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Review Article

Exchanging Pathogens the Other Way Round- Reverse Zoonoses & Wildlife

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Abstract

Reverse zoonoses, the transmission of pathogens from humans to animals, represents a largely overlooked dimension of community health. This phenomenon is particularly significant in the context of wildlife, where limited surveillance and research make animals vulnerable to novel infections. But zooanthroponoses has also been documented in domestic and companion animals. The zoo and feral animals presiding in the protected areas are equally at risk. Additionally, the contamination of common resources like water and soil with anthropogenic residues can facilitate the emergence of new infections. Pathogens may mutate to more virulent form and invade new reservoir or vector species. This review aims to examine documented instances of reverse zoonoses by analysing case studies retrieved through targeted internet searches using keywords like "reverse zoonoses" and "zooanthroponoses". The findings highlighted several cases involving viral, bacterial and parasitic pathogens transmitted from humans to animals. The prevention of such diseases is important and requires awareness and research in these areas. To ensure the compliance of 'One health', it is important to focus on the cyclic potential of transmission of pathogens and thus, both human and animal subjects to control or prevent any disease.

Keywords: Health, Reverse Zoonoses, Zoonoses.

Introduction

Zoonotic involves the transmission of pathogens that are naturally transmitted between vertebrate animals and humans and vice versa (WHO, 2020). The transmission of such pathogens involves the interaction of humans with wildlife, livestock, or companion animals through direct contact, food, water, fomites, and mechanical or biological vectors (Wikel, 2024). However, existing approaches to control zoonotic origin only focus on animals but not human subjects. Reverse zoonosis or zooanthroponoses is a type of zoonoses that involves the transfer of pathogens from humans to animals (Noman *et al.,* 2024). The incidence of reverse zoonosis is rising with time due to increase in the interaction of humans and animals amidst rise in synanthropic ecosystem. The probability of exchanging pathogens is exacerbated by factors like climate change, deforestation, modernization of agriculture, urbanization as well as wildlife trade. Reverse zoonoses poses the animal group involving pet animals, domestic animals as well as zoo animals at the risk of being inflicted by human- borne pathogens.

The relationship between humans and animals is expected to grow stronger in the coming decades, driven by factors such as animal husbandry practices, rising demand for protein, the expanding companion animal market, climate change, habitat disruption, and global travel and commerce. As a result, diseases are increasingly transmitted between animals and humans. It is predicted that over 60% of all known infectious diseases are transmitted from animals, and around 75% of new or emerging infections in humans originate from animals (CDC, 2021).

The significance of reverse zoonoses can be understood in terms of following criteria:

Animal Health**:** Humans can transmit diseases to domestic animals (pets, livestock) and even wild animals, leading to illness, mortality, and potentially impacting endangered species.

New Reservoirs**:** When humans infect animals, these animals can sometimes become new reservoirs for the pathogen. This means the pathogen can continue to circulate in the animal population, potentially evolving and then spilling back over to humans, creating a complex cycle of transmission.

Conservation Concerns: Transmission of human pathogens to wildlife, especially endangered species, can have devastating consequences for their populations.

Antimicrobial Resistance: The transfer of antibiotic-resistant bacteria from humans to animals can further contribute to the spread of AMR in animal populations and the environment (Samadi, 2025). In light of aforementioned facts, the review has been prepared with the aim to explore the different documented cases of reverse zoonoses, its responsible factors and the possible steps for their mitigation in light of one health.

Types of Reverse Zoonoses- Case Studies

1. Viral Zoonoses

Between 2003- 2006, wild chimpanzees (*Pan troglodytes*) at Mahale Mountains National Park, Western Tanzania to show respiratory signs like coughing, sneezing and lethargy, followed by the death of five chimpanzees- four adults and one neonate (Kaur *et al.,* 2008). The neonatal chimpanzee also suffered from diarrhoea and swollen eyelids before death. Samples were taken and tested for pan viral family PCR assay and confirmed the presence of Human metapneumovirus (hMPV) isolate. The mortalities were reported in the dry season that coincides with tourist season and suggested the transmission of virus from humans to animals. The authors suggested the importance of testing the park staff, researchers, tourists, tourist guides and local villagers for concluding the possible source of hMPV in the chimpanzee population.

Presence of Dengue virus serotype that had caused an epidemic in French Guiana in 2006 was isolated from the samples of Mouse opossum (*Marmosa murina*) in the ecotone zone of. It suggests that *Plasmodium* spp. and *Aedes* sp. facilitate such transmission. Thus, wild animals serve not just as reservoir but also host to many pathogens, *Aedes* spp. known to be mainly anthrophilic can be found in the edge of forest habitats (De Thoisy *et al.,* 2008). Samples were collected from 145 wild animals including Japanese Badger, Racoon, Siberian weasel, Japanese Serow and others which were rendered immobile due to traffic accidents or captured for preventing wildlife damage control. The samples were processed for detection of viral diseases. Rotavirus was detected in the samples of a

Japanese Racoon dog (*Nyctereutes procyonoides*) and a Masked palm civet (*Paguma larvata)* and the strain was found closely related to human rota virus strain. The authors conjecture this transmission to be due to transmission from humans or cats as the animals had been captured from urban settlements (Abe *et al.*,2010).

Five pet ferrets (*Mustela putorius furo*) were found to exhibit influenza- like signs including sneezing, coughing, inappetance and fever in three households in Nebraska and Oregon. Additionally, the pet owners reported developing sings like coughing, weakness, body ache and dyspnoea. The companion animals- cat and dog present in the house exhibited no such signs. The samples tested positive for H1N1 virus while the family member was medically diagnosed to be positive for Influenza A virus (Swenson *et al.,* 2010). The case involved the zoonotic transfer of pathogens among the pet owner and ferrets. It is supported by the fact that ferrets are used as an animal model to study influenza virus (Maher and Destefano, 2004).

The presence of SARS-CoV-2 virus was isolated from Amur tigers (*Panthera tigris altaica*), Spotted hyena (*Crocuta crocuta*) and African lions *(Panthera leo melanochaita*) in Denver Zoo, USA who were showing signs like coughing, sneezing, lethargy and nasal discharge. The animals recovered in 15 days. The infection was suspected to have been contracted from the zoo keepers (Gallichotte *et al.,* 2025).

2. Bacterial zooanthroponoses

The occurrence of *Campylobacter* spp., *Salmonella* spp. and *Shigella* spp. was discovered in the faecal samples of mountain gorilla (*Gorilla gorilla beringei*) in Bwindi and Mgahinga national parks, Uganda (Nizeyi *et al.,* 2001). It was assumed to have arisen due to close interaction of Gorillas with ranger guides, trackers, tourists and veterinarians. The habit of open defecation prevalent in local or tribal communities might have aided for the faecal-contamination of the water streams in the park.

The presence of *Mycobacterium tuberculosis,* an obligate human pathogen was detected in the carcass of three wild Asian elephants (*Elaphus maximus)* during post-mortem examination in Wayanad wildlife sanctuary, Kerala (Zachariah *et al.,* 2017). It is estimated that more than 3,000 native cattle resided within the sanctuary, cared for by the Animal Husbandry Department, Kerala State however, no cases of tuberculoses among cattle had been reported. Cattle were be more likely to be infected with *M. bovis* than with *M. tuberculosis*, but comprehensive testing would be conclusive. Several tribal groups resided in the protected area and some were employed by the forest department for ecotourism management and hence the spill over of pathogen from humans to elephants was suspected. The samples tested positive for acid fast staining as well as tetraplex PCR.

Methicillin-resistant *Staphylococcus aureus* (MRSA is another major prevalent challenge responsible for causing mastitis in cattle, exudative epidermitis in pigs and responsible for causing osteomyelitis, endocarditis, arthritis and several other infections. It is transmitted between pets, companion animals and owners. Infected humans can act as shedders. Asymptomatic colonization and dispersal of MRSA along with rise of antimicrobial resistance leads to establishment of MRSA in food chain (Morgan, 2008). The presence of MRSA was detected un the saliva samples of Rhesus monkey (*Macaca mulatta*) collected near the temple areas in Kathmundu suspected to have been transmitted from humans (Roberts *et al.,* 2018).

3. Parasitic zooanthroponoses

The faecal samples of African painted dog (*Lycaon pictus*) in Zambia and Namibia were assessed using coprodiagnostic techniques and revealed the presence of *Giardia duodenalis* protozoa. The African painted dog is accorded endangered status (IUCN, 2010). Higher prevalence was seen in captive population. The genotype of *Giardia duodenalis* has six assemblages that are host specific, the assemblage A and B that affect humans and are of zoonotic importance were detected in the examined faecal samples. It was suspected to be due to faecal- infection of common water streams in the wild. While captive populations might be affected by zoo- keepers. Although the parasitic concentration was not high enough to produce any visible signs but reported signs include diarrhoea and ill- thrift (Ash *et al.,* 2010).

4. Fungal zooanthroponoses

A parakeet was reported to be suffering from inappetance, weight loss, dullness and had greenish diarrhoea. The faecal sample was collected and processed for Lactophenol cotton blue staining and revealed the presence of *Candida albicans*. The pet owner was also undergoing antifungal therapy and thus might have transmitted the infection to the bird (Kumar *et al.*, 2017).

With Context to Domestic Animals

Bovine mastitis is the most common disease of dairy cattle. It renders the cattle unproductive over time, thus resulting in economic loss to the dairy farmers. It may be caused due to a variety of pathogens that maybe contagious (e.g., *Staphylococcus aureus*, *Streptococcus agalactiae*, *Mycoplasma* spp.) or environmental (e.g., *Escherichia coli*, *Enterococcus* spp., coagulase-negative *Staphylococcus*, *Streptococcus uberis*) (Radostits *et al.*, 2007). Milkmen maybe responsible several of these pathogens to cattle as well as aid in cattle- to-cattle due to lack of hygiene and improper milking methods.

Table 1: Summary of documented cases of Zooanthroponoses

S. No.	Animal Involved	Place	Pathogen	Author
Viral zooanthroponoses				
1	Wild chimpanzee (*Pan troglodytes*)	Mahale Mountains national park, Tanzania	Human metapneumovirus (hMPV)	Kaur *et al.* (2008)
2	Mouse opossum (*Marmosa murina*)	French Guinea	Dengue virus serotype (DENV-2)	De Thoisy *et al.* (2008)
3	Japanese Racoon dog (*Nyctereutes procyonoides*) and Masked palm civet (*Paguma larvata)*	Japan	Rota virus	Abe *et al.* (2010)
4	Ferret (*Mustela putorius furo*)	Nebraska, Oregon	H1N1 virus	Swenson *et al.* (2010)
5	Amur tiger (*Panthera tigris altaica*), Spotted hyena (*Crocuta crocuta*) and African lions *(Panthera leo melanochaita*)	Denver zoo, USA	SARS-CoV-2 virus	Gallichotte *et al.* (2025)
Bacterial zooanthroponoses				
1	Mountain Gorilla (*Gorilla gorilla beringei*)	Bwindi and Mgahinga national parks, Uganda	*Campylobacter* spp., *Salmonella* spp. and *Shigella* spp.	Nizeyi *et al.* (2001)
2	Asian elephants (*Elaphus maximus)*	Wayanad wildlife sanctuary, Kerala	*Mycobacterium tuberculosis*	Zachariah *et al.* (2017)
3	Rhesus macaque (*Macaca mulatta*)	Kathmundu	Methycillin resistant *Staphylococcus aureus*	Roberts *et al.* (2018)
Parasitic zooanthroponoses				
1	African painted dog (*Lycaon pictus*)	Zambia and Namibia	*Giardia duodenalis* assemblage A and B	Ash *et al.* (2018)
Fungal zooanthroponoses				
1	Parakeet	India	*Candida albicans*	Kumar *et al.* (2017)
Domestic animals				
1	Dairy cattle	Globally	*Staphylococcus aureus*, *Streptococcus agalactiae*, *Mycoplasma* spp.	Radostits *et al.* (2007)
2	Lhasa apso dog	Brazil	*Pseudomonas aeruginosa*	Fernandes *et al.* (2018)

A Lhasa apso dog was reported to show signs like head shaking and ear pruritis with purulent discharge. The presence of carbapenem-resistant *Pseudomonas aeruginosa* was detected in the infected ear samples. Detailed investigation revealed the pet owner had a severe accident and was hospitalised for a long period shortly and discharged shortly before the dog began showing signs. Surveillance cultures were collected from the owner's family's faecal samples, household (sofa, living room, balcony *etc.* The presence of carbapenem resistant *P. aeruginosa* isolates were detected from the collected samples. The whole genome sequencing of the *P. aeruginosa* isolates revealed the isolates were clonally related to a popular hospital-associated lineage ST233. It suggested the zooanthroponotic transmission of the nosocomial infection from the owner to the household that infected the dog. Thus, the study reported the transmission of infection from the pet owner to the household and then the pet (Fernandes *et al.*, 2018).

- In light of cases discussed above, zooanthroponoses is found to be driven by factors as enlisted below: Deforestation and encroachment of forests and natural settlements forcing the spillover of pathogens

- Captive animal settings (zoos, sanctuaries, research facilities) and wildlife trade that increase direct human–animal interactions which facilitate exchange of pathogens. Ecotourism and community-based conservation models expose wildlife to high numbers of human visitors.

- Globalisation and travel allow human pathogens to be transported across continents and into naive animal populations.

Impact of Reverse Zoonoses on Wildlife Conservation

Wildlife species, particularly those that are endangered, immunologically naive, or genetically vulnerable, face severe consequences from human-derived pathogens:

- Population declines: Small populations may not withstand an outbreak. For example, measles and respiratory viruses have led to population-level impacts in chimpanzees and gorillas.

- Genetic bottlenecks: Surviving individuals may have reduced genetic diversity, impairing resilience to future challenges.

- Conservation setbacks: Years of investment in species recovery can be reversed by a single outbreak.

- Captive breeding program risks: Pathogen exposure in breeding facilities may compromise animal health and welfare, and impact reintroduction programs.

Significance with Respect to One Health

The expansion of human population and the encroachment of wildlife habitats has driven the exchange of several pathogens. The international trade of livestock and livestock- products also aids in this. Additionally, smuggling or legal introduction of exotic or wild pets leads to the introduction of new pathogens. Anthropogenic factors driving the climate change and pollution of natural resources has also affected vector ecology and their expansion over new habitats aiding in transmission of vector-borne diseases.

One health involves the participation of stakeholders and expertise from different streams like medicine, ecology, veterinary science and others for devising effective prophylactic measures against all types of zoonoses. It will help formulate a sustainable and effective solution to the curb of re-emergence and emergence of pathogens (Khalil *et al.*, 2023).

The pet industry has emerged as a highly prolific enterprise worldwide involving domestic as well as exotic animals. As of 2024, 66% of families, estimated to 86.9 million individuals, in USA own a pet. There are more than 2.4 billion birds housed as pets worldwide (Zebra, 2024). This entails an equivalent rise in exchange of pathogens. Awareness and public education is important to tackle such challenges.

Antimicrobial resistance (AMR) is another major threat to resolving the crises of zoonoses and zooanthroponoses. The contamination of water reservoirs with sewage and livestock effluents containing antimicrobial resistant bacteria and antibiotics expose wild animals and all species visiting the same water source. This in turn prevents the resolution and aid in the development of pathogens. AMR also contributes to modification of the gut microbiota and thus the immunity of the specie (Vittecoq *et al.*,2016). All these factors have culminated in the rise of cases of reverse zoonoses over the years (Noman *et al.*, 2024).

Conclusion

Reverse zoonoses present a growing challenge in our increasingly interconnected world. As human activities continue to encroach on animal habitats, the likelihood of pathogen transmission in both directions increases. This review highlighted the instances of reverse zoonoses in wild as well as domestic or feral animals. It thus strengthens the call for better collaboration between different sectors of government for addressing challenges at root level. Issues like shortage of trained veterinary staff or lack of research facilities needs to be bridged to address the rise of any zoonotic disease. Better civic collaboration will also help tackle anthropogenic waste generated and polluting the environment and common resources Judicious use of antibiotics and training of livestock owners and common people about appropriate precautions while handling or being near animals can help reduce the burden of zoonoses. Understanding and addressing reverse zoonoses is critical for global health security, animal conservation, and the sustainable coexistence of humans and wildlife.

Ethical Compliance

The clinical studies and animal subjects reported in this review article were conducted in compliance with the protocol and local authority standard operating procedures, ensuring adherence to ethical principles outlined in the Declaration of Helsinki.

Contribution by Authors

All the authors contributed equally to writing the manuscript. The final manuscript was read by all authors and consented to publication.

Conflict of Interests

There is no conflict of interest.

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