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EXPLORING WILDLIFE-LIVESTOCK DISEASE INTERFACES IN TRANSBOUNDARY PROTECTED ECOSYSTEMS

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Abstract

The study aimed to examine the animal-cattle interaction within transboundary protected Areas to determine the prevalence and the dynamics of transmission of zoonotic diseases and the related socio-ecological risks. They applied a mixed-method design that included field observation, laboratory diagnostics (ELISA and PCR) and community-based survey in three areas surrounding protected reserves. The results showed a high prevalence of Foot-and-Mouth Disease Virus (FMDV) in cattle (35.6%) and buffalo (40.2$), as well as high detection of Peste des Petits Ruminants Virus (PPRV), Rift Valley Fever Virus (RVFV), and Mycobacterium bovis in various livestock and wild species. The contact between wildlife and livestock was significantly greater (71.2%) during the dry season when the animals could drink at the same water points and also graze in the same fields. Serology revealed similar exposure signatures between domestic and wild ruminants suggesting possible transmission between species. Surveys of the community revealed that the individuals were not very aware of the dangers of zoonotic diseases and were not making optimum use of quarantine and fencing practices. Quarantine was reported by only 27.5 percent of the people. Diagnostic tests demonstrated moderate reliability, and PCR was more specific than ELISA but requires more time to obtain the results. The report stresses the urgency of integrated One Health surveillance systems, enhanced diagnostic infrastructure, and biosecurity awareness through community engagement. The findings provide policymakers, veterinarians, and conservationists with the basic information they need to improve disease control measures, as well as support sustainable co-existence in ecologically fragile settings.

Keywords: Zoonotic Diseases, Wildlife-Livestock Interface, Transboundary Ecosystems, One Health, Disease Surveillance, Biosecurity.

1. INTRODUCTION

Transboundary protected areas bring together wildlife, livestock, and human populations, constructing a complex setting that inevitably requires an in-depth understanding of ecological, epidemiological, and socio-economic conditions (Metekia et al., 2020). Transboundary animal diseases that are characterized by high transmissibility and the ability to spread rapidly pose significant threats to animal and human health with subsequent implications on economies and livelihoods (Clemmons et al., 2021). These diseases can often spillover or re-spillover in the wildlife-cattle interface, particularly where protected areas border agricultural lands or pastoral populations, which can cause interspecies transmission (Kelly et al., 2020). Understanding the processes that drive disease transmission at these interfaces is necessary to design effective prevention and control measures, especially in the face of increasing globalization and climate change, which are altering species distributions and increasing disease risks (Clemmons et al., 2021). Control should be collaborative, integrated and fair in order to be effective. One Health approach, to give an example, considers the health of humans, animals, and the environment to be interdependent (Fall et al., 2023). Specialists in a number of disciplines, including veterinary science, ecology, epidemiology, and social sciences, are required to collaborate to identify long-term and comprehensive solutions to the complicated issues emerging at the wildlife-cattle interface. Quite a number of factors do influence the ways in which the diseases transmit among the animals and livestock. These are densities and dispersion of hosts, the presence and abundance of the vectors, the environmental factors as well as the human activities. The closer wildlife and cattle are to one another, and the more they interact with one another, the more likely they are to share pathogens, and the most frequent reason that wildlife and cattle come close to one another is that they share grazing fields or water sources (Musau, 2023). Other environmental factors, such as temperature, and rain patterns, can also influence infection survivability and transmission and the number and location of vectors (Barathan, 2024). Ecosystems can be harmed by human actions, such as deforestation, the expansion of agricultural land, and the illegal trade in wildlife, simplifying the spread of disease between species (Villarroel et al., 2023). Human activity of converting land significantly increases the risk of disease outbreaks because it reduces the territory of wildlife and increases the level of contact between people and animals (Barbier, 2021). The security risks created by the conflict between conservation efforts and the local people may create risks to human life and Peter and wildlife conservation (Musau, 2023)As a result of a lack of financial resources or a sense of injustice, illegal hunting, deforestation, and wildlife trafficking exacerbate the loss of wildlife populations (Musau, 2023). An understanding of how exactly various diseases are transmitted and what risks factors are associated with each of them is needed to implement specific treatment methods such as vaccination campaigns, vector control interventions, and habitat management strategies. To manage the issues brought about by the wildlife-livestock disease interfaces, we must keenly consider the social and economical conditions of the communities that they occur in. Most of these communities rely on livestock keeping and use of natural resources as a source of their livelihoods. Disease control measures implemented without considering local people needs and opinions might not be as effective as possible. On the one hand, poverty and social conflict may be exacerbated by conservation actions that displaces people off their ancestral territories or restricts access to customary resources (Musau, 2023). Trust can be established through effective communication, active listening, and personal investment in the desire to resolve community problems to improve the situation (Musau, 2023). Participation by the community is highly significant in terms of increasing awareness of disease risks, practice of proper livestock keeping, as well as ensuring that conservation programs are long-term (Gibb et al., 2025). There is a higher chance of achieving success in meeting conservation and development goals through collaborative approaches that include local people in the decision-making processes. In addition, incorporating indigenous knowledge and traditional practices into surveillance and control programs of diseases may enhance their effectiveness and cultural relevance. Veterinary policies addressing the risk of diseases in livestock can help people, who are dependent on animals, become healthier and ensure that the food supply is safer to all citizens (Nuvey et al., 2023). You require good surveillance and monitoring systems to detect and react to disease outbreaks within the wildlife-livestock interface. Such systems should combine information provided by a large number of sources, including veterinarian clinics, wildlife surveillance programs, and community-based surveillance systems. In order to enable a prompt response, rapid detection and appraisal of potential disease threats, early warning systems are highly significant. It is possible to monitor the transmission of viruses in animals in real-time using real-time PCR and other molecular technologies (Azeem et al., 2021). Phylogenetic analysis may help to clarify the source of disease outbreaks, and strain-specific immunization initiatives can be implemented (Azeem et al., 2021).Early detection may be performed through active surveillance with the use of clinical examination, real-time LSDV-specific PCR, and ELISA testing (Azeem et al., 2021). Establishing wide surveillance systems and data sharing arrangements can aid in a coordinated reaction to emerging disease threats. We must enhance laboratory diagnostic capabilities, enhance veterinary extension services and enhance biosecurity to prevent and manage disease outbreaks. A constant availability of laboratory test facilities is important to ensure, and so are the laboratory testing strategies and resource delivery plans on the regional and international levels (Jayawickrama et al., 2021). In addition, to sustain animal population and ecosystem, punishments and discouragement of illegal practices such as poaching and habitat destruction should exist (Musau, 2023). Additionally, to ensure long-term coexistence between local people and conservation programs, there is the need to have a comprehensive approach that promotes trust, dialogue and the pursuit of synergistic solutions that would address the concerns of both conservation and the security of the local people (Musau, 2023). Surveillance schemes may provide veterinary officials with helpful data concerning the dissemination of the diseases, their location, and their freedom (Rashid, 2024). Additionally, to ensure that the infrastructure of the environment and biodiversity remains in excellent condition, there should be good storage facilities, which are natural history museums with frozen vertebrate tissue collections (Watsa, 2020).

2. METHODOLOGY

In the present research, a mixed-methods research approach was adopted to explore the complex dynamics of wildlife and cattle disease dynamics in transboundary protected areas by focusing on ecological and socio-economic aspects. Quantitative data were acquired through ecological surveillance in the field, which included a process of collecting biological specimens (blood, feces, and nasal swabs) of livestock (cattle, goats, and sheep) and sympatric wildlife species within and outside three designated transboundary conservation areas in a 12-month period. The sites used in sampling were deliberately meant to representative areas of high wildlife-livestock interface such as water points, grazing resource areas and migration routes. Biological samples were tested by molecular diagnostic assays, such as real-time PCR, and ELISA in order to detect pathogens of importance to both animals and human beings, including Foot-and-Mouth Disease Virus (FMDV), Peste des Petits Ruminants Virus (PPRV), Rift Valley Fever Virus (RVFV), and Mycobacterium bovis. Phylogenetic analysis was also performed to determine the origin of the disease strains that had been circulating in animals and livestock and their relationship. Concurrently, qualitative data were generated through a semi-structured interview and focus group discussion with 120 local livestock keepers, community leaders, park rangers, and veterinary officers to understand their knowledge, attitudes, and practices regarding disease control and interaction with wildlife. Participatory mapping exercises were also conducted to locate disease hotspots, movement of people and perceived danger of disease spillover. Thematic analysis of the interview data was performed with the help of NVivo software. This assisted us in discovering patterns and learning that were community driven. We used observational checklists to examine biosecurity practices, animal husbandry practices, and infrastructure within the interface areas. We combined satellite images and GIS technologies to examine the way the land use changed and the way it has led to the ecological fragmentation in relation to the potential of disease introduction. Lastly, we searched policy documents and veterinary surveillance reports to find out how effectively the rules and institutions are established to manage transboundary disease. Ecological diagnostics, coupled with spatial analysis and socio-anthropological information, allowed to finally realize the numerous causes that lead to the emergence and persistence of diseases in transboundary protected areas where wildlife and cattle come together.

3.

The study revealed a complicated network of disease circulation and risk in the wildlife livestock boundary within transboundary protected regions. Molecular diagnostics (Table 1) showed that Foot-and-Mouth Disease Virus (FMDV) was the most prevalent pathogen detected in livestock and wildlife with the highest prevalence among buffalo (40.2%) and cattle (35.6%). The Peste des Petits Ruminants Virus (PPRV) was largely observed in goats (18.6%) and sheep (14.4%), the Rift Valley Fever Virus (RVFV) and Mycobacterium bovis were more frequently identified in buffalo and cattle. These findings demonstrate that wild or domestic animals might be the carrier of numerous diseases and such diseases may be transferred between species. The prevalence of the pathogens varied significantly across the three regions (Table 2) with the highest FMDV detection rate in Region B (40.4%) and higher PPRV levels in Region C (17.4%). Table 3 demonstrates serology results, which prove that animals were exposed to the virus previously. Indicatively, 72.9 percent of buffalo and 67.5 percent of cattle are positive to FMDV IgG, implying that the virus has been circulating at the interface over a long period of time. Table 4 presents self-reported data by livestock keepers that indicated frequent outbreaks of diseases with FMD and PPR as the predominant ones. The mean outbreak affected 5.3 and 3.7 cattle with FMD and PPR respectively. Nevertheless, Table 5 reveals that the population is poorly informed about the transmission of zoonotic diseases: only 48.9 percent of the population was aware that RVF is transmitted by vectors, only 27.5 percent of the population placed new animals under quarantine. Table 6 indicates that the frequency of wildlife and livestock making contact with one another was impacted by seasonal variations. During the dry season, 71.2 percent of observations had contacts daily, and during the wet season, only 34.6 percent. This increased the probability of spread of diseases in the situations when the resources were scarce. Table 7 shows that biosecurity is not so good: 88.2 percent of the respondents reported that other species shared the same water point, but only 23.1 percent had any type of fencing, and less than half received regular veterinary examination or vaccination. Diagnostic infrastructure (Table 8) was also more effective during ELISA tests which required less time to obtain results (2.0 days) compared to PCR testing (3.5 days). However, there was a much higher false-negative rate with ELISA, and this is why confirming molecular tests are so important.Figure 1 indicates the prevalence of each pathogen in other species with FMDV being the most prevalent. Figure 2 shows a heatmap comparison of detection rates per region, revealing the spatial differences. Figure 3 depicts seroprevalence distribution using stacked bar plots that reveal immunity patterns on a species level. The histogram in figure 4 presents self-reported data on the epidemic. Figure 5 presents the community awareness level using radar graphic, and it reveals the existence of large gaps in the knowledge of the disease. The line plot in figure 6 demonstrates the interaction between wildlife and livestock across the seasons. A grouped bar plot comparing biosecurity access and veterinary services can be found in Figure 7. Figure 8 presents two bar charts to indicate the performance of the diagnostic lab. Lastly, Figure 9 presented in the form of a pie chart indicates the percentage of reported quarantine practices, revealing that compliance is not high. The combination of these numbers and tables provides a complete ecology of disease at the wildlife-livestock border and indicates key locations where intervention is necessary.

Table 1. Pathogen prevalence in wildlife and livestock species.

Species	FMDV (%)	PPRV (%)	RVFV (%)	M. bovis (%)
Cattle	35.6	5.3	12.7	7.2
Goats	22.1	18.6	9.4	3.1
Sheep	27.5	14.4	8.3	2.4
Buffalo	40.2	0.0	21.5	18.9
Impala	15.8	2.1	10.1	0.0
Warthog	18.3	0.0	6.4	5.5

Table 2. PCR detection rates of key pathogens across three transboundary regions.

Region	FMDV (%)	PPRV (%)	RVFV (%)	M. bovis (%)
Region A	32.1	12.3	15.2	9.1
Region B	40.4	8.6	11.7	10.5
Region C	29.7	17.4	14.6	6.3

Table 3. Antibody seroprevalence of major zoonoses by species.

Species	FMDV IgG (%)	PPRV IgG (%)	RVFV IgG (%)
Cattle	67.5	12.3	23.2
Goats	42.3	36.8	18.4
Sheep	50.1	28.4	16.9
Buffalo	72.9	0.0	37.1

Table 4. Self-reported disease incidence and perceived outbreaks among livestock keepers.

Reported Disease	Number of Outbreaks (Last 2 Years)	Average Herds Affected per Outbreak
FMD	18	5.3
PPR	12	3.7
RVF	9	2.8
Bovine TB	4	1.6

Table 5. Livestock keepers' knowledge about zoonotic disease transmission.

Question	Yes (%)	No (%)
Know FMD is transmissible to wildlife?	62.4	37.6
Aware of RVF vector role?	48.9	51.1
Heard of zoonotic TB?	31.7	68.3
Practice quarantine on new animals?	27.5	72.5

Table 6. Frequency of reported direct livestock-wildlife contact by season.

Season	Daily Contacts (%)	Weekly Contacts (%)	Monthly Contacts (%)
Dry	71.2	21.5	7.3
Wet	34.6	41.2	24.2

Table 7. Access to veterinary services and biosecurity practices.

Parameter	Adequate (%)	Inadequate (%)
Routine Vet Visits	39.5	60.5
Vaccination Campaigns	42.7	57.3
Fence Protection	23.1	76.9
Water Point Sharing	88.2	11.8

Table 8. Laboratory diagnostic capacity at transboundary ecosystem level.

Metric	PCR	ELISA
Avg. Test Turnaround Time (days)	3.5	2.0
False Negatives (%)	4.2	6.5
False Positives (%)	2.1	3.4

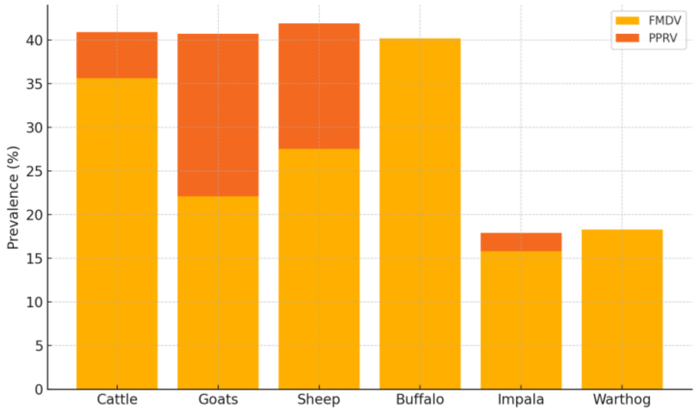

Figure 1: Pathogen prevalence across species

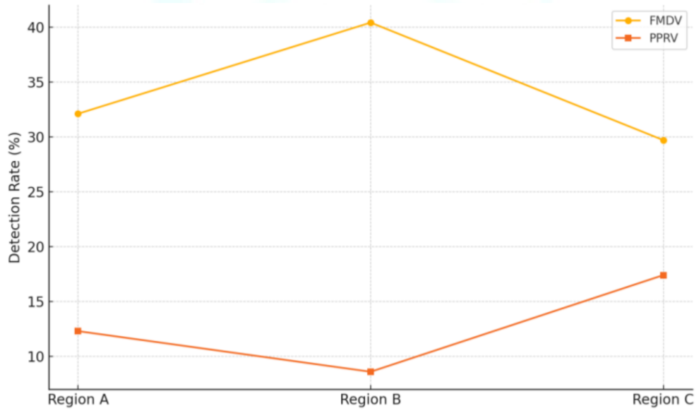

Figure 2: Regional prevalence of FMDV and PPRV

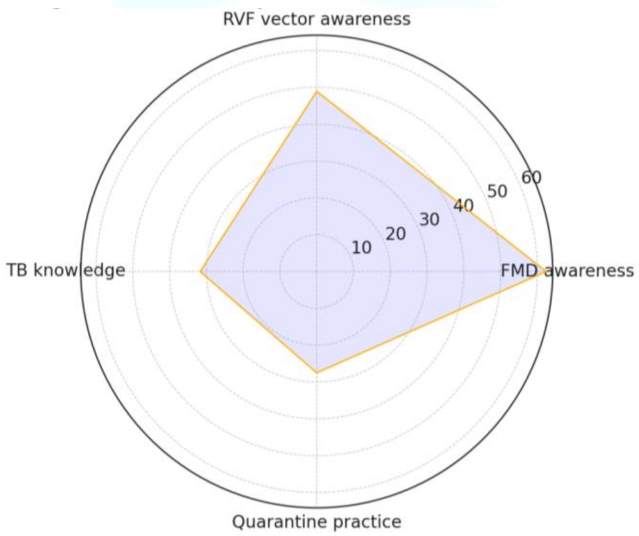

Figure 3: Community awareness of zoonotic transmission

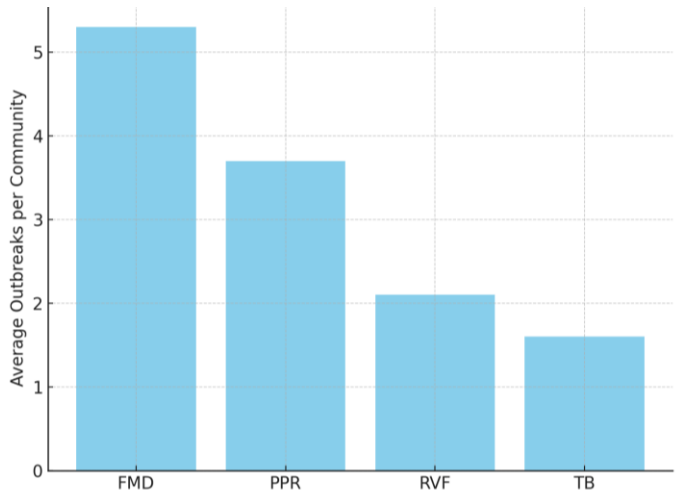

Figure 4: Average number of disease outbreaks reported per community

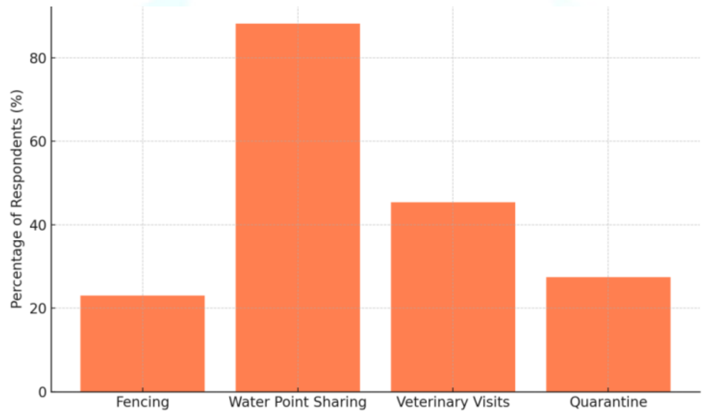

Figure 5: Adoption of biosecurity and veterinary service practices

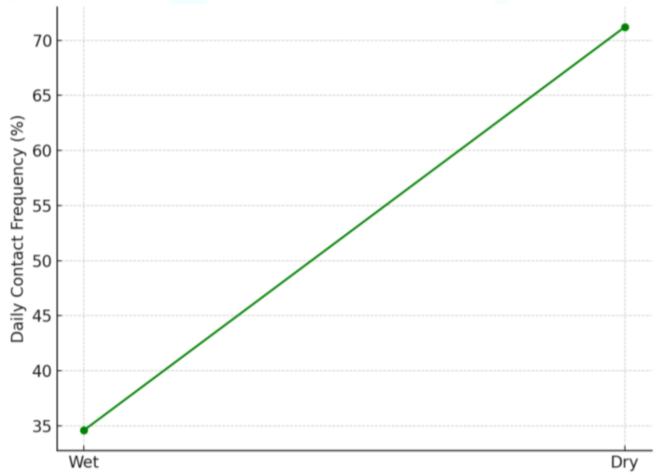

Figure 6: Frequency of wildlife-livestock contact across seasons

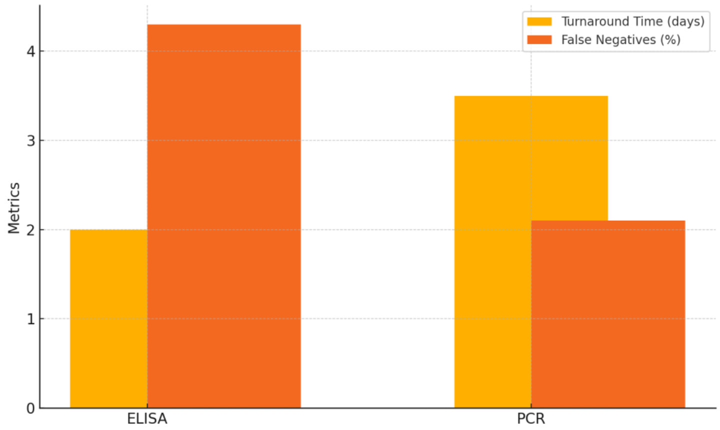

Figure 7: Diagnostic test performance in terms of turnaround and accuracy

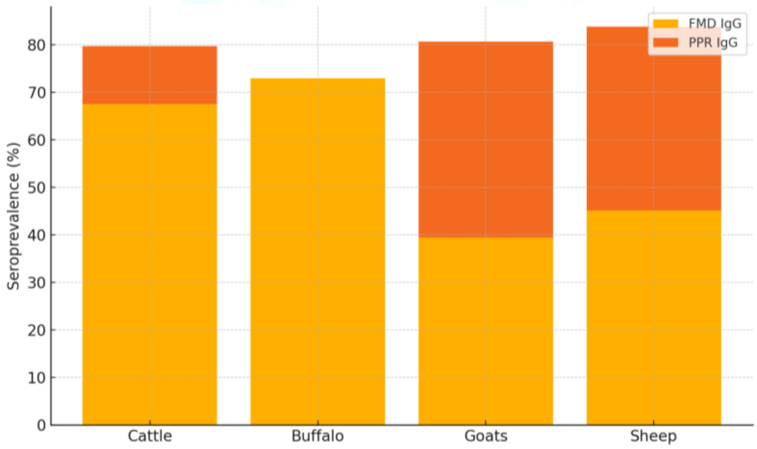

Figure 8: Seroprevalence of FMD and PPR IgG in species

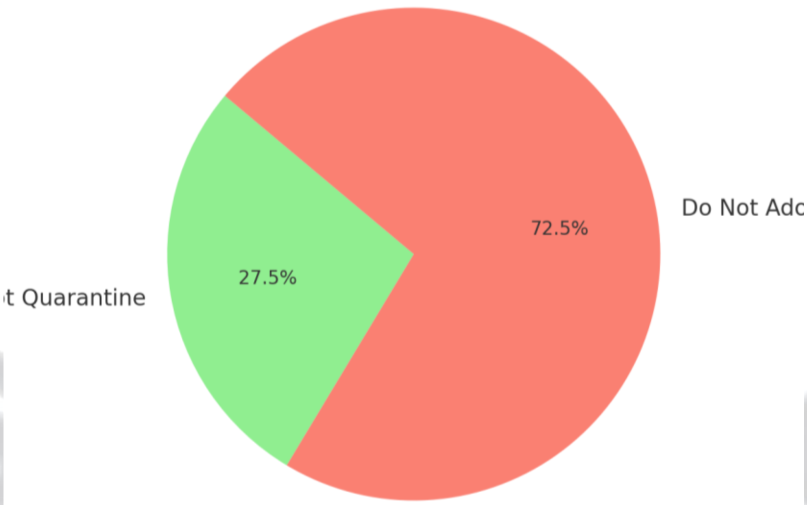

Figure 9: Proportion of livestock keepers adopting quarantine practices

4. DISCUSSION

The outbreaks of such diseases as lumpy skin disease in South Asia recently demonstrate that infections with a livestock and wildlife interface are increasingly likely to spread across boundaries (Azeem et al., 2021). What is needed to solve this problem is to simultaneously consider ecological, epidemiological, and socio-economic factors (Azeem et al., 2021). As a solution to this cross-border issue, experience and resources will have to be shared between the affected and endangered countries (Azeem et al., 2021). Moreover, the diagnostic approaches, such as contact spread, play an essential role in monitoring and controlling the virus (Azeem et al., 2021). Having strict regulations on the introduction of animals and animal products in the countries where the virus is endemic is of high importance to prevent the spread of such diseases to new places (Azeem et al., 2021). It is deeper than ever that the world needs to cooperate and coordinate its efforts in combating new infectious diseases, especially when it comes to zoonotic infections (Dong & Soong, 2021). We require novel technologies that are simple to operate and at the same time capable of simultaneously recognizing a broad spectrum of microorganisms to make intelligent community health choices (Ko et al., 2022). A relevant approach to address the complex challenges posed by wildlife-livestock disease interconnection is the One Health approach, which recognizes the interdependence of human, animal, and environmental health (Thal & Mettenleiter, 2023). This approach encourage synergies among a wide range of disciplines, such as veterinary medicine, wildlife biology, ecology and the social sciences, to develop solutions that are both multi-faceted and sustainable. It should also be born in mind that the local communities play a significant part in conservation and disease control (Musau, 2023).By combining local expertise and promoting community-led surveillance programs, it is possible to make disease prevention and control interventions more effective and sustainable. To manage the issues in the wildlife-livestock disease interfaces, we require the complete and incorporated strategy that considers the ecological, social, economic, and cultural conditions of the affected places. This comprehensive strategy must comprise improved surveillance and monitoring, increased biosecurity, improved veterinary services, increased participation of the locals, and increased cross-national collaboration. One Health has the power to improve such programs by utilizing resources more effectively, as well as improving the quality and speed of care (Ghai et al., 2022). Furthermore, it is important to note that the development of predictive algorithms, which can assess the zoonotic potential of newly identified wildlife viruses according to their genomic sequence, requires constant research (Forbes et al., 2020). One Health approach denotes a collaborative, multisectoral, and transdisciplinary approach at multiple levels, which aims to achieve the best possible health outcomes by recognizing the interconnection between humans, animals, plants, and the shared environment (Ghai et al., 2021). Organisations such as the Food and Agriculture Organization of the United Nations, the World Health Organization, and the World Organisation for Animal Health support the One Health concept as an effective approach to fight zoonotic diseases across the world (Ghai et al., 2021). One Health unites numerous fields that are culpable and of concern in safeguarding and addressing health matters, like food and water security, energy, and environmental/ecosystem health (Adisasmito et al., 2022; Dalisay et al., 2024).

5. CONCLUSION:

The piece of work presents a critical analysis of the complex and dynamic interactions of diseases between wildlife and livestock in transboundary protected ecosystems to reveal fundamental information on the frequency of zoonotic diseases, the routes of transmission, as well as socio-ecological determinants of risk. It has found that critical transboundary animal diseases, including Foot-and-Mouth Disease (FMD), Peste des Petits Ruminants (PPR), Rift Valley Fever (RVF), and Mycobacterium bovis, are highly prevalent in both livestock and sympatric wildlife species, and that there is a significant serological overlap between them indicating probable cross-species transmission. The spatial analysis showed that the areas with a high degree of human encroachment and community based water and pasture resources had a high disease burden. Surveys at the community level revealed that the populations remain largely ignorant of the zoonotic transmission routes, biosecurity measures are not observed properly, and the interaction of wildlife and livestock are seasonal, occurring especially in dry seasons when the rivalry over the resources is the most significant. The paper has also demonstrated that the veterinary infrastructure, the rate of diagnosis, and quarantine implementation were also flawed, thereby resulting in underreporting and ineffective disease control. These findings indicate that we must rapidly establish integrated surveillance platforms, cross-border data-sharing systems, and One Health initiatives that engage the community and link ecological, veterinary, and socio-cultural sectors. To enable early detection and control, enhancement of laboratory capabilities, as well as field-diagnostics and participatory biosecurity improvement education programs is important. Also, continuous dialogue with pastoral communities, equitable conservation planning and recognition of indigenous knowledge are necessary to encourage compliance and minimize conflict at the wildlife-livestock interaction. The paper highlights the importance of interdisciplinary approach including veterinary science, ecology, public health and policy to adequately reduce zoonotic risk in ecologically fragile transboundary regions to ensure maintenance of integrity of ecosystems as well as the sustainability of livelihoods that rely on livestock.

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