Title

Assessment of Rural Community Knowledge and Perceptions of Animal Vaccines to Prevent Zoonotic Disease Spillover in Sierra Leone

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Publication Date

2023

Peer reviewed|Thesis/dissertation

Assessment of Rural Community Knowledge and Perceptions of Animal Vaccines to Prevent Zoonotic Disease Spillover in Sierra Leone

By

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THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

INTERNATIONAL AGRICULTURAL DEVELOPMENT

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

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2023

ABSTRACT

Lassa fever is a zoonotic viral hemorrhagic fever endemic to West Africa. Currently, no approved and commercially available human vaccine exists to prevent Lassa fever. In addition to human vaccines to control Lassa fever, research efforts have suggested that vaccination of the reservoir host rodent species may be an effective alternative, especially new vaccine technologies such as self-spreading or transmissible vaccines. To date, very little research exists related to the sociological barriers to adoption of wildlife vaccination or perceptions of these new vaccine technologies in West Africa. To identify effective intervention strategies including development of reservoir host vaccination by both traditional and potentially self-disseminating approaches, this study sought to assess the knowledge, attitudes, and perceptions of community members and other key stakeholders.

To assess these factors, 203 individual interviews and 20 focus group discussions were conducted across 22 communities in Sierra Leone and analyzed using quantitative and qualitative methods. Survey participants were asked questions related to their previous experiences with human and animal vaccines, knowledge and risk perception of viral disease, and willingness for nearby wildlife to receive traditional and self-disseminating vaccines.

Almost all study participants (94%) were aware of Lassa fever, although the majority (62%) perceived the disease to be low risk. However, this perception was not correlated with a hesitancy toward preventive measures, as 94% of respondents said they would accept a human Lassa fever vaccine if offered and 98% said they would allow rodents in their homes to be vaccinated. Out of the 203 individuals surveyed, 201 said they would allow rodents to receive a self-disseminating vaccine if it would prevent disease. While attitudes toward self-spreading or transmissible vaccination are generally positive, respondents raised genuine concerns about the feasibility of the technology, its impact on traditional consumption of rodent meat, and potential negative effects to adjacent animal and human populations. Focus group discussions revealed further cultural considerations tied to vaccine hesitancy, including the impact of community education, role of religion, and best communication platforms for health messaging.

This study suggests that when developing new disease prevention technologies, it is critical to work together with intended beneficiaries, socialize key concepts, and co-create strategies that effectively address all concerns to health, safety, and equity. Additionally, the high levels of trust and reliance on hierarchical systems of power and responsibility in study communities point to the essential need for robust regulatory frameworks to guide the development and potential implementation of new technologies. Further participatory research is needed to expand upon the findings of this study and continue developing shared knowledge and understandings of community knowledge, attitudes, perceptions, and practices related to viral zoonotic disease and human and animal vaccines.

INTRODUCTION

The growing threat of emerging infectious diseases, especially from wildlife is one of the most pressing global health issues of the 21st century (Taylor et al., 2001). Viral diseases such as Lassa fever, COVID-19, and Ebola virus disease, among others, have recently captured public attention as outbreak events have increased in frequency and severity. It is believed that many of these diseases originate in animal species, usually wildlife, and it is known that they can be transmitted from multiple animal species to humans. Lassa fever is one such zoonotic viral hemorrhagic fever and is caused by the Lassa virus (*Lassa mammarenavirus*; Family *Arenaviridae*), and is transmitted to humans primarily through contact with *Mastomys natalensis* rodents, also known as multimammate rats or African soft-furred mice (Bell-Kareem & Smither, 2021). Spillover infection, the transmission of Lassa virus from rodents to humans, occurs through contact with rodent urine or feces (Bonwitt et al., 2017) or through consumption of rodents (Bonwitt et al., 2016). Lassa fever is endemic to sub-Saharan West Africa, including Sierra Leone, (Shaffer et al., 2014) although its range has been observed to be expanding in recent years (Gibb et al., 2017; Sogoba et al., 2012). Development of a human vaccine against Lassa fever is ongoing, although there may be significant challenges to implementation of a future vaccine due to limited healthcare infrastructure in the affected region (Saied et al., 2022). Vaccination of the host rodent species has been suggested as a means of directly reducing the disease's prevalence and preventing spillover into humans (Morse et al., 2012). Since person-to-person transmission of Lassa fever is less common than spillover transmission, effectively targeting host rodent species for vaccination could be a significant part of Lassa fever control and eradication (Nuismer & Bull, 2020).

Although wildlife vaccination has been successfully utilized to reduce transmission of other zoonotic diseases such as rabies, it poses unique challenges to implementation (Rupprecht et al., 2004). Wildlife populations may be dispersed over large areas and difficult to access. Funding for veterinary interventions in wildlife populations of low ecological concern is often limited, especially in low-resource settings (Plumb et al., 2007). Most significantly, the short lifespan of certain species, such as the *Mastomys natalensis*, creates a rapid population turnover that significantly hinders the ability to reach herd immunity within a population (Schreiner et al., 2020). One proposed solution to these challenges to wildlife vaccination is a new type of vaccine technology known as a self-disseminating vaccine (Afrough et al., 2019). Self-disseminating vaccines are typically considered to be either transferrable or transmissible. Transferrable vaccines are administered to target animals externally, then other animals are exposed to and consume the vaccine through grooming behavior or other physical interactions. In contrast, transmissible vaccines are conceptually designed to utilize an endemic, species-specific but benign virus that exists within the target wildlife population, which is altered to contain immunogenic material that prevents the spread of the target disease (Nuismer & Bull, 2020). Hypothetically, the transmissible vaccine is administered to the natural evolutionary hosts of a zoonotic pathogen, for example in the case of Lassa virus, *Mastomys natalensis*. The vaccine then provides immunity to the animal from the pathogen and the animal then transmits the protective immunity onward to other animals through vaccine shedding (Basinski et al., 2018). Notably, transferrable vaccines cease dissemination after the initial vaccine material has been entirely utilized or is washed off the original target animal, while transmissible vaccines theoretically continue disseminating through the target population and could even be transmitted by animals that did not initially receive a vaccine (Nuismer & Bull, 2020).

As with all new technologies, self-disseminating vaccines (especially transmissible vaccines) come with significant and challenging ethical, legal, regulatory, and social implications. Ethically, transmissible vaccines raise significant questions of individual and community consent. Obtaining consent for traditional vaccination of wildlife populations is a complex question; the ability of a community to consent to wildlife they are in close contact with receiving a vaccine that is intended to continue spreading is significantly more complex (Bhutta, 2004). Even defining the community affected by transmissible vaccine technology is challenging due to uncertainty about geographic spread; theoretically and depending on the vaccine construct and targeted wildlife host range, a transmissible vaccine could spread over wide ecological range with regional and transboundary implications (Sandbrink et al., 2021). A reasonable understanding of the health risks and potential benefits of the transmissible vaccine is necessary for informed consent to be obtained from communities and individuals. Additionally, transmissible vaccine technology poses potential environmental and ecological risks that are not yet fully understood (Sandbrink et al., 2021). As transmissible vaccines are still under development, it is not yet possible to fully understand and compare the risks and benefits of this technology. Understanding, communicating, and mitigating the environmental, ecological, and health risks will be crucial for ethical consideration of use of a transmissible vaccine, if one is proven effective for disease prevention and approved for use in field trials.

In terms of legal considerations, no regulatory framework currently exists for field testing or implementation of transmissible vaccines (Lentzos et al., 2022). Vaccine developers and regulatory authorities will need to conduct robust environmental risk assessments and hazard identification and work in collaboration alongside bioethicists to develop comprehensive regulatory frameworks for development, testing, and potential implementation before

transmissible vaccines can be seriously considered (Sandbrink et al., 2021). All of the above will be strongly influenced by the social implications and context of self-disseminating vaccine technology. Increases in vaccine hesitancy and misinformation tied to the COVID-19 pandemic continue to be relevant to other health and vaccination issues, (Mercedes et al., 2022) especially a technology as potentially controversial as a vaccine which virally spreads from one animal to another. Additionally, as a genetically engineered technology, transmissible vaccines may be subject to social and regulatory concerns related to genetically modified organisms (Afrough et al., 2019). In addition to appropriate regulatory development and approvals, robust and appropriately targeted risk communication and stakeholder engagement will be necessary for social acceptance of self-disseminating vaccines.

The locations of development, testing, and implementation of self-disseminating vaccines also carry significant ethical and social implications (Fallah & Ali, 2022). Research in the Global South has a long history of abuse perpetuated by lack of oversight and neocolonial prioritization of certain individuals as more "disposable" or exploitable (Flint, 2020). In light of this, intentional effort is required on the part of researchers and regulatory bodies to ensure marginalized perspectives are not only considered, but prioritized in development, implementation, and regulation of new technologies, especially ones with significant potential risk.

During and following the 2014-2016 Ebola epidemic, investment in zoonotic disease research increased, including efforts to develop and trial an Ebola vaccine (WHO Ebola Response Team, 2016). Although not as prevalent as biomedical research, research on social dimensions of zoonotic disease transmission and prevention gained traction following the challenges of the 2014-2016 Ebola epidemic (Huo et al., 2016a). Although this body of research largely focused

exclusively on Ebola, other viral diseases were brought to the world's attention, including Lassa fever. During and following the COVD-19 pandemic, research on perceptions of viral disease and vaccination once again increased (Farber & Harris, 2022). These studies have generally focused on zoonotic diseases from an epidemiological perspective, seeking to understand the transmission patterns and clinical characteristics of these diseases. Increasing vaccine hesitancy and distrust in public health institutions following the COVID-19 pandemic have brought more awareness to the need for participatory, community-based research that seeks to examine deep-rooted attitudes and perceptions of zoonotic disease and vaccination, the knowledge that informs those attitudes and perceptions, and the practices people adopt because of or in spite of these (Wild et al., 2021). Little research exists related to social dimensions of Lassa fever prevention, especially in countries other than Nigeria. One study in Nigeria found high awareness of Lassa fever among participants but low specific knowledge of disease symptoms or risk factors, as well as high perceived risk of Lassa fever infection (Usuwa et al., 2020). Another Nigerian study, which focused on rodent control to suppress Lassa fever infection, found low awareness of Lassa fever as well as poor knowledge of Lassa fever transmission and prevention (Olalekan, 2015). The only published research on perceptions of Lassa fever in Sierra Leone focused on health care workers and community health workers, who reported technical challenges to formal diagnosis of Lassa fever (Rohan, 2022). These results suggested challenges to Lassa fever awareness in target communities, such as low initial awareness and knowledge, lack of perceived risk of Lassa fever, and lack of access to healthcare, but did not fully explore these challenges.

Understandings of disease prevention behaviors are grounded in several sociological models and theories, including the Health Belief Model, the Theory of Planned Behavior, and Social Cognitive Theory. The Health Belief Model posits that the likelihood of an individual making a

desired health decision or pursuing a “healthy” behavior is largely based on their “perceptions of disease severity and personal susceptibility to the disease combined with perceived benefits and barriers to that behavior” (Etheridge et al., 2023). In this model, individuals who perceive themselves to be at a high enough risk of a negative health outcome, severe enough to meet their personal standard of unacceptable risk, will pursue behaviors to avoid that outcome unless prevented by barriers. These barriers can take many forms and are often given significance through perception by the individual (Rosenstock et al., 1988). Social Cognitive Theory, also known as Social Learning Theory, builds on this model to include a focus on the cultural conditions that create expectations in individuals, including the expectations of efficacy or lack of efficacy of actions that may impact adoption of a target behavior (Rosenstock et al., 1988). The Theory of Planned Behavior categorizes beliefs or perceptions that impact action into three types: “behavioral beliefs, which translate into attitudes toward the behavior; normative beliefs, which relate to perceived attitudes of peers and respected figures toward the behavior; and control beliefs, or perceived ability to perform the behavior” (Etheridge et al., 2023). This theory translates the cultural context which underlays Social Cognitive Theory into its impacts on perceived peer support of an action and expands the theory to include an individual’s belief in their own ability to perform an action, separate from their own perceptions of the efficacy of the action. In summary, to adopt a desired health behavior, such as accepting a vaccine or allowing wildlife in one’s community to be vaccinated to prevent zoonotic spillover, individuals and communities must believe that this action will effectively address a reasonable threat to their own or their community’s well-being, be acceptable to the other members of their community, and carry a lower risk than the outcome to be avoided.

Quantifying barriers to acceptance or adoption of a behavior in the above theories can prove challenging. Vaccine hesitancy, which is defined as "refusal, delay or acceptance with doubt about vaccine usefulness," (Verger & Dubé, 2020) and can also be seen as a "continuum between vaccine acceptance and refusal" (Cooper et al., 2018). Although vaccine hesitancy or refusal is often perceived as being caused by a lack of knowledge about vaccines or disease, it is more often tied to concepts of trust or distrust (Goldenberg, 2016). This trust or lack of trust can be broken up into trust in the quality of the vaccine itself, trust in the healthcare provider administering the vaccines, and trust in the political and healthcare systems underlying the implementation of the vaccine (Larson et al., 2018). Many factors influence individual's and communities' level of trust in vaccines, including historical trust/mistrust between groups, the context of the target vaccine's development, and the role of social capital. Communities and individuals with high levels of social capital, visualized as highly connected social networks and high levels of generalized trust (separate from trust in specific individuals or institutions), can more easily disseminate health information and trust recommendations from individuals within those social networks (Larson et al., 2018). Unfortunately, the majority of vaccine hesitancy research has focused on wealthy, Western nations, leaving gaps in understanding of the role of various factors on trust in vaccines in an African context (Cooper et al., 2018; Larson et al., 2018). One study conducted in border communities in the Kambia District of Sierra Leone to assess knowledge and trust in human vaccines found that individual's perceptions of vaccines were shaped by trust or lack of trust shaped by previous experiences with the healthcare system, specific characteristics of the community itself and power dynamics within the community, and contextual knowledge of vaccines (Enria et al., 2021). Enria et al., highlighted the role of vaccine "rumors" and anxieties as expressions of broader mistrust in government and healthcare systems

caused, in certain marginalized communities within Sierra Leone, by a lack of social integration and connection with healthcare workers. Within Sierra Leone, existing research has highlighted the high levels of trust still placed on traditional authority through chiefdom (Sawyer, 2008) and the high levels of trust given to healthcare workers who are well-integrated into the communities they work in (Enria et al., 2021).

In addition to research gaps identified above, there are no existing published studies of social considerations of self-disseminating vaccines in a community context. Based on the lack of existing research and the continuing development of new vaccine technologies to address zoonotic diseases in human and wildlife populations, this study was developed with the objectives of exploring knowledge, attitudes, practices, and perceptions related to viral zoonotic diseases, human vaccines, and domestic animal and wildlife vaccines (including traditional and transmissible vaccine approaches) among key stakeholders in Sierra Leone. Our goal was to explore social and ethical implications of new vaccine technologies to better inform strategies for risk communication and community engagement, and to provide recommendations for initiatives seeking to introduce innovative and experimental technologies with lifesaving potential.

METHODS

Integrated Stakeholder and Bioethics Collaboration for Study Design. The research presented here was the result of five years of robust collaboration between local and national stakeholders, bioethicists, and researchers in the biological sciences as part of the Preventing Emerging Pathogenic Threats (PREEMPT) project. The PREEMPT project worked closely with the Ethical, Legal, and Social Implications (ELSI) expert panel of the Defense Advanced Research

Projects Agency (DARPA), who funded the project, beginning with the project kickoff meeting in November 2018. ELSI meetings were held throughout the life of the project and panel recommendations were instrumental in informing regulatory and legal strategies for the transmissible vaccine technology, as well as stakeholder engagement activities from international to local community levels. ELSI recommendations enabled the project to build in new tasks to the statement of work focused on risk communication and community engagement, workshops, and social science studies exploring local knowledge and perceptions of vaccine technologies in Sierra Leone.

At the project kick off, a series of district level community gatherings were held with key representatives and stakeholders from all communities invited to share an overview of the project plans and potential activities. These meetings included not only the field surveillance activities, but also detailed discussions on the potential development during the project of self-disseminating vaccines for rodents to prevent Lassa fever transmission. Project staff clearly indicated that these vaccines, if developed, would not be utilized in Sierra Leone or any other endemic area during the duration of this project, and would only be tested in laboratories in the United States or Europe as proof-of-concept prototypes. Team activities in Sierra Leone were limited to rodent surveillance, community engagement and surveys, and laboratory testing of field collected rodent specimens. Sierra Leone national independent press representatives were invited to these kick-off meetings, and the project Principal Investigator and government representatives gave interviews. Later, during each rodent collection and sampling trip, as part of ongoing community engagement during the life of the project, each sampling event was begun with a meeting with local community leaders and community members to review project goals and work, and to answer any community member questions prior to initiating any team activities

in the community. Typically, community appointed liaison officers and key representatives of the district government (medical and veterinary officers) were present and participated as part of the sampling teams.

All field-based studies were conducted in collaboration with and approvals from the Sierra Leone Ministry of Health and Sanitation and Ministry of Agriculture and Forestry. Initial engagement with national level ministry officials was complemented by robust district level sensitization meetings with District Medical and Veterinary Officers. Working directly with these government representatives, key communities and sites across Sierra Leone were engaged by our Sierra Leone team based at the University of Makeni, and community meetings and discussions were held with local citizens and community stakeholders to inform them of the planned activities in Sierra Leone which included rodent trapping, site surveys, and rodent sampling. At any time, a community could decide to not participate in the sampling activities. After the initial rounds of dialogue and discussion with community, sub-national, and national representatives, an agreed upon approach was developed that enabled safe and humane rodent sampling and consistent engagement with local community members during the life of the project.

Finally, in close collaboration with DARPA, the ELSI panel, and a broad array of international and Sierra Leone-based stakeholders, the PREEMPT team explored theoretical pathways for transitioning the transmissible vaccine technology to future small-scale controlled field trials, which would require considerable regulatory, legal, and social foundations to inform experimental design, safety, and community outreach and engagement. While the initial proof-of-concept experiments demonstrated the potential of a transmissible vaccine for zoonotic virus

control in animals, deploying such a technology outside of laboratory settings should only be done after careful examination and in close consultation with intended beneficiaries and local and international regulatory authorities.

To further this work, a stakeholder workshop "From Research to the Real World: A Workshop to Explore Applications for Transmissible Vaccines" was held with international and Sierra Leonean stakeholders on May 12, 2021. The goal of the workshop was to build consensus towards a declaration of support for the concept of a transmissible vaccine for Lassa and Ebola viruses, with the expected outcome outlining expert views on the barriers, opportunities, and pathways towards regulatory, ethical, and social acceptance of a transmissible vaccine. Participants included representatives of DARPA and DARPA's ELSI panel, an expert on ethics from the World Health Organization (WHO), members of the Sierra Leonean government (Ministry of Health and Sanitation and Ministry of Agriculture and Forestry), conservation groups (World Wildlife Foundation), global health and vaccine experts (Coalition for Epidemic Preparedness Innovations – CEPI) , US government agencies with regulatory expertise in animal vaccine development (U.S. Department of Agriculture – USDA), and the PREEMPT consortium. During the workshop, the concept of transmissible vaccines along with associated ecological, biological, ethical, social, and regulatory challenges and opportunities were discussed, enabling the development of a blueprint for future research and outreach (e.g., ecological studies, anthropological studies, regulatory options), along with potential steps to ensure safety and transparency of any further investigations that were beyond the scope of the PREEMPT project. Building on feedback from this stakeholder workshop and in close coordination with the DARPA ELSI panel, a study was designed to explore knowledge, attitudes, practices, and perceptions of vaccines and vaccine for animals (including new technologies such as

transmissible vaccines) with the end goal of informing and guiding strategies for effective vaccine interventions.

Study Area and Population. In September and October 2021, 203 individual survey interviews and 20 focus group discussions were conducted with key stakeholders in 22 communities. Demographically, survey respondents were generally representative of their communities, although women were slightly underrepresented. Participating communities were located in 8 of Sierra Leone's 16 districts and were selected through previous participation in the PREEMPT project's rodent trapping and viral surveillance. (See Figure 1 for geographic distribution of survey participants and focus groups.)

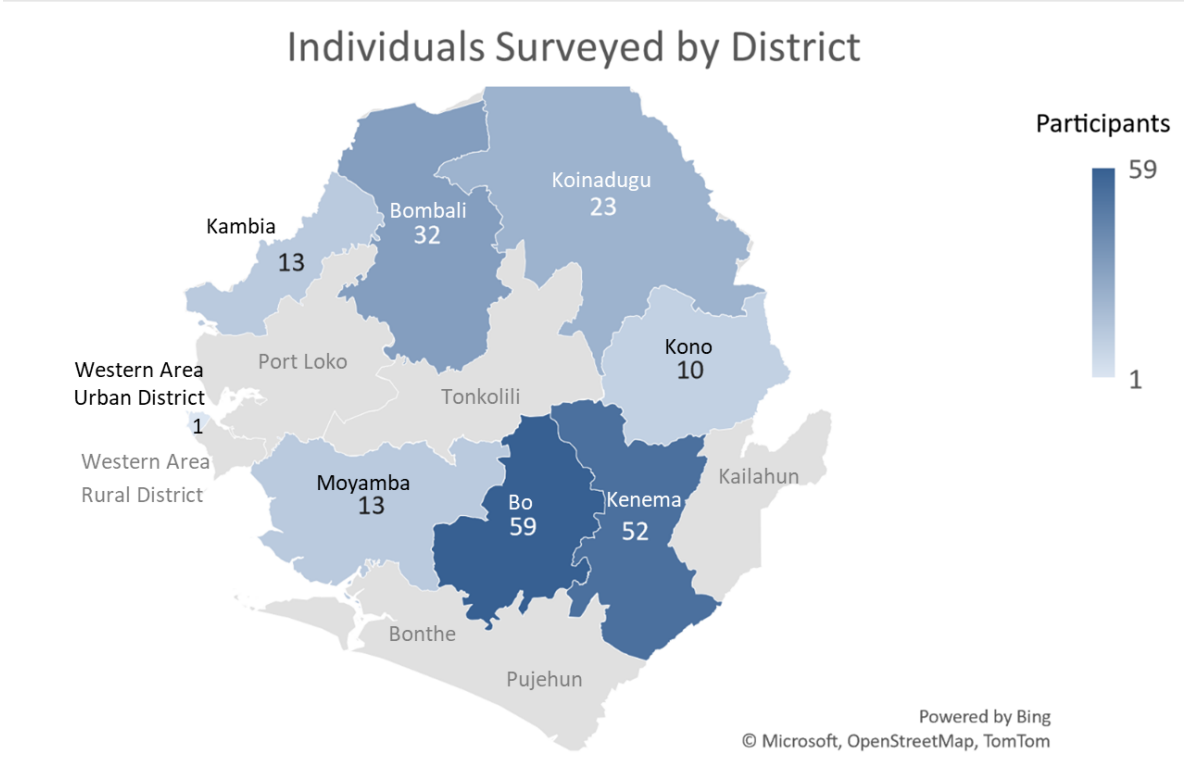

Figure 1: Geographic Distribution of Survey and Focus Group Discussion Participants by District

Survey Interviews. Survey participants were interviewed at their homes or places of work using a standardized 55-question questionnaire administered by a trained interviewer in the local communal language Krio. The questionnaire included questions about previous vaccination; awareness of diseases and vaccinations available; and perceived risk of Lassa fever, COVID-19, and Ebola virus disease following a Knowledge, Attitudes, and Perceptions (KAP) survey format (Kaliyaperumal, 2004). Additionally, respondents were asked about their willingness for self, family members, domestic animals, and nearby wild animals to receive vaccines and sentiments about a theoretical transmissible rodent vaccine to prevent Lassa fever. The survey responses were translated into English by the interviewers before being digitally input using the Kobo platform for tablet.

Focus Group Discussions. Sierra Leonean PREEMPT project members facilitated discussions with various stakeholder groups on knowledge, attitudes, and perceptions of viral disease (especially Lassa fever) and vaccination. Focus group discussions were conducted with those in positions of community influence, such as chiefs and local government officials; those at higher risk of zoonotic disease exposure due to their occupation, such as taxi drivers or farmers; or those likely to be underrepresented in the general survey, such as youth and women. These discussions were anchored around discussing barriers to acceptance of preventive healthcare within the community context as well as community understanding and perception of transmissible vaccines. The discussions were conducted in Krio and audio recorded, then later transcribed and translated into English.

Statistical Analysis. Survey data were analyzed using the Real Statistics Resource Pack for Microsoft Excel (Release 8.7). Bivariate analyses using the Pearson's chi-square and Fischer's exact tests for independence were used to test for significant correlations between categorical

survey responses, with a P-value of <0.05 considered significant (McHugh, 2012). The Cramer's V test was performed on results found to be significant to test the strength of correlation, with a Cramer's V of less than 0.10 considered weakly associated or not associated, between 0.10 and 0.15 considered moderately associated, between 0.15 and 0.25 considered strongly associated, and any Cramer's V value above 0.25 considered very strongly associated (Akoglu, 2018). Focus group discussion transcripts were analyzed using QSR International's NVivo Software (Release 1.7.1). Thematic analysis frameworks were applied to focus group discussion transcripts and responses to open-ended survey questions through iterative coding (Castleberry & Nolen, 2018). At each step of analysis, research team members from Sierra Leone were consulted to provide cultural context and additional considerations and direction for continuing analysis.

RESULTS

Introduction and Overview of Results. The results of the surveys and focus groups, generally, show high levels of trust in human healthcare systems and high support for innovative disease prevention strategies, but low levels of knowledge related to disease and vaccine mechanisms. The large majority of respondents replied "yes" when asked if they knew what Lassa fever, COVID-19, and Ebola virus disease are, but few named specific symptoms or other details when asked what they know about these diseases. These diseases were generally perceived as low risk by respondents, although this did not translate to higher-than-average hesitancy towards human or animal vaccines. Survey and focus group participants were overwhelmingly accepting of human and animal vaccines to prevent viral zoonotic diseases, including a theoretical self-disseminating animal vaccine. The surveys and focus group discussions revealed relevant context

to these attitudes, including key trusted sources of information about vaccines and culturally relevant concerns.

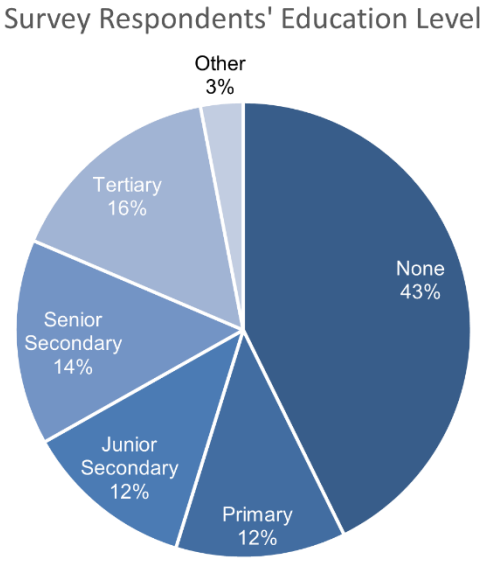

Figure 2: Survey Respondents by Reported Education Level

Demographics. Men represented 69% of survey respondents, although this varied by region, with Kenema and Moyamba districts having the most equitable gender ratios of respondents. The majority of respondents lived in rural communities (88%) and were between the ages of 25 and 55 (65%). Respondents' ethnicities varied by district,[1] with Mende, Temne, and Limba identities being most common. About half of all respondents reported working in agriculture as their primary occupation, with commerce, government employment, healthcare, education, and trade being other significant professional fields represented; 58% of respondents reported multiple occupations. While some respondents were highly educated, 109 respondents (54%) reported having received only a primary education or less. (Figure 2)

Among survey respondents, 66% identified as Muslim and 34% identified as Christian. The majority of respondents,

Reported Survey Respondent Participation in Community Groups	
Community Development Group	10
Finance or Savings Group	9
Elders' Group	8
Married People Group	3
Men's Group	7
Labor Union/Guild	25
Religious Group	28
Social/Recreational Group	11
Sports Group	9
Women's Group	12
Youth Group	27
None	42
Unknown	9
No Response	3

Table 1: Reported Participation in Different Types of Community Groups

[1] Association between self-reported ethnic group and region: $p<0.0001$, Cramer's $V=0.64$.

158 out of 203, reported participating in a community group, often religious, occupational, or related to another shared identity. (Table 1)

Viral Disease Knowledge and Perceptions. Although 199 respondents out of 203 replied "yes" when asked if people should worry about getting sick from an animal virus, respondents rarely cited animals when asked how illnesses are transmitted and were unlikely to bring up the virus when asked what they knew about specific zoonotic diseases. (See Appendix 2 for complete responses to survey questions.) Focus group discussion participants were able to have more expansive discussions related to their knowledge of disease transmission. Although poor sanitation and hygiene were the most popularly named sources of disease in both the survey and focus group discussions, focus group participants talked more in depth about concerns about zoonotic sources of disease. Many respondents specifically mentioned rodents causing disease, with a number stating they had been told about the dangers of diseases transmitted by rodents by PREEMPT staff: "They said Lassa fever is a sickness. It comes from rats that have long mouths. We have avoided it, and it is also not coming near us anymore. Since you gave us the advice the last time, it is not coming close to our houses." Focus group participants also named other animals, including monkeys, bats, and domestic animals, as possible sources of disease transmission. (See Appendix 1 for complete focus group discussion response coding).

Although 94% of respondents reported knowing what Lassa fever is when asked in a yes/no format, 41% didn't respond when asked what they knew about the disease and 11% responded they didn't know anything about Lassa fever. Even among respondents who had some knowledge of Lassa fever, responses were generally brief and non-specific; 20% simply described Lassa fever as "dangerous", 17% were able to list symptoms, and 15% knew the disease was caused by contact with rodents. Results for COVID-19 and Ebola virus disease were

similar to Lassa fever; 97% of questionnaire respondents reported knowing what COVID-19 and Ebola virus disease are. During interviews, 37% and 41% of respondents declined to respond when asked what they know about COVID-19 and Ebola virus disease (respectively), and 12% and 9% responded that they did not know anything about COVID-19 and Ebola virus disease. For knowledge of COVID-19, the most common response was that it is a "dangerous" or "deadly" disease (25% of respondents), with smaller numbers of respondents describing symptoms or the mode of transmission and precautions to prevent COVID, such as handwashing or mask wearing. Similarly, 28% of respondents simply described Ebola virus disease as dangerous or deadly, 14% named symptoms of Ebola virus disease, and 6% described the means of transmission in general terms.

Despite their awareness of zoonotic diseases, respondents generally perceived these diseases to be a low risk to themselves and their families. Survey takers asked respondents to independently rate Lassa fever, COVID-19, and Ebola virus disease's risk to themselves and their families on a three-point scale ("Is the risk low, high, or in-between?") and a five-point scale, with one being no risk and 5 being a very high risk. When asked to rate Lassa fever on a scale of one to five, 63% of respondents rated the disease as no risk or low risk. Similarly, 64% of respondents rated COVID-19 as low or no risk and 71% rated Ebola virus disease as low or no risk. There was no significant correlation between an individual's perception of how risky a disease was and whether they reported being aware of the disease,[2] nor were there any correlations between

[2] Lack of correlation between awareness of Lassa fever and perceived risk of Lassa fever: p=0.9; lack of correlation between awareness of COVID-19 and perceived risk of COVID-19: p=0.06; lack of correlation between awareness of Ebola virus disease and perceived risk of Ebola virus disease: p=0.66.

disease risk perception and participant gender,[3] age,[4] or religion.[5] However, some other demographic correlations emerged for respondents' perceptions of disease risk. People with no formal education, farmers, tradespeople, and government employees were more likely to rate Lassa fever as low risk while healthcare workers were more likely to rate Lassa fever as higher risk.[6] People living in rural communities, with no formal education, with primary education only, who participate in exclusively social groups, and who reported no community group participation were more likely to say COVID-19 is low risk. People with tertiary education and people who participated in community groups focused on occupational organizing or community development were more likely to rate COVID-19 as higher risk. Individuals in these development or occupational groups were also more likely to rate Ebola virus disease as a higher risk while those in exclusively social groups or not in a community group were more likely to rate the disease as low or no risk.

[3] Lack of correlation between perceived risk of Lassa fever and gender: p=0.19, lack of correlation between perceived risk of COVID-19 and gender: p=0.15, lack of correlation between perceived risk of Ebola virus disease and gender: p=0.16.
[4] Lack of correlation between perceived risk of Lassa fever and age: p=0.85, lack of correlation between perceived risk of COVID-19 and age: p=0.28, lack of correlation between perceived risk of Ebola virus disease and age: p=0.11.
[5] Lack of correlation between perceived risk of Lassa fever and religion: p=0.22, lack of correlation between perceived risk of COVID-19 and religion: p=0.16, lack of correlation between perceived risk of Ebola virus disease and religion: p=0.39.
[6] Correlation between education level and perceived risk of Lassa fever: p=0.045, Cramer's V=0.20; correlation between occupation and perceived risk of Lassa fever: p=0.044, Cramer's V=0.25

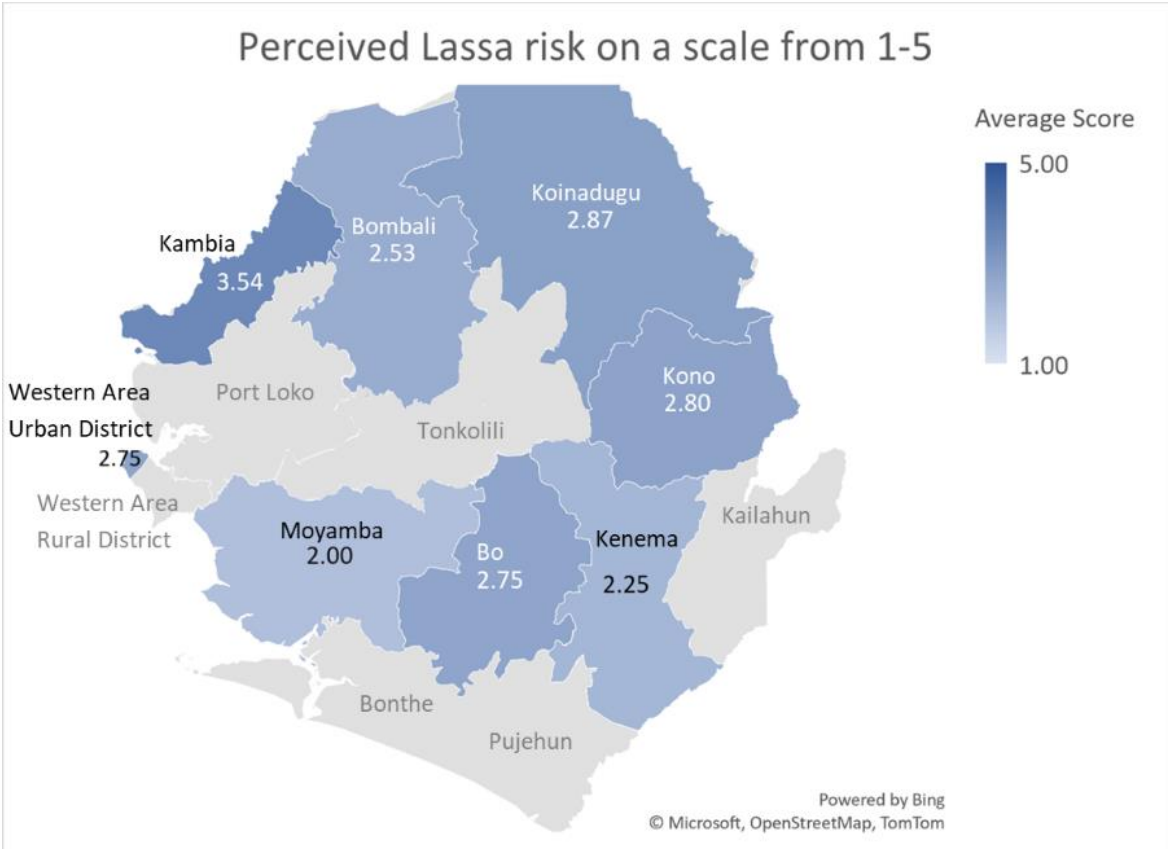

Figure 3: District-wide Average Perceived Risk of Lassa Fever

Across all three diseases, there was a significant correlation[7] between the geographic location of respondents and how risky they perceived these diseases to be. (See Figure 3: Perceived Lassa Risk on a Scale from 1-5) Respondents in the Kambia and Koinadugu districts perceived Lassa fever, COVID-19, and Ebola virus disease to be higher risk than respondents in other districts, and respondents in the Moyamba district had the lowest perceived risk of these diseases. Perceptions of risk were associated with not only respondents' district, but also their specific

[7] Correlation between perceived risk of Lassa fever and geographic region: $p<0.0001$, Cramer's $V=0.33$; correlation between perceived risk of COVID-19 and geographic region: $p<0.0001$, Cramer's $V=0.34$; correlation between perceived risk of Ebola virus disease and geographic region: $p=0.005$, Cramer's $V=0.28$.

village or town of residence,[8] with one community (Bafodia) having the highest perceived risk of all three diseases. While respondents' average risk ratings for Lassa fever, COVID-19, and Ebola virus disease on a scale of one to five were 2.6, 2.6, and 2.4 respectively, respondents in Bafodia average risk ratings were 3.6, 3.5, and 3.7, respectively. The interpretation of the geographic trends is uncertain, although respondents in the north of Sierra Leone generally perceived the diseases as riskier than those in the south.

Additionally, although asked independently, there were significant correlations between individual respondents' ratings of each disease's risk.[9] On the three-point scale, 102 respondents rated all three diseases as low risk, 7 rated all three diseases as moderate risk, and 18 rated all three diseases as high risk for a total of 63% of respondents who rated all three diseases as the same level of risk. Even respondents who did not rate all three diseases as the same level of risk tended to rate two or more diseases at the same level and very few had dramatically different perceptions of risk for different diseases. For example, no respondents rated Lassa fever as no risk and COVID-19 as high or very high risk. These results suggest that respondents' expressed perceptions of disease risk are tied more closely to external factors than to experiences with or knowledge of specific diseases.

Knowledge, Attitudes, Perceptions, and Practices of Human Vaccination. Respondents were generally aware of the function of vaccines (to prevent illness) but lacked understanding of specific mechanisms. This lack of specific knowledge did not limit vaccine acceptance, with

[8] Correlation between village and perceived risk of Lassa fever: $p<0.0001$, Cramer's $V=0.42$; correlation between village and perceived risk of COVID-19: $p<0.0001$, Cramer's $V=0.51$; correlation between village and perceived risk of Ebola virus disease: $p<0.0001$, Cramer's $V=0.51$.

[9] Correlation between perceived risk of Lassa fever and perceived risk of COVID-19: $p<0.0001$, Cramer's $V=0.44$; correlation between perceived risk of Lassa fever and perceived risk of Ebola virus disease: $p<0.0001$, Cramer's $V=0.42$; correlation between perceived risk of COVID-19 and perceived risk of Ebola virus disease: $p<0.0001$, Cramer's $V=0.56$.

over 90% of respondents saying they would accept a Lassa fever, COVID-19, and Ebola vaccine if offered. While reported vaccine acceptance was high, several causes for vaccine hesitancy and barriers to human vaccination emerged through the survey and focus groups.

When asked what a vaccine is, about half of respondents (n=99) replied simply that it is "a medicine"; 28% did not respond; and 12% said that vaccines are something to prevent sickness. When asked why humans get vaccines, 66% of respondents said they are for "protection" and "prevention of sickness" and 24% declined to answer. This lack of specific descriptions did not translate to lowered perceptions or reported utilization of vaccines among respondents. When asked "Can you tell me how you feel about vaccines?", 144 survey participants or 71% said they feel positively. Only 8 participants reported having neutral or mixed feelings about vaccines and only 1 participant reported strictly negative feelings about vaccines, although 25% of respondents declined to answer. An overwhelming majority, 93% of respondents, reported having previously received at least one vaccine and 80% said they would trust nurses and healthcare workers in their community to administer a vaccine. Healthcare professionals were also the most reported source of information about vaccines, with 63% of respondents reporting receiving information from them. Radio was the second most popular source of information about vaccines, with 45% of respondents. Smaller proportions of respondents (<5% each) reported receiving information about vaccines from other community members, non-healthcare in-person outreach, social media, and other sources; 14% of respondents did not answer. Although there was no correlation between sources of information about vaccines and past vaccination history,[10] people who reported primarily receiving information about vaccines from

[10] Lack of correlation between reported sources of information about vaccines and past vaccination history: p=0.99.

healthcare workers or the radio were more likely be willing to receive hypothetical future vaccines for Lassa fever[11] and Ebola virus disease.[12]

When asked if they would accept a hypothetical human Lassa virus vaccine if offered, 94% of respondents said "yes" and 97% said they would allow their child or family member to take it. When asked why, 104 respondents said it was "to protect themselves and their community" from disease. The few who responded that they would not accept a hypothetical Lassa virus vaccine said their decision was based on perceived low chances of catching Lassa fever and low chances of the disease being serious if they were to catch it. Similarly, when asked why they would allow a family member to take the vaccine, those who accepted it cited protection from disease and the few who said they would not accept the vaccine stated that "Lassa fever is not a serious issue near" them and that their family members would have to make the decision for themselves.

When asked if they had accepted or would accept a COVID-19 vaccine if offered, 97% of respondents said "yes" and 95% said they would have their child or family member take it. Similar to Lassa fever, the large majority of respondents said they would choose to take a COVID-19 vaccine and support a family member taking a COVID-19 vaccine to "prevent the disease" and "support good health". Several respondents reported having already received at least one dose of a COVID-19 vaccine. While some of those who said they would not accept a COVID vaccine cited a low risk of the disease, more were concerned with side effects or said they themselves are not healthy enough to risk taking the vaccine. Even among those who initially said they would take a COVID-19 vaccine if offered, some later clarified that they

[11] Correlation between source of information and willingness to receive human Lassa fever vaccine: p=0.01, Cramer's V=0.20.
[12] Correlation between source of information and willingness to receive human Ebola virus disease vaccine: p=0.04, Cramer's V=0.18.

would only take the vaccine if others, especially healthcare workers, take the vaccine first. Respondents had a variety of questions about COVID-19 vaccines specifically, summarized in Table 2.

Do you have any questions about the COVID vaccine?	
Is it effective? How does it work?	17
I have questions about the development/origin/production of the vaccine.	9
Who should get vaccinated?	5
Does it cause side effects?	13
How/when/where will it be distributed?	14
I have questions about COVID generally.	5
Why do we get vaccines?	6
No	143

Table 2: Survey Respondent Questions about COVID-19 Vaccines

Ebola virus disease vaccine had similar but slightly lower acceptance compared to the other diseases presented in the survey; 91% of respondents said they would accept an Ebola virus disease vaccine if offered and 92% of respondents said they would allow their child or family member to take an Ebola virus disease vaccine. Although the acceptance rate of an Ebola virus disease vaccine was lower, respondents reported similar reasoning for their choice as the other two diseases, i.e., that they would take the vaccine to protect themselves and their families. Those who said they would not take an Ebola virus disease vaccine notably did not cite concerns of side effects but did say they would not take it since "Ebola is no longer in our country."

All these results were consistent across geographic regions, varying education levels, ethnic groups, religious identities, and other demographic characteristics. The only exception to this came in acceptance of the Ebola vaccine and occupation; government and healthcare employees more likely to say they would allow family members to receive an Ebola vaccine, tradespeople

were more likely to say no.[13] There was also no correlation between stated awareness or perceived risk of a disease and willingness to receive a vaccine.[14]

Religious Perspectives on Vaccine Acceptance. The focus group results supported the conclusions from the survey and provided additional insight into issues such as religious causes of vaccine hesitancy, impact of project staff on communities, and concerns about side effects of vaccination. Although there were no significant correlations between reported religious identity and vaccine hesitancy or disease perception in the survey, several focus group discussions offered perspective on how religious belief influences health decision making among respondents and their peers. As one focus group participant said:

> Some sicknesses are spiritual, even if you take them to the hospital, they will not get better. So, you will have to take them to church and when you take them to church, they will be healed… Some sicknesses you can spend millions on and not get healed, but with God, he heals all sicknesses.

Focus group participants tended to be more comfortable describing why others in their communities might not take a vaccine or accept medical care, for example "We have the other faith-based groups who don't believe in the vaccine, they believe in their faith rather than the vaccines." Another said "Some believe that the blood of Jesus is sufficient for them, and they don't need the hospital." Ultimately, the participants seemed to collectively describe either neutral or positive influence from their religious beliefs and spiritual leaders on vaccine acceptance. As one said:

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[13] Correlation between occupation and willingness for family members to take Ebola virus disease vaccine: p=0.02, Cramer's V=0.31.

[14] Lack of correlation between awareness of Lassa fever and willingness to accept human Lassa fever vaccine: p=0.48; lack of correlation between awareness of COVID-19 and willingness to accept human COVID-19 vaccine: p=0.54; lack of correlation between awareness of Ebola virus disease and willingness to accept human Ebola virus disease vaccine: p=0.48.

> You cannot say if your child is sick, you will not take them to the hospital. We all believe in God, but we should take medicines when we are sick. This is what they tell us also at the clinic. In case this person died and you did not take them to the hospital, it is entirely your fault.

Others described their faith leaders, both Christian and Muslim, telling their congregations to get vaccinated both in informal settings and during religious gatherings.

Focus Groups and Concerns about Vaccine Side Effects. Although religious concerns were cited as a reason for potential vaccine skepticism, participants seemed more concerned about the potential effect of vaccination on human and animal populations. Participants expressed generally wanting to be aware of any potential side effects to inform their decision to take or not take a human vaccine or decide if a vaccine was worth it for their animals. Others shared their experiences experiencing side effects from vaccination "When I took my child for vaccination, the whole of the night we could not sleep because she was crying, so that is why I worry when I must go and take another vaccine." These experiences often coincided with social interactions encouraging or discouraging vaccination:

> But when people started saying that they get sick from taking the vaccine I did not go. So, the other day, I went to the doctor and ask him if I should take the vaccine and he encouraged me to take it because he had already taken it. So, I went and took it, the day I took it I slept long and well.

Death was the most frequently cited side effect for participants concerned about side effects, but seeing trusted community leaders receive vaccines and not suffer side effects was offered as a means of boosting confidence in vaccination:

> [The Village Development Committee Chairman] said that he should be an example to people, so he took [the vaccine] and the nurse also took it, and they did not die. So now I have the faith to get my children vaccinated.

Media, the COVID-19 Pandemic, and Mis/Disinformation. Multiple focus groups highlighted the role of the COVID-19 pandemic in increasing the spread of misinformation, especially through social media and messaging apps. As one participant told the group:

> I have seen on WhatsApp… a video of someone who was injected on one side, and he put a light bulb on the spot and the bulb lit up; but when he put it on the other hand that was not injected, the bulb did not light. So, he was showing that this vaccine is not good, and when we saw that we are afraid.

Another said:

> Those who are out of Sierra Leone and have family here, call to tell their families not to take the vaccine because they say in 3-6 months they will die. Or within 2 years they will die. This we have also heard from social media.

This misinformation was often tied specifically to the idea that COVID-19 vaccines are newly developed technology;

> One of the shortcomings of the COVID vaccine was it that was a trial and people did not know how it will react. That brought a lot of fear in people to take the vaccine.

One participant summed up fears and suspicions around COVID-19 vaccines succinctly:

> Some people refused the vaccine because of political influence and because of side effects ... These rumors will go around that if you take a certain vaccine, you will get side effects, and this prevents many people from taking the vaccine.

Knowledge, Attitudes, Perceptions, and Practices of Animal Vaccination. Participants were generally less aware of animal vaccines than human vaccines, although 85% of respondents were aware that vaccines for animals exist. Only 37% of respondents reported having previously vaccinated their domestic animals or livestock, although the most common reason reported for not vaccinating was not owning animals (35% of total respondents). About half of respondents who owned animals (57%) said they had previously vaccinated their animals, with most saying they did so to prevent illness in their herd or flock and stop the spread of diseases. Those who did own animals but did not vaccinate them most commonly reported not vaccinating because they didn't know they could or should vaccinate their animals or veterinary care being financially or geographically inaccessible to them. These results were consistent across demographic traits except religion and geographic distribution; Christians were more likely to report having previously vaccinated their animals.[15] Several districts and communities had significantly higher percentages of respondents who had previously vaccinated their animals,[16] but no specific geographic pattern (North vs. South, etc.) could be determined. There was no direct correlation between reported previous domestic animal vaccination and reported acceptance of wildlife vaccines[17].

When asked if wildlife should receive vaccines, 89% of respondents said "yes," with a majority citing the potential for wildlife to carry diseases which can affect humans and close interactions with humans as reasons for vaccinating. Those who believed wildlife should not be vaccinated reported not knowing or wanting to explain why they held that belief or felt the lack of

[15] Correlation between reported previous vaccination of livestock and religion: p=0.02, Cramer's V=0.17.
[16] Correlation between reported previous vaccination of livestock and district: p=0.002, Cramer's V=0.34; correlation between reported previous vaccination of livestock and village: p=0.005, Cramer's V=0.44.
[17] Lack of correlation between reported previous vaccination of livestock and acceptance of wildlife vaccines: p=0.94

interactions between wildlife and humans and infeasibility of wildlife vaccines negated the potential benefits.

When it came to willingness for wildlife in and near respondents' homes and fields, the results were overwhelmingly positive. Over 97% of respondents said they would accept rodents, bats, or other animals in their homes or fields receiving vaccines to prevent Lassa fever, COVID-19, and Ebola virus disease. These results were consistent across varying education levels, ethnic groups, religious identities, and other demographic characteristics with few exceptions. Women were slightly less likely to be willing to have animals in their homes receive a vaccine to prevent COVID-19 (although 94% of women respondents said they would be willing).[18] Older respondents (over 55) were more likely than others to be willing for bats in their homes to receive vaccines to prevent Ebola virus disease and younger adults (younger than 25) were less likely to be accepting.[19]

Knowledge, Attitudes, and Perceptions of Transmissible Vaccines. Participant acceptance of the transmissible vaccine concept was similarly positive but non-specific. An overwhelming majority of participants, 201 out of 203, said they would allow rats to receive a spreadable vaccine in their community if it stopped the spread of disease. When asked why they would allow this, 36% of respondents declined to answer, 52% said they would allow it to prevent or "stop the spread" of disease, 4% cited the proximity of animals to humans, and 2% specifically cited a trust in researchers and vaccine developers. In the focus group discussions, this trust in researchers emerged as a significant theme relevant to community approval of the transmissible

[18] Correlation between gender and willingness for animals in home to receive a vaccine against COVID-19: p=0.02, Cramer's V=0.17.
[19] Correlation between age and willingness for bats in home to receive a vaccine against Ebola virus disease: p=0.02, Cramer's V=0.22.

vaccine technology. As one group discussion participant stated, “Your idea is good because this is your job.” Across focus groups, participants expressed high levels of trust in government and healthcare institutions and project researchers, with an implicit or stated expression of responsibility assumed by experts. Focus group discussions gave participants space to ask questions about the transmissible vaccine concept and express more nuanced opinions and concerns. One supporter of the concept said:

> I want the animals to the vaccinated with the vaccine that when they give one animal it will share it with the other animals by touch. Because they will not be able to vaccinate all, this method will make them all get the vaccine.

In general, increased feasibility of vaccinating a significant rodent population was expressed as a perceived benefit of the transmissible vaccine over a conventional vaccine. Although most survey and focus group participants expressed no concerns about the transmissible vaccine, the most commonly raised concerns were vaccine efficacy (including how long the transmissible vaccine would take to eliminate the risk of virus transmission to humans), impact of the vaccine on the rodents as a human food source, and if there would be any potential negative effects on nearby humans.

Overall, the most common question to emerge from survey and focus group participants was “What’s next for this research?”. Participants showed high levels of investment in the research, asking questions like “If [the government] said they will come up with a vaccine to prevent diseases from animals, we are happy. But what I am asking is how long will this process take?”. The second most commonly asked question was, as mentioned above, “Can we eat the rodents after vaccination?”. As one respondent asked, “It is very important to vaccinate these animals, but my concern is: will these animals be edible?”. Participants also wanted to know if the

transmissible vaccine given to animals could have any effects on human populations (through other methods than consumption of rodents) and sought to understand the specific details of vaccine implementation as a means to assess risk. “There are rats all over, will the rats in the bush and our houses get the same vaccines?” one focus group participant asked. Another expressed: “I think if they are given the medicines this way [consuming bait], we should not be afraid to eat them. But if they are given injections, we will be afraid and think that it is poison.”

Survey and focus group responses made clear the perceived need for continued and expanded community engagement and education. “There are some villages that you will not be able to go to, but if you use local people, they can share this information.” One participant’s advice to researchers:

> If you think that you are bringing the vaccine next month, then this month the sensitization should have started, and it should be understandable. And when you come back with the vaccine you should use community people to educate the community about the safety of the vaccine.

DISCUSSION

Health Literacy, Knowledge, and Awareness. Study participants demonstrated generally high levels of awareness of zoonotic disease, lower levels of vaccine awareness, and low levels of specific knowledge of vaccines and zoonotic disease traits. The large majority of respondents said “yes” when asked if they knew what Lassa fever, COVID-19, and Ebola virus disease are; some variation of “it’s a dangerous disease” was the most common answer for all three diseases when respondents were asked what they knew. This lack of specific knowledge was also seen in the case of vaccines, which most respondents described as simply a medicine that can build good

health or protect against sickness. Many of the questions respondents asked when given space to ask researchers questions in general or specifically about COVID-19 vaccines support the finding of low health literacy, such as “How do vaccines work?”, “Why do we get vaccines?”, and “Who should be vaccinated?”. Although informative for the context of vaccine acceptance in target communities, these questions and lack of knowledge are not unique to the study area. A 2021 study in Oman about knowledge, attitudes, and perceptions of COVID-19 vaccines found that less than half of individuals surveyed knew that vaccines would be given in two doses (Al-Marshoudi et al., 2021). In a US study of university students related to Human Papillomavirus (HPV) vaccine, 89% of respondents reported having heard of HPV but the majority did not know that it can cause cancers (Kitur et al., 2022). A study of vaccine literacy in South Africa found limited vaccine literacy among respondents, especially women and non-white respondents (Engelbrecht et al., 2022). However, varying contexts also came with variances in whether low knowledge of diseases vaccines was correlated with increased vaccine hesitancy.

Vaccine Hesitancy. The results of this study support existing research on causes of vaccine hesitancy that indicate a lack of knowledge is not the primary reason for hesitancy or refusal (Cooper et al., 2018; Larson et al., 2018; Verger & Dubé, 2020). Although study participants did not demonstrate high specific knowledge about human or animal vaccines, they were willing to accept vaccines because of high trust in healthcare workers, the government, and the healthcare system generally. A basic awareness of disease and benefits of vaccination was often cited offhand by participants as a reason to get vaccinated, but especially when asked why they would trust new vaccine technologies, the approval of trusted, often local, authorities was far more significant than potential benefits. This manifested in two ways, the first being inherent trust of a technology introduced to community members by a trusted authority, exemplified by quotes such

as “your idea is good because it is your job” and the increased vaccine acceptance among those who reported primarily receiving health information from healthcare workers or radio shows. Secondly, almost all participants who reported some skepticism towards vaccines (either current or in the past) expressed that seeing an authority figure they trusted vouch for the vaccine and take it themselves had or would change their mind toward vaccine acceptance. While nurses and community health care workers were included as local authority figures, the actions and endorsements of other local leaders, such as chiefs, religious leaders, and leaders of Village Development Committees, were also referenced as significantly influential in healthcare decision making. In focus group discussions with local chiefs, they cited a generalized trust in government and researchers as informing their ability to trust and support new vaccine technologies. Healthcare workers and officials cited trust in government as influencing their support of vaccines, but also were much more interested in understanding the science behind vaccines and cited a trust in scientists and science generally as being influential. This fits with Larson’s theory of multi-layered trust being necessary for vaccine acceptance: trust in the healthcare provider administering vaccines, trust in the political and healthcare systems underlying the implementation of the vaccine, and trust in the quality of the vaccine itself (Larson et al., 2018).

Vaccine Acceptance and Perceived “Newness” of Technology. Participants across levels of power and influence were interested in and in some cases concerned by the process to develop and test new vaccines. Participant discussions of COVID-19 vaccines in particular illustrated the concern that can come with trial and implementation of new vaccine technology. Participants reported high levels of trust in healthcare providers and underlying systems, which led them to accept previous vaccinations, but reported increased hesitancy toward COVID-19 vaccines based

in the newness and origin of the vaccine itself. Interestingly, reported acceptance of vaccine technology in the survey was consistent across three very different types of vaccines. COVID-19 vaccines represent approved but new vaccine technology (mRNA vaccines); Ebola vaccines represent existing, traditional vaccine technology (recombinant vaccines that have been approved for use in humans and animals); and Lassa fever vaccines are yet to be approved for human or animal trials and in our study we presented a dramatically new technology (the self-disseminating vaccine concept). These differences may impact community perceptions and acceptance or hesitancy, and, perhaps more significantly, represent different regulatory frameworks. Both Ebola and COVID-19 vaccines encountered regulatory challenges to implementation and were both ground-breaking in the development of new vaccine use, (Abiri et al., 2022; Henao-Restrepo et al., 2016; Mahase, 2020) but public perceptions of both have been impacted by their implementation and regulation processes (Goldman et al., 2020; Mutombo et al., 2022). In the community context, experiences with different diseases may also impact acceptance of vaccines. The lack of current Ebola virus disease outbreaks was the most commonly given reason for not being willing to accept an Ebola virus disease vaccine. In the 2013-2016 Ebola virus disease epidemic, Sierra Leone suffered the most cases (both on an absolute scale and per capita) of any country affected (WHO Ebola Response Team, 2016). In a study conducted in 2016 in the immediate aftermath of the epidemic, researchers found that concerns about side effects and vaccine safety and efficacy were the most significant factors driving vaccine hesitancy (Huo et al., 2016b). As Ebola virus disease vaccines were developed and initially implemented during an ongoing epidemic, it's possible that attitudes toward COVID-19 and Lassa fever vaccination may shift to become more similar to attitudes toward Ebola virus disease vaccination if outbreaks decrease. This would likely look like a decrease in

feelings of urgency in getting vaccinated but decreased concerns about vaccine safety as new technologies become normalized.

The technological and bioethical context of this study's work were also complex and, in many ways, unprecedented (Henderson & Murphy, 2007; Lentzos et al., 2022). Transmissible vaccines to prevent Lassa fever represent not just a new vaccine, but a new category of vaccine that will likely encounter greater concerns related to the newness or trial aspect of the technology than previously introduced vaccines. Even a traditional human or animal Lassa virus vaccines may encounter hesitancy tied to its introduction, although the newness of the technology being limited only to the disease it addresses means it may be more readily accepted provided trust is well-established prior to implementation.

Trust, Power Hierarchy, and Outreach. In addition to accounting for biases, the results of this study must be viewed through the lenses of the cultural, technological, and bioethical frameworks which surround it (Rosenstock et al., 1988). Participating community members' knowledge, attitudes, perceptions, and practices related to zoonotic disease and human and animal vaccine are based in their own local and hyperlocal context. This includes the continuing legacy of colonialism and neocolonialism and their impacts on Sierra Leonean healthcare and education systems, (Fallah & Ali, 2022; Farber & Harris, 2022; Flint, 2020; Mutombo et al., 2022) previous disease outbreaks and the successes and failures of outbreak response, (Abiri et al., 2022; Dada et al., 2019; Henao-Restrepo et al., 2016; Huo et al., 2016a; Jalloh et al., 2018) locally relevant systems of power and information dissemination, (Enria et al., 2016, 2021; Sawyer, 2008) the rising impact of information technology and increasing globalization, (Mercedes et al., 2022) and many other cultural factors. Trust-building will be essential for the

acceptance of any new vaccine technology, (Larson et al., 2018) but must be locally relevant and driven by these factors.

The results of this study are in line with existing theories of behavior change and decision making, especially the Theory of Planned Behavior and Social Cognitive Theory (Etheridge et al., 2023). Through the survey and focus group discussion responses, we can see evidence of the cultural conditions that have influenced participant belief in the efficacy of vaccines as an intervention. These beliefs seem to be most influenced by normative beliefs (as presented in the Theory of Planned Behavior); participant support of vaccines was largely influenced by the perceived attitudes of their peers and respected authority figures in their lives (Etheridge et al., 2023). The decision-making factors described in the Health Belief Model are also present in the responses and reasoning of respondents. Those who expressed hesitancy towards vaccine often fit under the umbrella of perceived susceptibility presented in the model; they don't believe themselves or their loved ones are susceptible enough to zoonotic diseases to justify seeking vaccination. Ultimately, a clear understanding of perceived benefits and barriers to vaccination will be fundamental to designing impactful interventions.

Recommendations and Future Directions. The results of this study both directly and indirectly suggest future directions for related research. Community members directly recommended continued outreach and engagement for future vaccine development and implementation to be successful. Despite the high trust in healthcare professionals and researchers, community members emphasized that future outreach efforts should be conducted by members of local communities, not necessarily external experts. These suggestions that future outreach be led by "community people" exemplifies the complex hierarchy of trust that underlies this study's research communities (Enria et al., 2016; Larson et al., 2018). Researchers and healthcare

professionals are accepted as experts within their field, carrying a specific and limited section of biological expertise that is assumed to carry responsibilities with it. Researchers may be seen to know what is best for Lassa fever generally, but not necessarily understand what is best for a given community. From this perspective, it is the responsibility of scientific experts to interface with local experts such as village and paramount chiefs, local religious leaders, traditional healers, and leaders of local social groups. In the Sierra Leone context specifically, and likely generalizable broadly to many locations, the communities' perceived responsibility of researchers is to develop technologies or understandings of disease safely, understand the risks and benefits, and convey them to local experts, whose responsibility is to guide community members and make decisions based on hyperlocal context.

This research also opened several avenues of inquiry that deserve further investigation. The majority of participant responses to questions such as "What do you know about Lassa fever?" demonstrated low specific knowledge. Follow-up should be conducted to ascertain the actual level of knowledge and awareness through more specific questions to engage participants and gauge their knowledge of symptoms, disease transmission methods, and disease prevention. Additionally, the two survey questions related to livestock and other domestic animal vaccination provided interesting insights that lead to further questioning. Although the large majority of respondents approved of vaccinating animals, few actually vaccinate their own animals. Respondents who explained why they didn't vaccinate their animals cited geographic or financial inaccessibility or a lack of knowledge that domestic animals could or should be vaccinated; most respondents did not explain why they did or did not vaccinate their animals. More specific research is needed to identify knowledge, awareness, and perceptions of preventive veterinary care for livestock as well as barriers to accessing that care in West Africa.

The specific context in which this research was conducted also suggests the need for future research with broadened target communities. Since all the participants of this study came from communities who had previously interacted with research staff, additional research should expand the focus to communities not previously contacted by the research team. Many participants spoke positively of the impact of research project staff on their understanding of Lassa fever and other diseases and listed these staff as a significant source of information to prevent disease. Due to ongoing outreach in target communities, the level of disease awareness, knowledge, risk perception, and vaccine acceptance may be lower in Sierra Leonean communities not included in this research. Although survey participants were generally demographically representative of their communities, the inequitable distribution of respondent gender may have impacted survey results. Focus group discussions conducted exclusively with women offer some perspective to counter this impact, but the smaller number of women surveyed is a shortcoming of this study.

If a Lassa fever vaccine (either for humans or rodents) is to be implemented, there must be robust continued engagement with target communities to ensure concerns are addressed and certain issues are investigated to reach further clarity. If a rodent vaccine is developed (either traditional or self-disseminating approaches), care must be taken that it does not render rodents unsafe for human consumption. *Mastomys* spp. rodents are a nutritionally and culturally important food source in rural Sierra Leonean communities, (Bonwitt et al., 2016) and the edibility of vaccinated rodents was a key concern clearly expressed in this research. Understanding the cultural implications of different vaccine delivery methods will also be crucial, as some participants expressed greater hesitancy to vaccines delivered to rodents as injections than those delivered by baits. However, if baits are used, the vaccine must be rigorously tested to ensure it will not be

harmful to off-target species who may consume the bait (McClure et al., 2022). More specific follow-up is needed to determine if concerns around injected vaccines are held by a significant portion of the population and if they can be addressed.

Crucially, no formal regulatory framework currently exists to regulate the controlled field testing of a transmissible vaccine should a prototype emerge and be identified for evaluation. This is a critical lack of formal systems by which to evaluate and assess potential risks and benefits of this potential vaccine technology (Lentzos et al., 2022). Despite the acceptance of transmissible vaccines reported in this study, the cultural surroundings related to power and responsibility mean it is the responsibility of researchers to ensure they fully understand the risks and benefits of new vaccine technologies, cooperate with regulatory authorities and bioethicists to develop rigorous and well validated regulatory frameworks and approaches, to be held to locally and internationally approved high standards for development and use, and to fully and appropriately convey the risks, benefits, and regulations to local authorities and community members in a comprehensive engagement strategy that can overcome the significant cultural, educational, and power structure barriers identified. This study, from early engagement with stakeholders and bioethicists to ongoing community consent to incorporation of social science methods alongside biological sciences research, provides a model for potential research that could be done at a community level across West Africa to create stronger understandings of public health knowledge and create pathways to zoonotic disease prevention. Using this model to build robust continued engagement that prioritizes the voices of affected communities will help to ensure any traditional or new vaccine technologies can be implemented responsibly and that community trust in medical research is not abused.

CONCLUSION

The results of this study indicate strong potential community support for new and existing interventions to prevent transmission of zoonotic diseases, provided outreach is continued and expanded to continue to address concerns and reach communities not included in initial stages. Broadening the research to include perspectives not initially evaluated will be necessary to understand acceptability of new technologies to the communities they would impact and to build understanding of barriers to implementation of existing interventions. Robust national and international level regulatory frameworks for new vaccine technologies must be developed and adopted utilizing unbiased risk assessment tools and prioritizing the concerns and well-being of communities most vulnerable to zoonotic disease. This study's design provides an example of successful interdisciplinary collaboration to address social, ethical, and feasibility considerations of a solutions to a pressing public health issue. Future biomedical work should continue to include diverse stakeholders, from bioethicists to local governments to social scientists to intergovernmental organizations, in every stage of development, testing, and implementation of new technologies.

Continued community outreach and engagement with a focus on participatory methods which allow community-led decision-making processes will be essential for success of future work towards the development of vaccination programs for zoonotic disease reservoir hosts including both traditional and self-disseminating vaccine approaches. Leveraging community leadership and local expertise is an essential foundation for preventing zoonotic disease in humans and animals, whether with new or existing technologies. Community and individual trust in new and existing technologies and the teams developing and implementing them were more influential than knowledge of a disease, understanding of how vaccines work, or perceived risk of diseases.

The active, visible support of trusted local leaders was repeatedly reported to be the deciding factor for acceptance of interventions at the community level. High-level interdisciplinary collaboration will be essential to ensure ethical development of new interventions to prevent zoonotic disease, but local community members must lead the charge for successful implementation of any proposed solutions.

ACKNOWLEDGEMENTS

Thanks to all the communities who participated, the Sierra Leone Ministry of Health & Sanitation, the Sierra Leone Ministry of Agriculture & Forestry, District Level Medical and Veterinary Officers, community liaisons, the Univesity of Makeni Sierra Leone, the entire PREEMPT team, and all my colleagues at the One Health Institute, especially my co-authors: David Wolking, James Bangura, Edwin Lavalie, Emmanuel Amara, Amarina Koroma, Corina Monagin, Bruno Ghersi; along with my thesis committee members: Karen Saylors, Cameron Pittelkow, and Brian Bird.

FUNDING

This work described in this thesis was funded by DARPA grant no. D18AC00028 in support of the PREventing EMerging Pathogenic Threats (PREEMPT) program. Information on the University of California, Davis PREEMPT Project Consortium, including a list of Consortium members, is available at https://www.preemptproject.org. The funder had no role in study design, data collection and analysis, preparation of the manuscript, or decision to publish.

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APPENDIX 1: COMPLETE LIST OF FOCUS GROUP DISCUSSION THEMES CODED

- Trusted sources of information about disease
    - Health clinics
    - PREEMPT project staff
    - Radio
    - Television
    - WhatsApp/Social Media
- Knowledge of disease transmission methods
    - Wildlife
    - Monkeys
    - Rodents
    - Sanitation/Hygiene
    - Mosquitoes and other insects
    - Mental health
    - Malnutrition
    - Domestic animals
    - Age
- Experiences with Lassa fever
    - Firsthand
    - Secondhand
    - Third
- Vaccine decision process and factors
    - Changed mind about vaccines
    - Negative experiences with health care
    - Religion and vaccination
    - Side effects (vaccine)
    - Specific discussion of transmissible vaccine
    - Trust in government
    - Trust in healthcare system
    - Vaccine access
- Logistical descriptors of focus groups
    - Language barriers
    - Literacy challenges
    - Participation hesitancy

APPENDIX 2: SURVEY DATA TABLES

Demographics		
	Number	Percent
Male	140	69
Female	62	31
No Response for Gender	1	<1
Age Unknown	11	5
18-25 years old	29	14
26-55 years old	132	65
Older than 55 years	31	15
Karankor (ethnicity)	7	3
Kono (ethnicity)	11	5
Limba (ethnicity)	26	13
Mende (ethnicity)	112	55
Temne (ethnicity)	27	13
Other ethnic groups[20]	13	6
Multiple ethnicities reported	5	2
No response for ethnicity	2	1
Bo district	59	29
Bombali district	32	16
Western Area Urban district	1	<1
Kambia district	13	6
Kenema district	52	26
Koinadugu district	23	11
Kono district	10	5
Moyamba district	13	6
Urban	17	8
Rural	179	88
No response for urban/rural	7	3
Primary Occupation: Agriculture	111	55
Primary Occupation: Commerce	24	12
Primary Occupation: Government	16	8
Primary Occupation: Healthcare	12	6
Primary Occupation: Education	11	5
Primary Occupation: Trades	11	5
Primary Occupation: Bike rider	7	3
Primary Occupation: Student	6	3
Primary Occupation: Religious Leader	4	2
Primary Occupation: Retired	1	<1
Secondary Occupation: Agriculture	63	31
Secondary Occupation: None	85	42
Secondary Occupation: Trades	16	8
Secondary Occupation: Commerce	25	12

[20] Other ethnic groups reported were Fullah, Krio, Loko, Mandingo, Sherbro, and Susu.

Secondary Occupation: Government	5	2
Secondary Occupation: Education	3	1
Secondary Occupation: Bike rider	2	1
Secondary Occupation: Healthcare	2	1
Secondary Occupation: Religious leader	2	1
Muslim	133	66
Christian	70	34
No formal education	85	42
Primary education only	24	12
Junior Secondary education only	24	12
Senior Secondary education	29	14
Tertiary education	31	15
Other education reported	6	3
No education level reported	4	2
Development group participant	10	5
Finance group participant	9	4
Elders group participant	8	4
Married people's group participant	3	1
Men's group participant	7	3
Occupational group participant	25	12
Religious group participant	28	14
Social group participant	11	5
Sports group participant	9	4
Women's group participant	12	6
Youth group participant	27	13
Do not participate in a community group	42	21
Other group participant	9	4
No response: community group participation	3	1

Do you think people should worry about getting sick from an animal virus?		
Yes	199	98%
No	3	1%
No Response	1	0%
How do you think viruses make people sick?		
Animals	26	13%
Bodily contact	8	4%
Fluids	2	1%
Contaminated food or water	16	8%
Hygiene	1	0%
Symptoms	23	11%
Yes	51	25%
Don't know	12	6%
Other	7	3%

No response	70	34%
Do you know what Lassa Fever is?		
Yes	190	94%
No	12	6%
Do you know what COVID-19 is?		
Yes	196	97%
No	7	3%
Do you know what Ebola is?		
Yes	197	97%
No	5	2%
Could you tell us what you know about Lassa fever?		
Caused by rats	30	15%
Caused by virus	3	1%
Dangerous	40	20%
Symptoms	34	17%
Caused by an animal	4	2%
Heard of it	3	1%
Person to person spread	3	1%
Nothing	20	10%
Other	4	2%
NR	83	41%
Can you tell me what you know about COVID-19?		
Symptoms	23	11%
Transmission	14	6%
Pandemic	1	0%
Deadly	54	25%
Cold	3	1%
Precautions	12	6%
Nothing	25	12%
Other	5	2%
NR	80	37%
Can you tell me what you know about Ebola?		
Virus	6	3%
Deadly	56	28%
Symptoms	28	14%
Transmission	13	6%
Precautions	8	4%
Like other diseases	8	4%
Nothing	19	9%
Other	1	0%
NR	83	41%

Is the risk of Lassa Fever to you and your family low, high, or in between?		
Low	126	62%
Moderate	25	12%
High	49	24%
No Response	3	1%
What is the risk of Lassa to you and your family on a scale from 1 to 5?		
No risk	12	6%
Low risk	115	57%
Moderate risk	29	14%
High risk	35	17%
Very high risk	12	6%
Is the risk of COVID-19 to you and your family low, high, or in between?		
Low	129	64%
Moderate	29	14%
High	45	22%
COVID risk ranked on a scale of 1 (no risk) to 5 (very high risk)		
No risk	8	4%
Low risk	120	59%
Moderate risk	33	16%
High risk	34	17%
Very high risk	8	4%
Is the risk of Ebola to you and your family low, high, or in between?		
Low	142	70%
Moderate	28	14%
High	31	15%
No Response	2	1%
Ebola risk ranked on a scale of 1 (no risk) to 5 (very high risk)		
No risk	18	9%
Low risk	125	62%
Moderate risk	29	14%
High risk	28	14%
Very high risk	3	1%

	Why is your risk of Lassa fever low?	*Why is your risk moderate?*	*Why is your risk high?*
Animal interactions	6	3	19
General health	2	2	3
Confident in ability to prevent	44	7	0
Knowledge	3	4	3
Personal health	1	0	3
Uncommon	36	4	0
Other	1	1	0

No Response	33	4	21

Town/Village	*Perception of Lassa risk (average on a scale from 1-5)*	*Perception of COVID risk (average on a scale from 1-5)*	*Perception of Ebola risk (average on a scale from 1-5)*
Bo City	2.71	3.43	2.29
Balie	3.08	2.54	2.31
Benduma	2.31	1.92 (Lowest)	1.92
Baomahun-Njaguima	2.77	2.85	2.77
Patama	2.85	2.38	2.31
Bombali	2.00	2.00	3.00
Makeni	1.60 (Lowest)	2.80	2.60
Kapethe	2.15	2.62	2.31
Makuna	3.31	3.23	2.46
Freetown	3.00	3.00	3.00
Gbainkfay	3.38	2.92	2.54
Kenema	2.50	3.00	1.50 (Lowest)
Guala	2.08	2.15	2.00
Largo	2.08	2.00	2.00
Niawama	2.91	2.91	2.82
Talama	2.15	2.08	2.08
Badala	2.31	2.15	2.23
Bafodia	3.60 (Highest)	3.50 (Highest)	3.70 (Highest)
Yekeyor	2.80	3.20	2.70
Mokorie	2.00	2.00	1.92
Average	2.6	2.6	2.4

What is a vaccine?		
Builds immunity	3	1%
Don't know	2	1%
Good health	3	1%
Medicine	99	49%
Prevents sickness	25	12%
Technical answer	2	1%
Other	12	6%
No Response	57	28%
Why do we get vaccines?		
Good Health	9	4%
Illness prevention/protection	134	66%
Treatment	5	2%

Build immunity	4	2%
Other	2	1%
No Response	49	24%
Who would you trust to administer vaccines in your community?		
Community member	3	1%
Expert	7	3%
Healthcare worker	41	20%
No one	1	<1%
Nurse	121	59%
No Response	30	15%
Where do you get your information about vaccines?		
Healthcare professional	128	63%
Radio/Media	91	45%
Community members	11	4%
Other in-person outreach (ag extension, NGOs, training)	8	3%
Other	7	3%
Internet/social media	6	2%
No Response	29	14%
Have you received a vaccine before?		
Yes	188	93%
No	14	7%
No response	1	<1%
Can you tell me how you feel about vaccines?		
Positive	144	71%
Negative	1	<1%
Neutral	4	2%
Mixed	4	2%
No Response	50	25%
If there was a vaccine for Lassa, would you take it?		
Yes	179	88%
No	8	4%
Depends	3	1%
No Response	13	6%
Why would you take a Lassa vaccine?		
Disease spread	4	2%
Protect self and community	104	51%
Likelihood of contact	3	1%
Medical advice	7	3%
Good health	10	5%
Other	1	<1%
No response	50	25%
Why wouldn't you take Lassa vaccine?		
Protect self and community	2	1%

Likelihood of contact	3	1%
Don't need treatment	2	1%
Concerns about risk	1	<1%
No response	3	1%
Would you have your child/family member take it?		
Yes	196	97%
No	7	3%
Why would you have a family member take Lassa vaccine?		
Protect them	100	49%
Reduce risk	2	1%
Good health	8	4%
Autonomy	3	1%
Trust	2	1%
Situational	2	1%
Other	3	1%
NR	76	37%
Why wouldn't you have a family member take a Lassa fever vaccine?		
Autonomy	3	1%
Lassa not here	4	2%
If offered the COVID-19 vaccine, would you take it?		
Yes	193	95%
No	10	5%
Would you have your child/family member take it?		
Yes	192	95%
No	11	5%
If offered the Ebola vaccine, would you take it?		
Yes	185	91%
No	18	9%
Would you have your child/family member take it?		
Yes	186	92%
No	17	8%

Are there vaccines for animals?		
Yes	173	85%
No	30	15%
Have you ever taken your animals for vaccination?		
Yes	75	37%
No	126	62%
No Response	2	1%
Why have you gotten your animals vaccinated?		
Prevent sickness	48	24%
Stop spread	4	2%
Other	3	1%

No Response	20	10%
Why haven't you gotten your animals vaccinated?		
Didn't know	13	6%
Don't have animals	70	35%
Inaccessible	10	5%
No time	1	<1%
Don't know	6	3%
Other	4	2%
No Response	22	11%
Do you think that wildlife should receive vaccines?		
Yes	181	89%
No	22	11%
Why should wildlife be vaccinated?		
Feasibility	3	1%
Human interaction or lack	32	16%
Carry diseases	86	42%
Don't know	1	<1%
Other	4	2%
No Response	55	27%
Why shouldn't wildlife be vaccinated?		
Feasibility	4	2%
Human interaction or lack	7	3%
Don't know	7	3%
No Response	4	2%
What do you think about vaccinating wildlife?		
Stop the spread of disease	49	24%
Why not	1	<1%
Human interactions	11	5%
Good	76	37%
Kill them	1	<1%
Feasibility	1	<1%
Bad	1	<1%
Other	2	1%
No response	61	30%
If vaccinating rats would reduce your risk of getting sick from a virus like Lassa, would you be ok with people giving rats in your home a vaccine?		
Yes	200	99%
No	3	1%
If vaccinating rats would reduce your risk of getting sick from a virus like Lassa, would you be ok with people giving rats around your home and fields (yards and gardens) a vaccine?		
Yes	199	98%
No	4	2%

If vaccinating animals would reduce your risk of getting sick from a virus like COVID-19, would you be ok with people giving animals in your home a vaccine?		
Yes	197	97%
No	5	2%
No Response	1	<1%
If vaccinating animals would reduce your risk of getting sick from a virus like COVID-19, would you be ok with people giving animals around your home and fields (yards and gardens) a vaccine?		
Yes	196	97%
No	4	2%
No Response	3	1%
If vaccinating bats would reduce your risk of getting sick from a virus like Ebola, would you be ok with people giving bats in your home a vaccine?		
Yes	197	97%
No	4	2%
No Response	2	1%
If vaccinating bats would reduce your risk of getting sick from a virus like Ebola, would you be ok with people giving bats around your home and fields (yards and gardens) a vaccine?		
Yes	199	98%
No	4	2%
Would you be willing to allow rats to receive a spreadable vaccine in your community if it stopped the spread of disease?		
Yes	201	99%
No	1	<1%
No Response	1	<1%
Why would you allow rats to receive a spreadable vaccine?		
Stop spread of disease	46	23%
Prevent disease	59	29%
Close to humans	8	4%
Good	4	2%
Trust in researchers	2	1%
Vaccine safety	2	1%
Concerns	4	2%
Other	4	2%
NR	74	36%
What do you think about transmissible vaccine?		
Feasible	18	9%
Positive	103	51%
Side effects	1	<1%
Target population	1	<1%
Illness prevention	9	4%
Eradicate Lassa	2	1%
Other	1	<1%

NR	68	33%
What, if any, are your concerns about a vaccine that can spread from animal to animal?		
No concerns	83	41%
No Response	67	33%
Will it work?	17	8%
Eating rodents	9	4%
Harm to people	5	2%
Time to spread	4	2%
Other	3	1%
Harm to rodents	3	1%
How?	3	1%
Why give animal vaccines?	3	1%
Don't know enough about it	2	1%
When?	2	1%
How to know animals are vaccinated	2	1%
Ability to administer	2	1%
Disturbance to habitat	1	<1%
Can humans?	1	<1%
Virus mutation	1	<1%

Do you have any questions for us?		
No	120	59%
What's next for the research/vaccine development?	20	10%
Can we eat rodents after vaccination?	14	7%
How will this vaccine affect humans? Can humans get the vaccine?	13	6%
Does the transmissible vaccine work? How?	14	7%
How do vaccines for wildlife work? Why do we vaccinate wildlife?	8	4%
I have questions about other diseases.	6	3%
Why here? Why me? Who are you?	10	5%
Miscellaneous	7	3%
Do you have any questions about the COVID vaccine?		
Is it effective? How does it work?	17	8%
I have questions about the development/origin/production of the vaccine.	9	4%
Who should get vaccinated?	5	2%
Does it cause side effects?	13	6%
How/when/where will it be distributed?	14	7%
I have questions about COVID generally.	5	2%
Why do we get vaccines?	6	3%
No	143	70%