) of the pathogens were bacterial, 16 (29%) viral, 12 (21%) parasitic, and 7 (13%) fungal / others.

ii. Affected animals included: wildlife (28 reports, ~50%), livestock (24), and companion animals (13).

•Reverse zoonoses transmission "occurred in every continent except Antarctica," according to the authors, indicating a worldwide threat.

b. Drivers & Risk Factors

• A more recent comprehensive analysis indicated that important risk factors for reverse zoonosis include: urbanization, globalization, environmental change, animal commerce, and antibiotic resistance.

• According to this review, respiratory viruses, such as human influenza and SARS-CoV-2, are among the most commonly described causes of reverse zoonosis.

• Bacterial infections are also frequent, particularly MRSA (methicillin-resistant Staphylococcus aureus) and Mycobacterium species (tuberculosis).

c.Wildlife Examples & Conservation Implications

• About half of the cases that were recorded included wildlife, which is especially worrisome because infected wild animals may serve as new reservoirs, according to Messenger et al.

• A case study pertinent to SARS-CoV-2: humans may be able to infect free- ranging bats. According to one analysis, humans might unintentionally spread SARS-CoV-2 to wild bats, creating new wildlife reservoirs.

• Reverse zoonosis is both a public health and wildlife health concern from the standpoint of policy and conservation: human-introduced viruses can endanger vulnerable wild populations, particularly in environments like ecotourism or wildlife rehabilitation.

d. One Health Perspective

• Because human health, animal health, and ecosystem health are intricately linked, the issue highlights the urgent need for a One Health strategy. This analysis calls
for interdisciplinary surveillance, enhanced biosecurity, and more robust regulatory measures.

• Additionally, since many reverse-zoonotic events probably go unreported, they suggest conducting additional research in understudied areas and species.

4.5.3 Public Health & Conservation Implications

• Surveillance: It is crucial to keep an eye on both zoonotic spillover (animal → human) and spillback (human → animal), particularly in high-risk environments (zoos, wildlife sanctuaries, regions with frequent human–wildlife contact).

• Biosecurity: It is crucial to keep an eye on both zoonotic spillover (animal → human) and spillback (human → animal), particularly in high-risk environments (zoos, wildlife sanctuaries, regions with frequent human–wildlife contact).

• Policy: minimizing danger by controlling human activities (tourist, habitat incursion) and regulating the trafficking in wildlife.

• Conservation: Reverse zoonosis may be an overlooked issue, and protecting wildlife from human-borne viruses might be crucial for endangered species.45,46

5. Types of Human–Wildlife Interaction in Zoonotic Disease

5.1 Wildlife–Livestock Interface

• Description: Domestic animals (livestock) and wildlife share habitats, such as pastures, fences, grazing land, and water sources. This makes it possible for cattle and wildlife reservoirs to trade pathogens, which could then infect people.

• Example: The method demonstrates how zoonotic transmission can be fueled by both direct and indirect interactions between livestock and wild animals.

• Risk Mechanism: Zoonotic infections can be carried by wildlife, and once they infect livestock, the pathogens may adapt or grow there before spreading to people.47

5.2 Wildlife Trade / Wildlife Markets Interface

• Description: capture, transportation, and sale of wild animals (dead or alive) in wildlife trading networks and markets, commonly known as "wet markets."

• Example: "Wildlife wet markets" are a high-risk human-animal interface for newly emerging infectious illnesses, according to the mini-review.

• Risk Mechanism: Pathogen spillover is facilitated by intimate human contact, stressful environments, and a high density of varied organisms.48

5.3 Human‑Wildlife Contact via Habitat Encroachment / Land Use Change

• Description: Human-wildlife contact increases as a result of changes including deforestation, urbanization, and agricultural development.

• Example: In the book chapter Human-Wildlife Contact and Emerging Infectious Diseases, explains how anthropogenic environmental change increases contact and transmission risk, using cases like SARS, Ebola, and Nipah.

• Risk Mechanism: Humans encounter reservoir species more frequently when they invade wildlife habitats, which increases the likelihood of spillover.49

5.4 One Health / Environmental Interface

• Description: A "One Health" theory integrates ecological, animal, and human health through interactions between humans, wildlife, and the environment.

• Example: Numerous studies examine the human, animal, and environmental realms, but there is still little integration, according to the systematic review
"How studies on zoonotic risks in wildlife implement the One Health approach."

• Risk Mechanism: The dynamics of wildlife pathogens and human exposure are impacted by environmental changes, ecological upheaval, policy, and management choices.50

5.5 Wildlife Population / Ecological Disturbance Interface

• Description: Changes in wildlife population dynamics that affect reservoir host composition and behavior (caused by habitat fragmentation, species extinction, and climate change).

• Example: The rise of zoonotic diseases in the convergence of wildlife and livestock systems is driven by habitat degradation and fragmentation, as discussed in the systematic review of the wildlife-livestock system.

• Risk Mechanism: Disturbance may increase risk by favoring species that make ideal reservoir hosts, such as bats and rodents.51

6. Why Zoonotic Diseases Are So Widespread

6.1 High Proportion of Infectious Diseases Are Zoonotic

• A paper published in Frontiers in Microbiology states that over 75% of newly emerging infectious diseases originate from animals, and nearly 60% of all human infectious diseases are zoonotic.

• This demonstrates that the zoonotic load is crucial to the risk of infectious diseases worldwide and is not only incidental.52

6.2 Increasing Rate of Emergence

• According to the same review, greater mobility (tourism, travel), growing human populations, and environmental changes (urbanization, land-use change) all contribute to more frequent zoonotic spillover.

• Although only about 14% of human infections may be vector-borne, vector-borne zoonotic diseases account for about 22% of newly developing human diseases, according to a more recent Public Health analysis.

• This suggests that novel zoonotic risks are emerging more frequently and that transmission dynamics are changing.53

6.3 Global Burden of Neglected Zoonoses

• The International Livestock Research Institute (ILRI) conducted a systematic analysis on "neglected zoonotic diseases" (NZDs), which reveals a substantial global health burden, particularly in low- and middle-income nations.

• These NZDs are ubiquitous in various areas, have a significant disease burden (deaths, disabilities), and have received little research.54

6.4 Wildlife Origins and Anthropogenic Drivers

• The global spread of zoonotic infections is closely associated with anthropogenic land-use change, such as deforestation, urbanization, and agricultural intensification. Such land-use changes modify mammalian reservoir ecosystems and raise the danger of spillover, according to a systematic review.

• These shifts are particularly important in areas that are rich in biodiversity yet are developing quickly, like sections of Asia and South America, as these areas may become hotspots for the rise of zoonotic diseases.55

6.5 One Health Perspective & Global Risk

• Because human, animal, and environmental health are intertwined, zoonotic infections are a global hazard, according to a review published in the One Health Journal.

• According to the research, many recent pandemics have their roots in animals, and over 60% of emerging infectious diseases (EIDs) worldwide are zoonotic.

• Zoonotic infections are spreading through more interfaces due to environmental degradation and global demographic dynamics (people expansion, urbanization).

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