Research Article

Expanding Participatory Epidemiology to Explore Community Perceptions of Human and Livestock Diseases among Pastoralists in Turkana County, Kenya

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In Kenya, pastoralists grapple with significant health and livelihood challenges due to livestock, zoonotic, and human diseases. These diseases threaten the sustainability of their unique food production system and its considerable value. Disease control and prevention in arid and semi-arid lands (ASALs) are currently inadequate due to underfunded and ill-adapted health programs coupled with a shortage of personnel. Participatory epidemiology (PE) presents a valuable tool for understanding community perceptions of disease importance and epidemiology, thereby aiding in improving control measures and promoting community involvement in centralized service delivery programs. Yet, the use of PE has been primarily confined to livestock and zoonotic diseases, leaving perceptions of human disease and the complex interplay between pastoralists, their livestock, and the rangelands unexplored. To address this gap, we utilized PE to achieve three objectives: 1) establish links between human and livestock diseases, 2) determine perceptions of disease priorities, and 3) assess knowledge of disease epidemiology. Our findings indicate that the relationships between human and livestock diseases primarily manifest in two categories: disease symptoms and zoonoses. Disease priorities differed between locations, with no apparent pattern emerging that human or livestock diseases are considered more important. Importance indicators such as prevalence, mortality, morbidity, and spatial/temporal variation were shared across human and livestock diseases. Diseases perceived as more prevalent and deadly were deemed most significant, while those seen as less prevalent, less deadly, and exhibiting more spatial/temporal variation were considered less critical. Our results underscore the added value of broadening the application of PE to include human diseases, which can help to improve disease prevention and control initiatives among pastoralists. Future studies and human, animal, and environmental health programs can leverage and expand upon our approach, combining it with traditional sero-syndromic surveillance to address health challenges among pastoralists in ASALs in Kenya and beyond.

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Abbreviations

- AHO: Animal health officer
- ASALs: Arid and semi-arid lands
- CBPP: Contagious bovine pleuropneumonia
- CCP: Contagious caprine pleuropneumonia

- FGD: Focus group discussion
- FMD: Foot and mouth disease
- NGO: Non-governmental organization
- PE: Participatory epidemiology
- PPR: Peste des petits ruminants
- RVF: Rift Valley Fever

One Health impact statement

Participatory epidemiology (PE) has primarily focused on livestock and zoonotic diseases, leaving perceptions of human disease unexplored. Our study expands the scope of PE to encompass human diseases. This One Health perspective carries immense potential for bolstering human and livestock disease control by pinpointing community disease priorities and knowledge, thereby shaping disease prevention and control programs. Our low-cost approach also integrates academic, medical, and indigenous knowledge and helps empower communities to participate in disease control and prevention initiatives actively. Our work serves as a blueprint for future studies and health programs, encouraging a more holistic, cooperative approach to health challenges in pastoralist settings in Kenya and beyond.

Introduction

Pastoralism plays a vital role in Kenya, particularly in the arid and semi-arid lands (ASALs), contributing significantly to the economy, food security, and preserving ecosystem integrity. However, the pastoralist way of life is increasingly jeopardized by infectious diseases. This study aims to identify the added value of broadening the scope of participatory epidemiology (PE) to encompass human diseases, alongside zoonotic and livestock diseases, in the context of pastoralist communities.

Kenya's ASALs, inhabited by pastoralists, cover more than 80% of the country's land area and are home to over a third of the human population (Catlety et al., 2007; Schilling et al., 2012). Pastoralism is a specialized food production system that harnesses variable environmental conditions in ASALs to produce meat, milk, livelihoods, and income (Food and Agriculture Organization, 2018). Pastoralists rely on mobility, flexible land tenure systems, and herd diversity (i.e., process variability) to match the temporal and spatial variation in rainfall in ASALs (Krätli & Koehler-Rollefson, 2021). In Kenya, over 8 million pastoralists manage most of the national livestock, including 70% of the cattle, 80% of the sheep and goats, and all camels (Wanyama, 2020). Kenya’s pastoral sector is worth US$1.13 billion, contributes 13% of the gross domestic product, and provides most of the meat consumed in the country (Nyariki & Amwata, 2019). Pastoral lands in Kenya are also home to most of its wildlife (~90%) and biodiversity, contributing significantly to the tourism economy (Homewood et al., 2012).

In Kenya, livestock, zoonotic, and human diseases pose severe challenges to pastoralists' health and livelihoods, threatening the sustainability of their unique food production system and the immense value it provides. Livestock diseases negatively impact pastoral livelihoods through illness and death, decreased production, and market bans (Catley

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et al., 2009). The most common livestock diseases among pastoralists include contagious bovine pleuropneumonia (CBPP), foot and mouth disease (FMD), and anthrax in cattle; peste des petits ruminants (PPR), parasitosis, and sheep pox in sheep; and PPR, parasitosis, and contagious caprine pleuropneumonia (CCPP) in goats (Adriss & Nersy, 2017).

In addition to these livestock diseases, pastoralists face exposure to numerous zoonotic diseases due to their close interaction with livestock, consumption of animal-source foods, and the harsh environmental conditions they inhabit (Mangesho et al., 2017; Zinsstag et al., 2016). Public health and veterinary officials in Kenya have identified the most critical zoonoses as anthrax, trypanosomiasis, rabies, brucellosis, and Rift Valley Fever (RVF). (Munyua et al., 2016).

Furthermore, while not unique to pastoralists, human diseases such as diarrhea, respiratory infections (including tuberculosis), and malaria pose additional threats (Schelling et al., 2016). Pastoralists face a higher risk of these diseases, mainly due to inadequate policy and institutional support for their way of life, compounded by insufficient health infrastructure (Krätli & Koehler-Rollefson, 2021). As a result, pastoralists' health outcomes tend to be poorer compared to those of more sedentary populations (Griffith et al.,2020; Lawson et al., 2014; Pertet et al., 2018; Zinsstag et al., 2006).

The implementation of effective disease control strategies in pastoral areas is currently hampered by a lack of epidemiological data, such as disease patterns in various geographic regions, agroecological zones, and seasons; and a lack of information regarding community disease priorities and indigenous knowledge (Gizaw et al., 2020). Furthermore, traditional surveillance methods, primarily designed for sedentary populations, fail to serve mobile pastoralists' needs. This challenge is further exacerbated by underfunded human health, veterinary, and environmental services, coupled with a shortage of personnel in ASALs (Gitonga, 2018). Given these challenges, a One Health approach is needed to improve disease control within pastoralist communities.

One Health is an "integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent" (Adisasmito et al., 2022). It is well-suited to pastoralists due to the nature of pastoral livelihoods, cultural preferences, limited available resources in ASALs, and demonstrated success in improving pastoralists' health and livelihoods (Griffith et al., 2020; Zinsstag et al., 2015). In light of the risks posed by zoonoses, as well as livestock and human diseases among pastoralists, a One Health approach of joint human and animal health surveys is needed to understand disease dynamics, collect disease and intervention cost estimates, and understand geographic and cultural factors that influence health (Schelling et al., 2016). This health assessment method captures the full scope of pastoralists' health challenges and can tailor solutions to their specific circumstances.

Participatory epidemiology (PE), defined as the systematic use of methods that facilitate the empowerment of people to identify and solve their health needs, can help to achieve these goals (Alders et al., 2020). This methodology is particularly beneficial in resource-poor ASALs, where conventional diagnostic tools and surveillance data are often lacking. Its primary applications encompass disease investigation, control, surveillance, and descriptive epidemiology (Allepuz et al., 2017).

Standard PE methodology falls into four categories: informal interviews, ranking and scoring, observations, and validation workshops (Catley et al., 2012). "Participation" in PE can be conceptualized and implemented in various ways, ranging from passive involvement to active self-mobilization. In self-mobilization, the highest level of engagement, participants actively initiate contact with external institutions to acquire necessary resources and technical advice, while maintaining control over resource allocation and usage (Table 1).

Typology	Characteristics of each type
1. Passive participation	People participate by being told what is going to happen or has already happened. It is a unilateral announcement by an administration or project management without listening to people's responses. The information being shared belongs only to external professionals
2. Participation in information giving	People participate by answering questions posed by extractive researchers using questionnaire surveys or similar approaches. People do not have the opportunity to influence proceedings, as the findings of the research are neither shared not checked for accuracy
3. Participation by consultation	People participate by being consulted, and external people listen to views. These external professionals define both problems and solutions and may modify these in the light of people's responses. Such a consultative process does not concede any share in decision making, and professionals are under no obligation to take on board people's views.
4. Participation for material incentives	People participate by providing resources, for example labor, in return for food, cash or other material incentives. Much on-farm research falls in this category, as farmers provide the fields but are not involved in the experimentation or the process of learning. It is very common to see this called participation, yet people have no stake in prolonging activities when the incentives end.
5. Functional participation	People participate by forming groups to meet predetermined project objectives related to the project, which can involve the development or promotion of externally initiated social organization. Such involvement does not tend to be at early stages of project cycles or planning, but rather after major decisions have been made. These institutions tend to be dependent on external initiators and facilitators but may become self-dependent.
6. Interactive participation	People participate in joint analysis, which leads to action plans and the formation of new local institutions or the strengthening of existing ones. It tends to involve interdisciplinary methodologies that seek multiple perspectives and make use of systematic and structured learning processes. These groups take control over local decisions, and so people have a stake in maintaining structures or practices.
7. Self – mobilization	People participate by taking initiatives independently of external institutions to change systems. They develop contacts with external institutions for resources and technical advice they need but retain control over how resources are used. Such self-initiated mobilization and collective action may or may not challenge existing inequitable distributions of wealth and power.

Table 1. A typology of participation. Adapted from Pretty et al. (1995).

Participatory epidemiology practiced by animal and public health professionals has been used in multiple settings to elucidate the epidemiology of emerging and transboundary diseases, including avian influenza, PPR, and Rift Valley fever

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(Bett et al., 2015; Coffin et al., 2015; Jost et al., 2010; Mariner et al., 2012; Mariner et al., 2014; The International Livestock Research Institute, 2011; Walker et al., 2015). In addition, PE has been instrumental in identifying disease priorities and understanding local knowledge, thereby contributing to the design of targeted disease control interventions (Amenu et al., 2017; Gitonga, 2018; Gizaw et al., 2020; Legesse et al., 2018; Onono et al., 2019).

While PE aims to enhance community engagement in disease control initiatives, it often fails to achieve "self-mobilization" or "interactive participation," instead falling most frequently under "functional participation," where community participation contributes to project goals set by external agencies or actors. This lack of true empowerment could be considered a limitation of current PE practices (Allepuz et al., 2017). Nevertheless, Catley (2020) suggests that PE is an approach that can improve participation in more conventional and extractive approaches to policy and research, leading to effective disease control efforts in various contexts. This can be explicitly seen in humanitarian contexts when PE has increased local consultation and involvement in designing and evaluating projects (Catley, 2020).

Despite its potential, PE has often been limited in scope, frequently overlooking aspects of human health among pastoralists beyond zoonoses. There have been limited published examples of participatory epidemiology used in East Africa to investigate human health and nutrition. One study explored malnutrition among pastoralists in Karamoja, while another used them to understand perceptions of health at the human-animal-environment interface among pastoralists in Marsabit County, Kenya (Catley et al., 2018; Salza, 2018). Expanding PE methods to include human diseases is needed to address pastoralists' health and livelihoods and consider the interdependent, entangled health relationships between pastoralists, their livestock, and the rangelands (Catley et al., 2012). In this study, we piloted a One Health approach to examine human, livestock, and zoonotic diseases among Turkana pastoralists.

Materials and Methods

Study Area

Turkana County is situated within the Karamoja Cluster, a region along the borders of Kenya, Ethiopia, South Sudan, and Uganda (Figure 1). It is the largest county in Kenya, with a total area of 77,000 km^2. It has an estimated population of 1,256,152 people, almost all of whom practice pastoralism due to limited and variable rainfall conditions found in ASALs (Turkana County Government, 2022). The county is home to 2,828,010 cattle, 6,731,414 sheep, 6,906,686 goats, 871,707 camels, and 623,312 donkeys (Turkana County Government, 2022).

Since devolution in 2010, the provision of human and animal health, environmental, and administrative services is primarily under the purview of the county government. However, non-governmental organizations (NGOs) still contribute to Turkana's service delivery and surveillance activities (Griffith et al., 2023).

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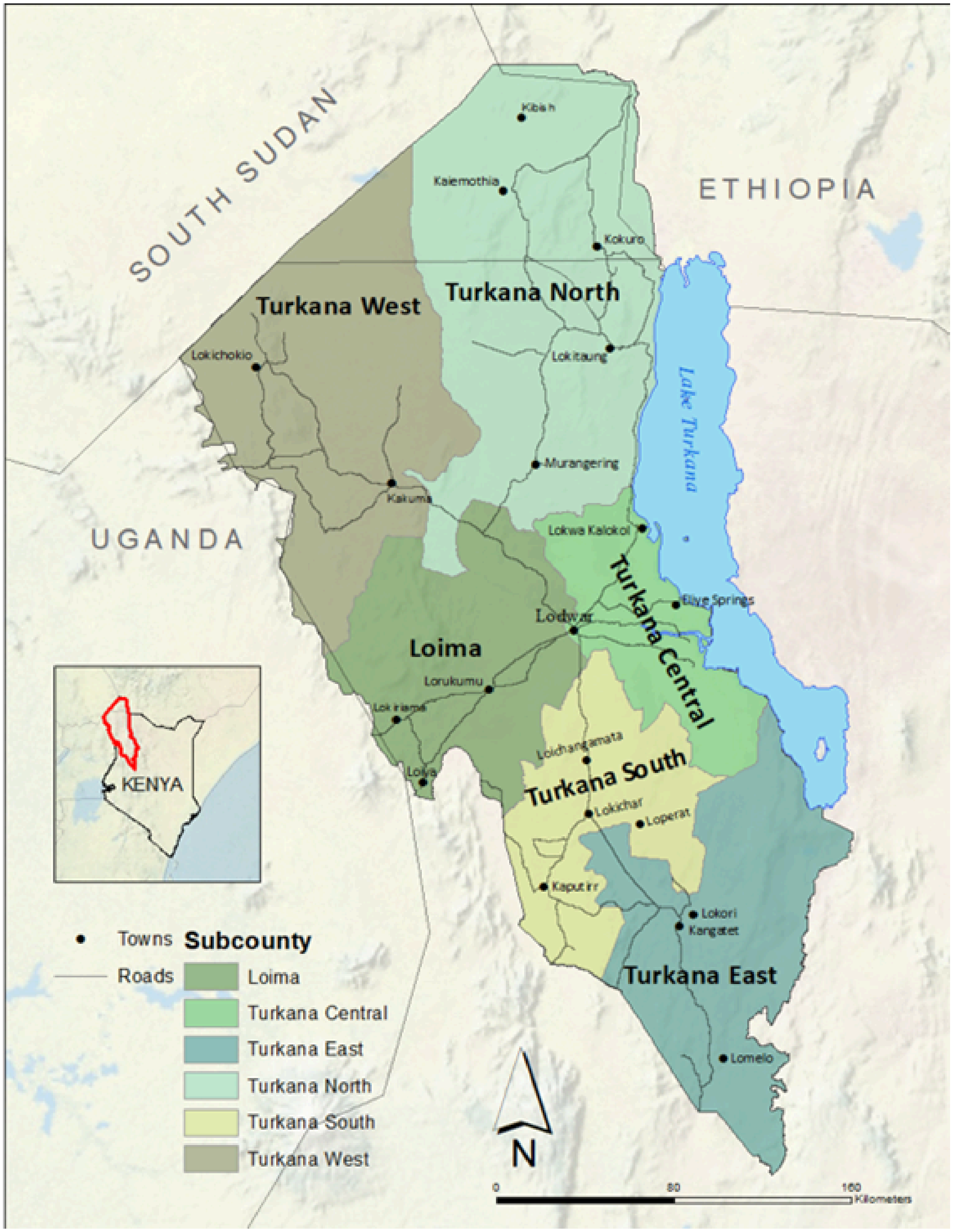

Figure 1. Turkana County, Kenya. This map was created with ESRI ArcMap 10.8.2. Data source: ArcGIS Online.

Study design and sample

In this cross-sectional study, we engaged Turkana livestock keepers through focus group discussions (FGDs). To ensure the reliability of our data-gathering process, we field-tested the interview guide before the actual study. The discussions took place in conveniently accessible locations, each lasting approximately an hour. With participants' consent, each session was audio-recorded for accuracy. EFG and JRK led the meetings, supported by a local interpreter in each location. The FGDs were conducted over a three-week period in August 2018.

We organized the FGDs in four strategic locations: Nadapal, Turkwel, Kakuma, and Lokwamosing (Figure 1; Table 1). Each subcounty was randomly selected, while specific locations within each subcounty were chosen purposefully. This method enabled us to gather diverse perspectives from respondents living near towns (Nadapal and Turkwel), those residing away from urban centers (Lokwamosing), and those near refugee camps (Kakuma). Table 1 provides a summary of the composition of each FGD. We employed a convenience sampling approach in participant selection, considering the availability of individuals from each location.

Village/Town	Ward	Subcounty	FGD composition
Nadapal village	Turkwel	Loima	Two women, three men
Turkwel village	Turkwel	Loima	Five men
Kakuma town	Kakuma	Turkana West	Seven men
Lokwamosing village	Kachodin/Lokori	Turkana East	Four women, six men

Table 1. Composition and location of FGDs with livestock owners

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Figure 2. PE methods, including simple ranking and proportional piling. Built with Creately (https://creately.com).

Data collection

We use various PE tools, such as simple ranking and proportional piling, to gain insights into the community's perceptions of disease connections, significance, and epidemiology (Figure 2). Initially, participants were prompted to list their community's most significant human and livestock diseases. Each disease or syndrome was identified by its local or traditional name and English translation. Subsequently, we explored and discussed connections between diseases within each category. We used probing questions to investigate the participants' understanding of the connection between human and livestock diseases. Following this, we conducted a ranking exercise where participants were asked to rank the top five human and animal diseases based on their perceived importance, drawing from the previously listed diseases.

Next, a proportional piling exercise was conducted, wherein participants distributed 100 counters (represented by stones) among the diseases. In Nadapal, the counters were distributed separately among the top five human and livestock diseases. In contrast, the top diseases were combined in the other three locations, and participants distributed the counters among the ten diseases. The distribution of counters was guided by participants' perceptions of the diseases' importance.

Open-ended questions were employed to probe the counter distribution between human and livestock diseases, and participants discussed disease symptoms and epidemiology. Notably, the term 'importance' was not pre-defined for the ranking or proportional piling exercises. Instead, participants were encouraged to rank diseases and distribute stones based on their perceptions. Follow-up questions were then asked to clarify their reasoning and thought process.

Data interpretation and analysis

All audio recordings from each meeting, transcripts, and field notes were securely stored on a password-protected, cloud-based drive. Interview transcripts and field notes were systematically categorized into themes, such as types of disease connections and significance indicators employed during the proportional piling exercise.

Given the limited sample size, quantitative data, such as disease scorings from different groups, are presented descriptively. The outcomes of the qualitative coding process were utilized to interpret and elucidate observed trends in the data.

Semi-quantitative data was collated and prepared for reporting using Microsoft Excel. Graphics representing the results of the proportional piling exercise were generated using Tableau Desktop (2018.2.8). For in-depth analysis, transcripts and field notes were processed using NVIVO 12.

Results

Participant-generated disease connections

Participants of the FGDs were prompted to identify and elucidate any perceived correlations or relationships between the listed human and animal diseases. The responses generated by the participants are consolidated in Table 2. These responses fell broadly into two categories: disease symptoms (e.g., coughing, jaundice, diarrhea) and zoonotic diseases (e.g., brucellosis, anthrax, and rabies).

'Disease symptoms' emerged as the most frequently reported category, with eleven instances, followed by 'zoonotic diseases,' which were mentioned ten times. In Nadapal, pneumonia and CCPP were mistakenly identified as zoonotic diseases. Participants listed rabies and hydatid disease under livestock diseases in the same location but failed to establish any connections between these diseases in livestock and humans.

In Turkwel and Kakuma, trypanosomiasis was categorized under livestock diseases but was not recognized as a zoonotic disease. Participants from all locations identified brucellosis as a zoonotic disease.

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Location	Disease: livestock (L) or human (H)	Participant Description	Category
Nadapal	Yellow fever (H), l*onyang*/ anaplasmosis (L)	"Paleness" (i.e. jaundice) in both people and livestock	Disease symptoms
	Loir (H/L)	*Loir* is a fungal infection in livestock and a (fungal) eye infection in people	Other
	Ekitowo (L), malaria (H)	*Ekitowo*, also known as three-day-sickness in livestock, generally lasts for three days which is the same amount of time malaria drugs are administered for	Other
	Eremonu/diarrhoea (L), *lolewa*/cholera (H)	*Eremonu* is the name for diarrhea in livestock, which is a symptom also seen in people who have cholera	Disease symptoms
	CCPP (L), pneumonia (H)	Same disease in both people and livestock	Zoonotic disease
	Edeke akiring/brucellosis (H/L)	Same disease in both people and livestock	Zoonotic disease
Turkwel	*Enomokere*/anthrax (H/L)	Same disease in both people and livestock	Zoonotic disease
	Edeke akiring/brucellosis (H/L)	Same disease in people and livestock	Zoonotic disease
	Lopelei/worms (L), *eremonu*/diarrhoea (H)	Diarrhea is a symptom of parasitosis in livestock, while eremonu is the name for diarrhea in people	Disease symptoms
	Ewalanu/coughing (H), *loukoi*/CCPP (L)	A symptom of CCPP in livestock is coughing, which is described as ewalanu in people	Disease symptoms
	Elachit/lice (H/L)	Lice are found on both people and livestock	Other
Kakuma	*Lokwakel*/HIV/AIDS (H), *lomoo*/PPR (L)	Both cause emaciation	Disease symptoms
	Ewalanu/tuberculosis/pneumonia (H), *loukoi*/CCPP/CBPP (L)	Coughing is a shared symptom in both people and livestock	Disease symptoms
	Enomokere/anthrax (H/L)	Same disease in both people and livestock	Zoonotic disease
	Long'okwo/rabies (H/L)	Same disease in both people and livestock	Zoonotic disease
	Lotebwo/hydatid disease (H/L)	Same disease in people and livestock	Zoonotic disease
	Edeke akiring/brucellosis (H/L)	Same disease in people and livestock	Zoonotic disease

Location	Disease: livestock (L) or human (H)	Participant Description	Category
	Etune/pox (L), *ameriwosin*/scrapies (H)	Similar symptoms in both people and livestock	Disease symptoms
	Naosin/parasites (L), *ngipelei*/parasites (H)	Same helminth infection in people and livestock	Zoonotic disease
	Tuberculosis (H), HIV/AIDS (H)	Co-infections with these diseases are often noted	Other
Lokwamosing	*Lolewa*/diarrhoea (H)	People get diarrhea from consuming animals that have died from infectious disease	Other
	Naosin/*ngiritan*/parasites (L), *lolewa*/diarrhoea (H)	Diarrhea is symptom of parasites in livestock, while lolewa describes the symptom of diarrhea in people that has multiple causes	Disease symptoms
	Loukoi/CCPP (L), tuberculosis/chronic bronchitis (H)	Both cause coughing in people and animals	Disease symptoms
	Edeke Akiring/brucellosis (H/L)	Same disease in both people and livestock	Zoonotic disease
	Lanyang/anaplasmosis (L), yellow fever (H)	Jaundice in both people and livestock	Disease symptoms
	Lokul/bladder incompetence/urinary tract infection	Occurs in people and livestock (especially goats)	Disease symptoms

Table 2. Connections between livestock and human diseases. The category labeled as 'other' referred to anything that didn't fall under disease symptoms or zoonotic disease.

Zoonotic diseases and local terminology

Brucellosis was consistently identified as a zoonotic disease across all locations. Livestock keepers in Lokwamosing elaborated on its transmission through the consumption of meat and milk from infected livestock. Other diseases identified as zoonoses included anthrax, rabies, hydatid disease, and parasitic infections, though this recognition was not uniform across all sites. In addition, CCPP and pneumonia were mistakenly classified as zoonotic infections, likely due to their similar clinical signs. Although listed under livestock diseases, rabies and hydatid disease were inconsistently recognized as zoonoses. Trypanosomiasis, listed as a livestock disease in all locations, was never identified as a zoonotic disease.

There were also notable differences in the descriptive, syndromic terminologies used across different locations. For instance, human pneumonia was referred to as 'edeke loerorung' in Nadapal and 'erarum' in Lokwamosing. However, in Kakuma, 'erarum' was used to denote pneumonia and tuberculosis. The term 'lopelei' was consistently used across all locations to describe parasitosis in livestock. However, in Lokwamosing, the terms 'naosin' and 'ngiritan' were also used to refer to the same condition.

Perceptions of disease importance and epidemiology

The results from the proportional piling exercise and the indicators of disease importance are outlined in Table 3. These indicators encompassed perceived prevalence, mortality, morbidity, and spatial/temporal variation. Diseases believed to exhibit the highest prevalence and mortality rates were deemed the most significant. For instance, PPR and malaria were the top priority in Nadapal; CCPP/CBPP in Turkwel; tuberculosis, HIV/AIDS, and PPR in Kakuma; and brucellosis, PPR, and malaria in Lokwamosing.

Conversely, diseases perceived to have lower prevalence and mortality rates and those demonstrating high spatial and temporal variation (i.e., diseases not consistently present throughout the year or across different environments) were considered low priority. These included intestinal parasites, mange, pneumonia, and diarrhea in Nadapal; edema and tick-borne diseases in Turkwel; tick-borne diseases and diarrhea in Kakuma; and pneumonia and intestinal parasites in Lokwamosing.

Participants also exhibited a deep understanding of epidemiology, such as disease structure (e.g., mortality rates across different age groups) and disease etiology. The ten most significant diseases in Turkwel, Kakuma, and Lokwamosing are illustrated in Figure 3.

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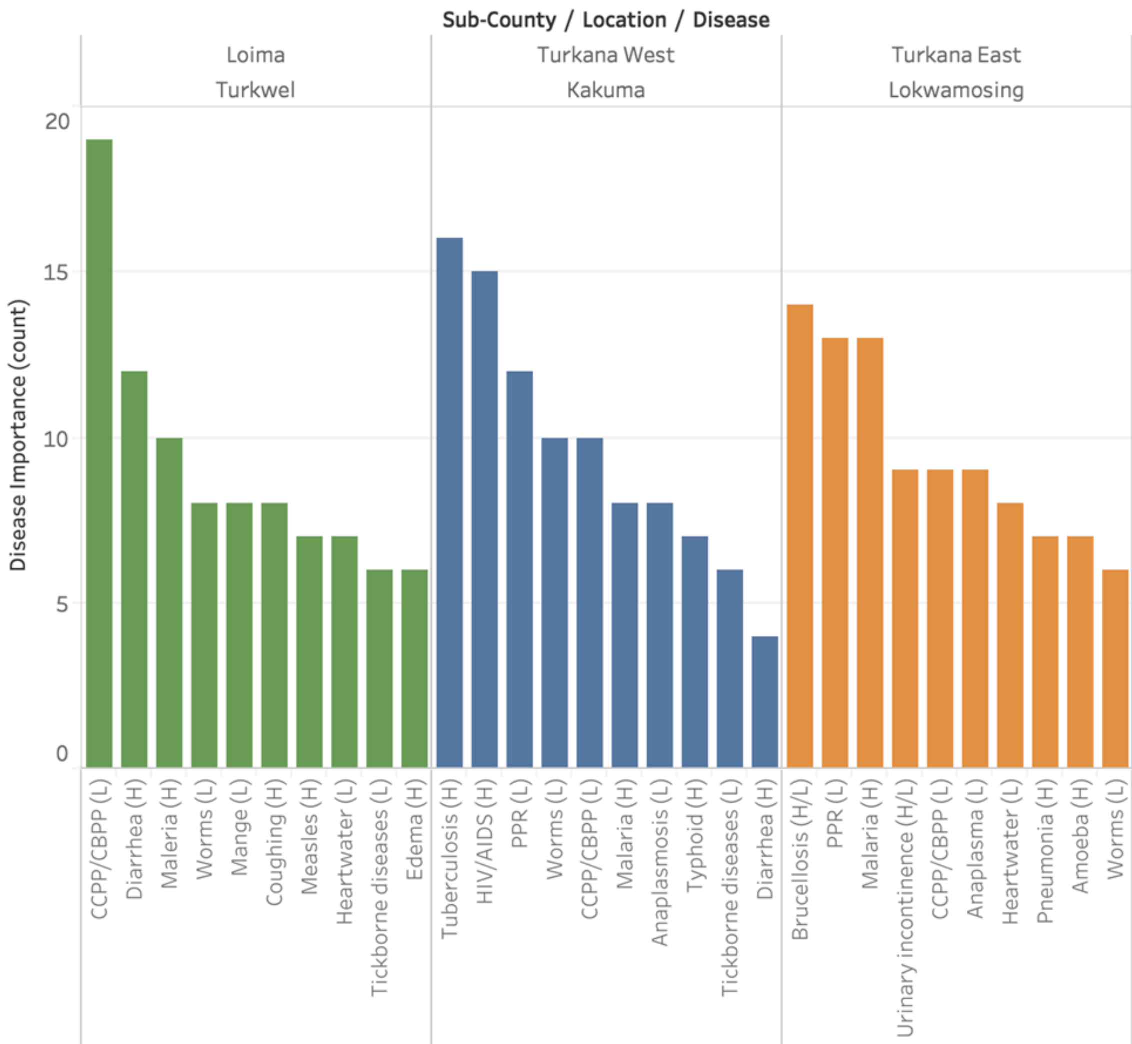

Figure 3. The ten most significant diseases in Turkwel (green), Kakuma (blue), and Lokwamosing (orange). Disease importance is represented by the number of counters assigned to each disease during the proportional piling exercise.

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Location	Disease: human (H), livestock (L)	Importance (count)	Reasoning					Additional epidemiologic knowledge
			Prevalence	*Mortality*	*Morbidity*	*Spatial/ temporal variation*	*Other*	
Nadapal	*Lomoo*/PPR (L)	40	X	X	X		X (economic cost)	• Highest mortality during drought
	Lookot/ haemorr-hagic Septicaemia (L)	23		X		X (rainy season)		
	Loukoi/CCPP (L)	16			X			
	Lopelei/worms(L)	6			X			• Kills mostly young animals
	Lotome/ mange (L)	2			X	X (rainy season)		• Kills all ages, but mostly young animals
	Malaria (H)	56	X	X				• Abundant mosquito vectors
	Siir/*lobute*/ edema (H)	19		X				• Indicates malnutrition • Children die if not taken to the hospital
	Tuberculosis (H)	12		X				• Coughing is a symptom • Die without medication
	Edeke loerorung/pneumonia (H)	7			X	X (cold times of year)		
	Lolewa/diarrhea (H)	6			X			• Multiple causes (cholera, food toxicities) • Palm fruit without out food results in

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								diarrhoea
Turkwel	Loukoi/CCPP/CBPP (L)	19	X	X				• Highest mortality in goats and cattle
	Eremonu/diarrhea (H)	12	X			X (rainy season)		• Caused by contaminated water
	Lokou/ malaria (H)	10	X			X (rainy season)		
	Ewalanu/ coughing (H)	8	X					
	Lopelei/ worms (L)	8	X					
	Lotome/ mange (L)	8			X			
	Puru/ measles (H)	7	X (low)					
	Amil/ heartwater (L)	7	X (low)					
	Siir/edema (H)	6	X (low)					• Mostly adults get siir
	Ngimadang/many ticks (L)	6	X (low)			X (ticks in bushy habitat accessed in the dry season)		
Kakuma	*Erarum*/ pneumonia/ tuburculosis (H)	16	X			X (dry season)		
	Lokwakel/ HIV/AIDS (H)	15	X				X (can be managed but there is no cure)	• High sexual activity • Often co-infection with tuberculosis
	Lomoo/PPR (L)	12		X			X (can be managed, but there is no cure)	
	Loukoi/CCPP/CBPP (L)	10					X (treatment available so	

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							of less importance)	
	Lopelei/ worms (L)	10					X (treatment available so of less importance)	
	Longyang/ *lopid*/anapl-asmosis (L)	8				X (rainy season)		
	Lokou/ malaria (H)	8				X (rainy season)		
	Typhoid (H)	7	X (low)			X (common in town but not in villages)		
	Emadang/ tick (L)	6	X (low)			X (only found where habitat is suitable for ticks)		• Causes death in young camels
	Lotewa/ diarrhea (H)	4	X (low)			X (rainy season when there is stagnant water)		• Includes cholera
Lokwamo-sing	*Lokiring*/ brucellosis (H/L)	14	X					• People get infected by consuming contaminated meat and milk
	Lomoo/PPR (L)	13	X	X				• "When they get sick they normally die"
	Malaria (H)	13	X	X				

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	Loukoi/CCPP (L)	9			X		X (cannot eat meat of infected animals)	• Damages the thoracic cavity (scarring)
	Lanyang/an-aplasmosis (L)	9				X (rainy season)	X (cannot eat meat once you see jaundice	
	Lokul/ urinary incontinence (H/L)	9	X					• Multiple etiologies including UTIs or bladder stones • Multiple causes including: becoming dehydrated and drinking salty water and not drinking from the same water source • Common across species (e.g., goats and people)
	Amil/ Heartwater (L)	8	X (low)			X (access pasture that is good tick habitat during the dry season)		
	Amoeba (H)	7	X (low				X (can be treated easily)	• foodborne/waterborne illness
	Erarum/ pneumonia (H)	7					X (easy to treat)	
	Naosin/ *ngiritan*/ *lopelei*/ parasites (L)	6		X (low)		X (rainy season)		

Table 3. Proportional piling results from each group meeting. Disease/syndrome names are given in English and Turkana when the local name was provided. Human and livestock diseases were examined separately in Nadapal, but combined in Turkwel, Kakuma, and Lokwamosing. For each disease, the importance indicators are given, as indicated by an 'X,' including prevalence,

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mortality, morbidity, and spatial/temporal distribution. Additional epidemiological information gathered during each interview is also summarized.

Discussion

While PE has been widely utilized to investigate livestock diseases and enhance control measures, its application to human diseases remains largely untapped. Cately (2020) recently suggested that PE can be used to improve measles vaccination efforts, signifying a growing recognition of PE's potential contributions to human health initiatives. Leveraging the past successes of PE in guiding livestock disease control strategies among pastoralists, our study illuminates how participatory methodologies can be harnessed to discern perceptions on the importance and epidemiology of human, livestock, and zoonotic diseases. This One Health perspective carries immense potential for bolstering human and livestock disease control by pinpointing community disease priorities and knowledge, thereby shaping disease prevention and control programs. Our approach was also relatively low-cost compared to more intensive disease surveillance programs, helping to overcome the challenge of limited resources in Turkana and other pastoral areas.

We adjusted the study methodology to directly compare combined human and livestock diseases in a proportional piling exercise after the first FGD to more accurately reflect a One Health approach. Constructive participant feedback and internal author discussions underscored that this approach would yield more pertinent information for integrated service delivery, which is being adopted by the Turkana County government (Griffith et al., 2023). Furthermore, this method aligns more closely with how Turkana pastoralists perceive diseases, recognizing their interconnectedness among humans, animals, and the environment.

Our findings reveal that study participants did not prioritize either human or livestock diseases over the other. For instance, when comparing human and livestock diseases directly, CCPP, tuberculosis, and brucellosis were deemed most significant in Turkwel, Kakuma, and Lokwamosing, respectively, as depicted in Figure 3. This result contrasts with a previous study where livestock health was valued above human health (Salza, 2018). This discrepancy could be attributed to variations in study methodologies, underscoring a prevailing gap in the scientific and medical comprehension of pastoral communities' cultural and environmental contexts. Ideally, these factors should be thoroughly understood before implementing health policies.

The parity observed in the importance of human and livestock diseases in our study is likely due to the consistent indicators used for assessing each disease, including prevalence, mortality, morbidity, and spatial/temporal variation. Other PE studies have identified similar indicators, though their focus did not extend to human diseases (Alemu et al., 2019; Gizaw et al., 2020; Onono et al., 2019). Our findings emphasize that participants' perceptions of disease importance did not hinge on species, accentuating the necessity for a One Health approach that avoids the artificial division of human and livestock diseases in health surveys and surveillance systems among pastoralists.

Disease priorities varied by location, emphasizing the importance of “local context” in designing and implementing health programs (Catley, 2020). Alemu et al. (2019) found that national disease control programs often do not align with the priorities of livestock keepers. The strategies tested in our study illustrate a practical approach for health sectors in Turkana to identify disease priorities for humans and livestock, which can subsequently guide health programming. For

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example, healthcare providers could focus their prevention and control measures on diseases deemed highly significant by the community, thereby aligning centralized health services with local priorities.

Leveraging local knowledge can significantly enhance disease prevention and control measures. Participants in our study exhibited substantial epidemiological understanding, including the spatial and temporal prevalence of diseases (for instance, urban versus rural settings and during wet versus dry seasons) and disease etiology. Human health and veterinary departments can utilize this knowledge to plan and execute disease control initiatives strategically. For instance, the observation that ticks are primarily found in specific habitats, typically accessed during the dry season, can guide the targeted application of tick control measures (such as acaricides) in these areas and during these specific periods of the year.

Study participants demonstrated mixed knowledge of zoonotic diseases, the most commonly reported emerging and re-emerging infectious diseases in Sub-Saharan Africa (Mangesho et al., 2017). This result contrasts a study among pastoralists in Ethiopia that found low awareness of zoonotic diseases (Alemu et al., 2019). In Nadapal, participants identified human pneumonia and CCPP as the same disease, likely due to similar symptoms. However, the bacterium *Mycoplasma capricolum subsp. capripneumoniae* is the etiological agent of CCPP and does not cause human disease. Some zoonoses, like brucellosis, were commonly reported. However, others, like hydatid disease and trypanosomiasis, were not identified. Turkana had the highest incidence of hydatid disease (i.e., cystic echinococcosis) in the world in the 1980s, and continues to have a high prevalence, demonstrating the importance that livestock keepers are aware of this neglected zoonotic disease (Solomon et al., 2017).

Trypanosomiasis exists in two forms: Human African Trypanosomiasis (HAT), which is fatal if left untreated, and African Animal Trypanosomiasis (AAT). The etiologic agents of HAT, *Trypanosoma brucei rhodesiense* and *T. b. gambiense,* are zoonotic, with cattle and other domestic animals servings as reservoirs (Kivali et al., 2020). In contrast, the etiologic agents of AAT, including *T. vivax*, *T. congolense*, and *T. brucei,* do not infect humans. In Kenya, AAT, i.e., nagana, is a major constraint to agricultural production, increasing livestock mortality, reducing milk yield, causing infertility, and increasing susceptibility to other diseases (Ngari et al., 2020). Camels are hosts for *T. evansi*, also known as "surra." This disease is common in Turkana, where camels are an important livestock species. One PE study found an annual incidence of 11.4% (Mochabo et al., 2005). HAT has been historically reported in Kenya's western and coastal regions, but there are no reported cases of HAT in Turkana County to our knowledge.

Moreover, in 2020, the Kenya Tsetse and Trypanosomosis Eradication Council (KENTTEC) did a baseline seroprevalence survey on trypanosomiasis in Turkana County. They did not isolate any zoonotic species (personal communication, J.R.K.). Thus, pastoralists likely did not identify trypanosomiasis as a zoonotic disease due to the relative differences in incidence between HAT and AAT. Similarly, a study examining Maasai pastoralists' vulnerability to trypanosomiasis found a similar lack of knowledge of this disease in people. However, it was identified in livestock, highlighting the importance of AAT as a production constraint among pastoralists (Nnko et al., 2017). These results in the context of the literature show that targeted zoonotic disease extension is required in Turkana, which can be best undertaken by joint zoonotic disease extension with human and animal health officials (Griffith et al., 2020). While livestock keepers were aware of zoonoses, zoonoses were not prioritized. Only brucellosis was listed as one of the most critical diseases among the four locations.

This contrasts other studies that have found zoonoses, including anthrax, bovine tuberculosis, and RVF, among the most critical diseases in pastoral areas (Zinsstag et al., 2016).

Like other studies using PE to investigate disease importance among pastoralists, local disease terms described disease syndromes (e.g., symptoms and vectors) and biomedical disease names (Queenan et al., 2017). This variation highlights the ambiguity in local terminology commonly found in PE studies and the importance of clarifying disease names' local (and hyperlocal) meaning and confirming diagnoses using biomedical methods when possible (Queenan et al., 2017). Without taking the time for such clarification, researchers, healthcare providers, and educators may waste time and energy in miscommunication or misdirected activities. Matrix scoring, another PE technique, can ensure local disease terms are correctly identified by their biomedical name (Dunkle & Mariner, 2013).

While our study offers significant insights, it is important to acknowledge certain limitations. Firstly, the modest sample size precluded any statistical analysis of the findings, thus constraining our interpretive scope. Additionally, we enlisted Animal Health Officers (AHOs), who typically work within Turkana's veterinary department conducting syndromic surveillance in livestock, as interpreters. This could introduce a bias given AHOs' greater familiarity with livestock biomedical conditions, despite our emphasis on direct translation during interviews. Moreover, validating reported disease presence through biomedical methods and directly quantifying actual mortality, morbidity, and prevalence for each disease could have enhanced the accuracy of disease identification as per Western clinical disease terminologies. Another limitation lies in the study's failure to thoroughly explore the intersection of environmental quality (e.g., rangeland degradation) with human and animal health, which is integral to pastoralism and a holistic One Health approach (Salza, 2018). Future studies can use more in-depth PE methods to elucidate disease epidemiology, while a larger sample size will allow for quantifiable results. Finally, our study employed "functional participation," in which people form groups to meet predetermined project objectives (e.g., disease control and prevention) typical of PE. While this type of participation can significantly improve disease control, it does not reach "interactive" or "self-mobilization" participation, thereby failing to empower communities truly (Ebata et al., 2020). More research is needed on how to employ higher-level participatory PE methods and what institutional structures facilitate "self-mobilization" to fully realize community empowerment through PE (Allepuz et al., 2017). This may be challenging, given the centralized, top-down service delivery common to pastoral areas like Turkana County, national and international disease priorities (Catley, 2020; Griffith et al., 2020).

Participatory epidemiology has been used to identify perceptions of disease priorities among pastoralists, but these investigations have typically been confined to livestock and zoonotic diseases. Our study breaks new ground by showcasing the feasibility and significant benefits of incorporating human diseases into these inquiries. This expansion is vital for safeguarding the health and livelihoods of pastoral communities. Future research and health initiatives can leverage and expand upon our methodology to adopt a comprehensive One Health strategy for addressing the health challenges faced by pastoralists Kenya's ASALs and beyond.

Conclusions

We successfully implemented a low-resource method to identify community disease priorities and knowledge. We found that disease significance varied by location, yet no discernible pattern suggested the greater importance of human or livestock diseases. Indicators of disease importance remained consistent across human and livestock diseases, reinforcing the necessity and efficacy of a holistic One Health approach. Our methodology also yielded a profound understanding of disease knowledge, enabling targeted health promotion and educational initiatives.

Based on our findings, we strongly advocate for future research, developmental projects, and health programs conducted by government bodies or NGOs among pastoralists to encompass human, livestock, and zoonotic diseases within the framework of PE. Specifically in Turkana, we recommend that personnel in human, animal, and environmental health sectors undergo training in PE to enhance disease prevention and control strategies, which can directly contribute to the Turkana One Health strategy (2023-2027) objective of "strengthening surveillance, prevention, response and control interventions to safeguard One Health priorities" (Griffith et al., 2023). These methods can be combined with traditional sero- and syndromic surveillance, thereby bridging indigenous knowledge and community priorities with healthcare provider skills and resources, ultimately driving improvements in health and protecting livelihoods.

Conflicts of Interest

All authors read and approved the final version of the manuscript, agreed to be accountable for all aspects of the work, and declared no conflicts of interest.

Ethics Statement

The study protocol and FGD interview guide were submitted to and received approval from the Tufts University Institutional Review Board. Verbal consent was obtained after explaining the project's objectives and procedures. Human subject considerations were considered before and while conducting all meetings.

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Data Availability Statement

All relevant data are within the manuscript.

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Author Contributions Statement

Conceptualization, E.F.G., J.R.K., J.C.M, and J.C.S.; Data curation, E.F.G.; Formal analysis, E.F.G. and J.R.K; Funding acquisition, E.F.G. and J.C.M.; Investigation, E.F.G. and J.R.K., Methodology, E.F.G., J.R.K., and J.C.M., Supervision, J.C.M.

and C.A.W.; Writing–original draft, E.F.G.; Writing–review and editing, J.R.K., J.C.M., J.C.S., and C.A.W. All authors have read and agreed to the published version.

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