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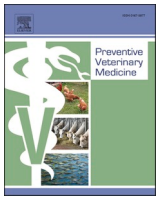

When farmers' knowledge matters: Improving epidemiological understanding of Peste des petits ruminants in northern Nigeria

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ABSTRACT

Peste des petits ruminants (PPR) is an endemic disease of sheep and goats in Nigeria and represents a major threat to the livelihoods of smallholders. Understanding the epidemiology of this disease and its management by livestock farmers is essential for developing appropriate surveillance and control programmes. This study aimed to enhance the knowledge about PPR by conducting a large-scale survey in 52 villages in Plateau, Bauchi and Kano states in the northern part of Nigeria. Our approach involved holding focus group discussions with farmers, both men and women, to collect their knowledge about the disease and to understand their perspectives on its management. The results showed that farmers use several different terms to refer to diseases that are likely to be PPR, and that these same terms might also be used to refer to diseases caused by other infectious agents. Farmers rarely call on veterinary services to prevent the disease and vaccination is seldom practiced. Disease control is attempted using conventional treatments, with or without veterinary supervision, or using traditional therapies. There is limited or poor implementation of good farming practices such as biosecurity measures. This study has increased our understanding of PPR and its management in areas with limited public and private veterinary services. In addition, it has also fostered trust between scientists and communities, paving the way for future participatory action research programmes.

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1. Introduction

Peste des petits ruminants (PPR) is one of the most devastating diseases of small ruminants in Africa, the Middle East and Asia (Banyard et al., 2010; Bataille et al., 2019). The disease is characterised by fever, ocular and nasal discharge, oral erosions, bronchopneumonia and diarrhoea (FAO, 1999). The severity of clinical signs and case fatality rate vary according to the virulence of the virus strain, the species and breed of the host, any concomitant infections and previous exposure of the population to the PPR virus (PPRV) (Banyard et al., 2010). The morbidity rate associated with an outbreak of PPR can reach 100 %, while mortality can reach 90–100 % of the herd in naïve flocks. In endemic areas, the mortality rate may be only 20 % of the herd (Diallo, 2003; Baron et al., 2016). The epidemiological characteristics of PPR and the existence of effective vaccines make it a potentially eradicable disease (Baron et al., 2016; Albina et al., 2013; FAO and WOAH., 2015; Mariner et al., 2016; Njeumi et al., 2020). The Food and Agriculture Organisation of the United Nations (FAO) and the World Organisation for Animal Health (WOAH) have therefore drawn up a global strategy to eradicate the disease by 2030 (FAO and WOAH., 2015). This strategy is based on mass vaccination campaigns to control the circulation of the virus, combined with surveillance activities to monitor changes in the presence of the disease and guide the eradication strategy along the way.

Nigeria is a West African country with more than 100 million small ruminants (FMARD, 2017). PPR is endemic in the country and represents a heavy burden for livestock farmers, particularly smallholders who rely heavily on their livestock as a food source and a financial reserve. In 2017, the country adopted a national strategy to eradicate the disease in line with the global strategy. While there is a national target of vaccinating 75–80 % of the small ruminant population, each of the country's 36 states adopts its own vaccination strategy to achieve this objective. means of achieving this fall within the competence of the. As a result, some states are actively involved in the vaccination campaigns and provide the vaccines for free, while others rely on the willingness of farmers to enrol in fee-paying vaccination programmes. As in many other countries around the world, little progress has been made in controlling the disease in recent years (Zhao et al., 2021). This can be partly explained by a scarcity of resources to produce and deliver vaccines in sufficient quantities, poor knowledge about the dynamics of the animal population (including cross-border movements), poor epidemiological surveillance systems to measure the extent of the disease, and insufficient knowledge of the epidemiological characteristics of the disease to effectively guide surveillance and vaccination strategies. Regarding this last point, although several studies have been carried out on the epidemiology of PPR in Nigeria, they are mainly based on serological or virological surveys of limited scope (Taylor, 1984; Luka et al., 2011; Mantip et al., 2022) and do not provide a general overview of the spread of the disease and its impact on herd health.

In this context, a mixed epidemiological survey, combining conventional and participatory epidemiology, was carried out to improve the understanding of the dynamics of PPR in the small ruminant herds of three Nigerian states, Plateau, Bauchi and Kano. The conventional study consisted of a large-scale serological survey, carried out in 502 villages across the three states, where around 5000 animals were sampled to assess their PPRV immunity status. The participatory study consisted of focus group discussions (FGDs) with farmer communities, primarily to assess the presence of PPR in the area and the terms they use to refer to it. Catley et al. (2012) defines participatory epidemiology as a branch of veterinary epidemiology that improves the involvement of animal keepers in the analysis of animal disease problems, and in the design, implementation and evaluation of disease control programmes and policies. This type of participatory survey has been successfully used in various sub-Saharan African countries to investigate the local characteristics of animal diseases and to incorporate farmers' knowledge into the development of surveillance and control strategies (Queenan et al., 2017; Gizaw et al., 2020).

The article presents the results of the participatory epidemiological survey focusing on communities' endogenous knowledge of PPR, which was conducted between 2021 and 2024 in Plateau, Bauchi and Kano States. It also discusses the usefulness and limitations of using local terminology of diseases when designing and implementing prevention and control measures.

2. Materials and methods

A cross-sectional study was undertaken among small ruminant smallholder farmers in Plateau, Bauchi and Kano, using FGDs with a highly structured interview guide.

2.1. Description of study area

The study was part of the EU-funded Livestock Disease Surveillance Knowledge Integration (LIDISKI) project, which aimed at improving surveillance and control of PPR in Northern Nigeria where the majority of the small ruminant population is concentrated. The project targeted smallholder farmers in three northern states, Plateau, Bauchi and Kano, connected by animal movements (Fig. 1). The climate is tropical, with two seasons: a dry season from November to March and a rainy season from April to October. The climatic and ecological conditions are conducive to agriculture, with the majority of the population engaged in agro-pastoralism (Grove, 2023). Small ruminants are a main source of subsistence for many farming families and can be owned by female or male farmers. Most frequently, the former are involved in the day-to-day management of sheep and goats, while the latter control aspects related to marketing and medication (Oluwatayo and Oluwatayo, 2012; Akindele et al., 2022; Tafida and Olayinka, 2021). Smallholder livestock farmers rearing sheep and goats are pastoralists or agro-pastoralists, adopting intensive, semi-intensive or extensive management practices depending on the season. When animals are contained, they are kept in roofed pens made of clay, concrete, and tree branches. Small ruminant smallholders usually sell their live animals at weekly markets or to middlemen. While the number of nomadic farmers has recently decreased (Braam et al., 2023), intense transhumance movements exist within and between all three states of the study, as well as with other Nigerian states and neighbouring countries, especially during the dry season. In addition, the area is at the crossroads of commercial movements between a large number of states (Ijoma et al., unpublished results). As often in Nigeria, the three states are characterised by a high degree of ethnic and religious diversity, with the majority of the population based in rural communities (Waziri and Yunusa, 2014). In Bauchi and Kano, Hausa is the most predominant ethnic group and Hausa farmers are sedentary agro-pastoralists. In these two states, members of the Fulani community also raise small ruminants and cattle, and undertake transhumance during the dry season. In Plateau, several different ethnic groups are engaged in rearing small ruminants, mainly goats. They are sedentary agro-pastoralists. Although English is the country's official language, indigenous local languages are commonly spoken by different ethnic groups, with Hausa being the lingua franca in the three states of the study.

Despite slight differences, the organisation of animal health systems is similar across the three states. Community animal health workers (CAHWs) and para-veterinarians are the first-line providers of animal health services. They work under the supervision of a public veterinarian, who reports to the state department of veterinary services. The vaccination strategy towards PPR eradication differs from one state to another. Vaccination is sponsored by the state government at 95 % in Bauchi and Kano, but only 20 % in Plateau. Consequently, farmers in that state hardly vaccinate against PPR. In general, vaccination campaigns are disrupted by security issues and by structural constraints, such as the shortage of doses or insufficient resources to ensure the last-mile delivery of the vaccines in good condition.

There is no reliable available data about the occurrence of PPR in the

three states. However, the serological survey conducted prior to the participatory survey suggested a widespread distribution of the disease (with almost all villages returning seropositive results) and estimated an overall seroprevalence of 40 % among unvaccinated animals (Rayyanu et al., unpublished).

2.2. Sampling strategy and participant recruitment

For the serological survey conducted prior to the participatory survey from November 2021 to February 2024, the village was considered as the most relevant epidemiological unit because animals from different herds are reared in close contact through shared water points and grazing areas. Two hundred villages in Plateau, 220 in Bauchi, and 82 in Kano were randomly selected (Rayyanu et al., unpublished). For the participatory study, we selected approximately 10 % of these villages for interviews with farmers, totalling 20 villages in Plateau, 22 villages in Bauchi and 10 villages in Kano. This sampling fraction was chosen to ensure the best geographical coverage with regard to the resources available. The selection process was made in consultation with the state veterinary services. The initial intention was to ensure a balanced representation between the number of PPR-seropositive villages (villages where at least one seropositive animal had been detected with the serological survey) and seronegative villages (villages where no positive animal had been detected), while maintaining good geographical coverage across the three states. However, as the serological results showed a significant spread of the virus across the three states, we were unable to achieve a balanced representation of seropositive and seronegative villages in the final sample. In addition, the rapidly changing security situation in the study area required adjustments to the initial list of villages throughout the study to ensure the safety of field staff.

For each of the selected villages, permission was sought from the village chief, who was then tasked with the responsibility of selecting 10 adult women and 10 adult men from goat- and sheep-owning households, ensuring that each participant was from a different household.

There was no attempt to balance ethnic and religious groups in the selection of villages or participants.

2.3. Data collection

In each surveyed village, one FGD with female farmers and one with male farmers were conducted separately by a female team and male team of investigators, respectively. Each team consisted of a facilitator, a note-taker and, if necessary, a translator, all researchers at the National Veterinary Research Institute of Nigeria and specifically trained to conduct the survey. A core team of seven researchers were involved in all field missions across the three states. They were occasionally assisted by four other colleagues. The discussions were conducted in Hausa, the lingua franca, except in Plateau where participants mixed Hausa and English. The discussions used interactive tools commonly applied in participatory rural appraisal, ethnoveterinary, or qualitative epidemiology surveys (Hannah and Jost, 2011; Catley et al., 2012). The use of these tools facilitates the expression of points of view and produces visual representations of the participants' responses, enabling them to visualise, reflect on and debate how their responses were understood and captured by the research team. Additionally, they help researchers to interpret, check their understanding of, and potentially reformulate the participants' statements (Bordier et al., 2020).

2.4. The interviews were conducted in four steps

The first consisted of introducing the research team and the objectives of the survey, as well as asking for the participants' consent. If

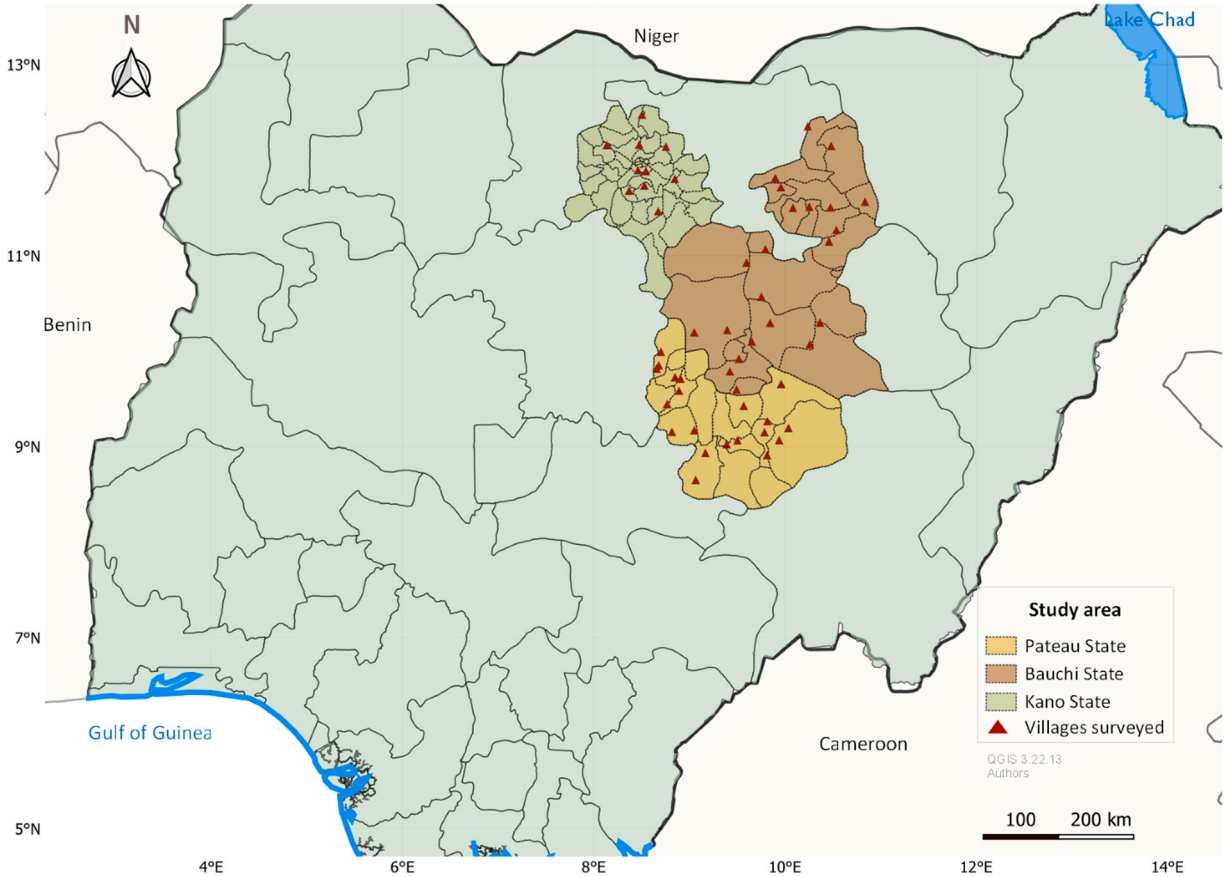

Fig. 1. Map of the study area indicating the villages where the survey was conducted.

consent was obtained, participants were then invited to introduce themselves.

The second stage focused on identifying and characterising the most devastating diseases affecting the participants' small-ruminant herds during the previous 12 months. Participants were asked a series of questions about the names and clinical signs of these diseases, their significance, the species and age groups affected, the period of occurrence and any preventive and control measures implemented. The information shared was recorded over the course of the discussion on a large sheet of paper placed between the facilitator and the group of participants (Fig. 2a). Once the diseases had been described, the participants were asked to rank them in decreasing order of severity for their herds.

The third step was to identify and characterise the diseases most likely to be PPR among those listed as the most devastating diseases by the participants. First, a disease-scoring matrix[1] was created with the participants to identify the relative importance of the most commonly mentioned clinical signs associated with the four most devastating diseases as ranked by each farmers' group (Fig. 2b). This stage provided an opportunity to cross-check the information on the clinical picture collected in the previous stage and to identify and discuss any inconsistencies between the two data sources. Once the matrix was completed, the research team identified any disease(s) that was thought likely to be PPR, based on the clinical signs commonly described in the literature: respiratory clinical signs such as coughing, lacrimation, sneezing, mouth erosions, fever, diarrhoea, and high rates of morbidity and mortality (Banyard et al., 2010; FAO, 1999). If none of the diseases was suggestive of PPR, the interview was stopped. Next, we asked participants to indicate the occurrence period of the PPR-like disease(s) on a seasonal calendar[2] previously drawn up with them (Fig. 2c). This helped to confirm the information about disease occurrence previously collected (Step 2). In the last part of the step three, participants used proportional piling[3] to estimate the number of animals that fall ill when the PPR-like disease occurs and the number that eventually recover, die, or are sold or consumed (Fig. 2d).

In the last step, in Bauchi and Kano States, if the identified PPR-like diseases were currently present in the village, an antigenic rapid test for PPRV (IDvet) was carried out on a sample (maximum five) of the animals displaying clinical signs of the disease. The choice of the sample depended on the most predominant clinical signs. In case of predominant respiratory signs, an ocular and nasal swab was used; in case of digestive signs, a rectal swab. A clinical observation of the animals was carried out and clinical signs recorded. No test was conducted in Plateau State because rapid tests were not available.

The interview guide is available in the supplementary materials (Supplementary file 1. Interview guide to conduct the FGD with farmers).

At the end of the FGDs, the research team provided recommendations related to PPR management, mainly in relation to the need to seek for animal health services when they observe clinical signs and to the importance of vaccination to prevent PPR.

While the FGDs were structured around specific questions related to the epidemiology and management of PPR, the farmers were given the opportunity to ask questions about other animal health issues of interest to them at the end of the discussion.

[1] A series of proportional piling exercises where a list of diseases is scored against a number of clinical signs to create a matrix.

[2] A visualization method to illustrate seasonal variations in disease incidence. A timeline representing a 12-month period is drawn on which participants are asked to mention events that make sense for them (farming activities, climatic seasons, religious festivities, etc.). Then participants are asked to indicate the period when the disease is occurring.

[3] Proportional piling allows farmers to give relative scores to a number of different items or categories according to one criterion.

2.5. Data management and analysis

All documents related to the FGD (consent forms, sheets of paper used to collect data at the various stages) were scanned and uploaded into a dedicated folder with the corresponding notes transcribed in English.

A form was developed in a spreadsheet to record and organise qualitative and quantitative data extracted from all documents. For textual data, an analysis was carried out to identify recurring themes and create categories. For any descriptive variables for which several sources of data were possible (seasonality, cause, prevention, and treatment of illness), we compared the consistency of the data across sources. In the event of a discrepancy between the different sources, the most frequently cited value was retained for the analysis. If a rapid test had been carried out in the village, the result was entered into the database for the disease concerned.

We conducted a descriptive analysis of the compiled database to summarise the key characteristics of PPR-like diseases. Based on the proportional piling results, we calculated the following epidemiological indicators for each PPR-like disease and each species (sheep and goats): morbidity rate (number of diseased animals/100); mortality rate (number of dead animals/100); case fatality rate (number of dead animals/(number of diseased animals - number of sold and consumed animals)). A *t*-test was conducted to compare the means of these indicators across species and states. The difference was considered significant if the p-value was less than 0.05. All calculations and comparisons were carried out using R (version 4.2.1) and R Studio software.

3. Results

3.1. Participants

A total of 104 FGDs were conducted in 20 villages (11 seropositive, 8 seronegative, and one with no serological results) across Plateau State between May and July 2021, 22 villages (21 positive, one seronegative) across Bauchi State in July and August 2022 and 10 villages (all positive) across Kano State in April and May 2024. Except in one village in Bauchi where farmers were nomadic agro-pastoralists, participants were all sedentary agro-pastoralists smallholder farmers. They practised extensive breeding during the dry season, intensive breeding in the early rainy season to avoid conflicts with agricultural activities in the fields, and semi-intensive in the mid-rainy season. Table 1 describes the participants recruited for the FGD in each state.

All the FGDs in all three states included both goat owners and sheep owners, except a few FGDs in Plateau that were exclusively attended by goat owners. The number of participants remained constant throughout each interview in Plateau and Kano, while it varied throughout some of the interviews in Bauchi, with participants arriving and leaving the group during the sessions to tend to family or professional matters.

3.2. Diseases with the greatest perceived impact

During the discussions, participants mixed English, Hausa or their local dialect (if different from Hausa) to refer to diseases. For the rest of the manuscript, we will use only the Hausa name (as stated by participants during the discussions) and we will use the generic term "disease" whatever the nature of the term used (e.g., a pathological condition, a clinical sign, a cause, or an affected organ).

In Plateau State, 35 major diseases were mentioned, 28 by women and 17 by men, with 10 mentioned by both. The diseases most frequently mentioned were: *zawo* (mentioned in 85 % of interviews), then *hanta* (35 %), *mura* (33 %), *tari* (23 %), *chiwon kofoto* (20 %) *kaska* (20 %), and *majina* (15 %). Of these illnesses, six were considered at least once to be the most serious: *zawo* (in 78 % of interviews), *mura* (8 %), *hanta* (5 %), *chiwon iska* (5 %), *annoba* (2 %) and *majina* (2 %) (Table 2).

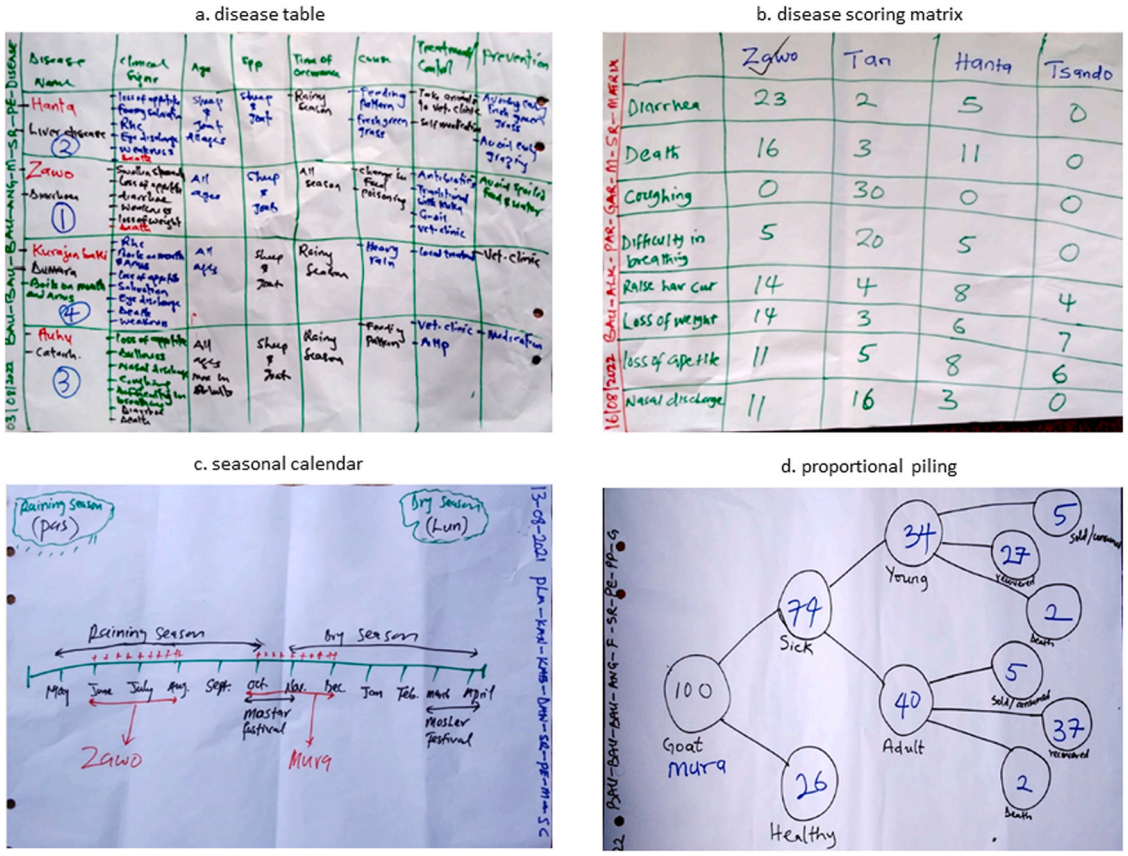

Fig. 2. Participatory tools used during focus group discussions with farmers to collect their knowledge about small ruminant diseases.

Table1
Description of the focus group discussion and of their participants.

	Plateau State	Bauchi State	Kano State
Number of female-only FGDs	20	22	10
Number of male-only FGDs	20	22	10
Number of participants in each FGD	6–12	7–12	10–11
Number of FGDs with participants raising sheep	8 (female) 12 (male)	22 (female) 22 (male)	10 (female) 10 (male)
Number of FGDs with participants raising goats	20 (female) 20 (male)	22 (female) 22 (male)	10 (female) 10 (male)

In Bauchi state, 35 major diseases were mentioned, 27 by women and 25 by men, with 17 mentioned by both. The diseases most frequently mentioned were *zawo* or its synonyms *gaduwa and zawayi* (mentioned in 82 % of interviews), followed by *kuraje* (50 %), *mura* (41 %), *huhu* (39 %), *hanta* (39 %) and *kofoto* (29 %). For *mura* (catarrh), farmers also used *sanyi* (cold) or *raba* (dew) to refer to this disease during the discussions. Eight of these illnesses were considered at least once to be the most serious: *zawo* (in 52 % of interviews), *hanta* (14 %), *huhu* (14 %), *bugau* (7 %), *chiwon daji* (5 %), *mura* (5 %), *chiwon saifa* (2 %) and *kuraje* (2 %) (Table 2).

In Kano State, 24 major diseases were mentioned, 14 by women and 18 by men, with eight cited by both. The diseases most frequently mentioned were: *hanta* (mentioned in 85 % of interviews), *huhu* (60 %), *zawo* or *gudawa,* which are synonyms and used interchangeably during discussions (50 %), *kwarkwata* (35 %), gishew (15 %) and *mura* (15 %). Among these illnesses, five were considered at least once the most serious: *zawo* (in 35 % of interviews), *hanta* (35 %), *huhu* (20 %), *zazzabi* (5 %), and *gishew* (5 %) (Table 2).

There is no significant difference between the male groups and the female groups regarding the most serious diseases affecting the small ruminants, in the three states. However, some diseases were prioritised by women that did not feature in discussions with men, and vice versa. In addition, in Plateau the women mentioned more diseases than the men.

3.3. Diseases possibly being PPR

Across the FGDs of Plateau State, at the end of the disease-scoring exercise six different diseases were considered at least once as possibly being PPR by the research team: *zawo* (in 85 % of the FGDs), *mura* (5 %), *annoba* (2.5 %), *hanta* (2.5 %), *chiwon iska* (2.5 %), and *majina* (2.5 %). In 19 of the 20 villages, *zawo* was identified in at least one of the two group interviews as the disease most suggestive of PPR (Table 3).

In Bauchi State, five diseases were considered at least once as possibly being PPR by the research team: *zawo* (in 61 % of the FGDs), *huhu* (20 %), *mura* (10 %), *hanta* (7 %) and *bugau* (2 %). In 19 of the 22 villages, *zawo* was identified in at least one of the two group interviews as the disease most suggestive of PPR. In the interviews where *huhu* was considered to be the disease most suggestive of PPR, *zawo* was also mentioned as one of the most devastating diseases and identified as the disease possibly being PPR in the other focus group in the same village (Table 3).

In Kano State, four diseases were considered at least once as possibly being PPR by the research team: *huhu* (in 45 % of the FGDs), *zawo* (45 %), *hanta* (20 %) and *mura* (10 %). In four interviews, two diseases were considered as possibly PPR (*zawo* and *mura* in two FGDs, *zawo* and *huhu* in one FGD, *hanta* and *huhu* in one FGD) (Table 2). The seasonal calendar showed that the two diseases were either concomitant or followed each other closely in time.

There is no significant difference between the male groups and the

Table 2
Diseases ranked by different FGDs as the single most serious affecting small ruminants, by number of mentions.

Plateau State				**Bauchi State**				**Kano State**			
Disease	F	M	Total	Disease	F	M	Total	Disease	F	M	Total
Zawo	13	18	31	*Zawo*	10	13	23	*Zawo*	3	4	7
Mura	3	1	4	*Hanta*	4	2	6	*Hanta*	5	2	7
Hanta	2	0	2	*Huhu*	2	4	6	*Huhu*	0	4	4
Chiwon iska	1	1	2	*Bugau*	3	0	3	*Zazzabi*	1	0	1
Annoba	1	0	1	*Chiwon daji*	1	1	2	*Gishew*	1	0	1
Majina	0	1	1	*Mura*	1	1	2				
				Chiwon saifa	0	1	1				
				Kuraje	1	0	1				

F = female groups; M = male groups

Table 3
Possible PPR-like diseases, by frequency of identification by the research team.

Plateau State					Bauchi State					Kano State				
Diseases	Meaning	F	M	Total	Diseases	Meaning	F	M	Total	Diseases	Meaning	F	M	Total
Zawo	Diarrhoea	16	18	34	*Zawo*	Diarrhoea	14	13	27	*Huhu*	Lung	4	5	9
Mura	Catarrh	2	0	2	*Huhu*	Lung	3	6	9	*Zawo*	Diarrhoea	4	5	9
Annoba	Death	1	0	1	*Mura*	Catarrh	3	1	4	*Hanta*	Liver	3	1	4
Hanta	Liver	1	0	1	*Hanta*	Liver	1	2	3	*Mura*	Catarrh	1	1	2
Chiwon iska	Madness	0	1	1	*Bugau*	Death	1	0	1					
Majina	Nasal discharge	0	1	1										

female groups regarding the diseases most frequently considered as possibly being PPR. However, some diseases have been considered as possibly being PPR in female groups only, and others in male groups only.

Overall, in the three states the diseases most often considered to be PPR, hereafter referred to as "PPR-like diseases", were *zawo* and its synonyms (65 % of cases), *huhu* (17 %), *mura* (7 %) and *hanta* (7 %) (Fig. 3). These terms corresponded to diseases with a predominantly respiratory (*mura* and *huhu*) or digestive (*zawo* and *hanta*) clinical signs.

3.3.1. Clinical features associated with PPR-like diseases

In Plateau State, *zawo*, the disease most often considered to be possibly PPR, was primarily associated with weight loss (85 % of cases), diarrhoea (82 %), loss of appetite (71 %), mortality (68 %), runny nose (50 %), shaggy hair (41 %), and weakness (32 %). Respiratory clinical signs such as difficulty breathing and coughing were less frequently reported.

In Bauchi State, the clinical signs of *zawo*, most often considered to be possibly PPR in that state, was characterised by mortality (75 % of cases), diarrhoea (72 %), loss of appetite (61 %), shaggy hair (50 %), weight loss (50 %), weakness (44 %), swollen belly (33 %), runny nose (25 %), cough (19 %), and fever (19 %).

In Kano State, *huhu* and *zawo* were considered most often to be possibly PPR in 50 % and 40 % of the cases, respectively. For *huhu*, the predominant clinical signs were: mortality (100 % of cases), cough (92 %), foamy salivation (69 %), loss of appetite (62 %), weight loss (46 %), difficulty breathing (46 %), diarrhoea (38 %) and salivation (31 %). For *zawo*, they were: diarrhoea (100 %), weight loss (100 %), mortality (100 %), loss of appetite (100 %), weakening (60 %), shaggy hair (50 %), nasal discharge (50 %), eye discharge (50 %), breathing difficulty (50 %), and bloating (50 %).

3.3.2. Seasonality of PPR-like diseases

Zawo and *mura* were described as occurring mainly during the rainy season in 70 % and 55 % of the cases, respectively. In the other cases, they were described as occurring all year round. *Huhu* and *hanta* were described as occurring all year round in 53 % and 40 % of the cases, respectively, with some groups reporting the highest incidence during

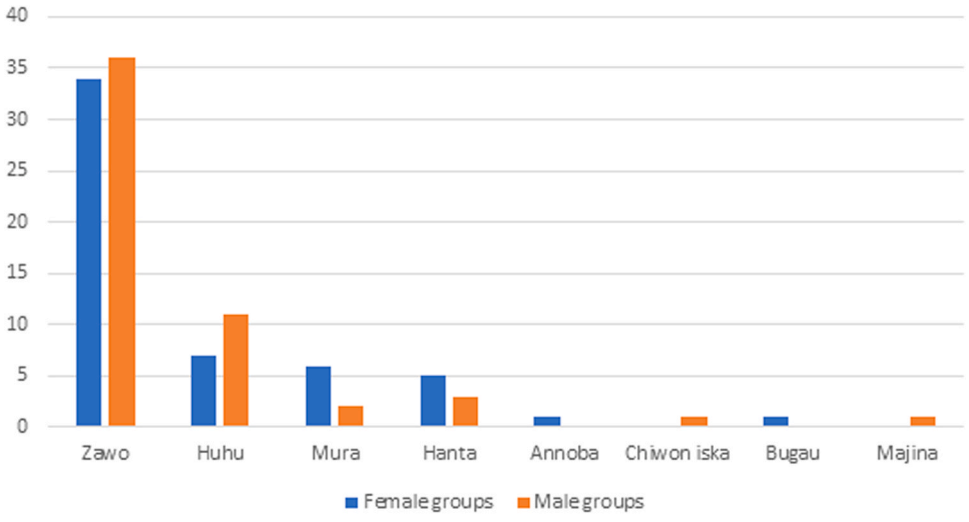

Fig. 3. Frequency of diseases considered possibly PPR in Plateau, Bauchi and Kano States.

the rainy season (22 % and 36 %, respectively), and others during the dry season (22 % and 13 %, respectively).

3.3.3. Cause of PPR-like diseases

In majority of cases, farmers in the three states were unable to identify the cause of the diseases. For diseases characterised mainly by intestinal clinical signs (*zawo* and *hanta*), the major cause mentioned was a change in the animal's diet. This change often occurs at the start of the rainy season when the animals gain access to fresh green grasses. For diseases predominantly exhibiting respiratory clinical signs (*mura* and *hanta*), a change in weather conditions (rising or falling temperatures, increased humidity and the presence of the Harmattan wind[4]) was the main cause mentioned.

3.3.4. Practices regarding prevention and control of PPR-like diseases

In Plateau and Bauchi States, approximately half of farmers took no measures to prevent PPR-like diseases (in 50 % and 54 % of cases respectively). When measures were taken, they consisted of conventional medication (manufactured drugs, such as antibiotics or dewormers). They consulted veterinary services in 29 % of the cases. Veterinary services in these cases were either veterinarians, para-veterinarians or CAHWs. However, farmers had difficulties in distinguishing different categories of animal health workers. Farmers in the two states made little use of vaccination (0 % and 14 %, respectively). In Kano, farmers used preventive measures in 76 % of cases. These measures mainly consisted of biosecurity practices in case of outbreaks in the surroundings (24 %), such as isolating sick animals, and avoiding animal gathering points and introduction of new animals into the herd, and good husbandry practices (11 %), such as hygiene and quality of the premises (clean and safe environment, proper ventilation, shade) and provision of quality food and water. Farmers sought assistance of veterinary services in 20 % of cases (veterinarians, para-veterinarians or CAHWs). In 18 % and 11 % of cases, respectively, farmers in Kano reported using traditional medicine (mainly plants, such as baobab powder, mahogany, kuka leaves, or salt and charcoal) or conventional medicine (dewormers, antibiotics). The use of vaccination as an intervention was mentioned in only 2 % of cases.

When one of the PRR-like diseases was observed on farms, farmers implemented control measures in 84 % of cases in Plateau, and always in Bauchi and Kano. They called in veterinary services in 34 % of cases in Plateau, 50 % in Bauchi and 96 % in Kano. Livestock farmers in Plateau and Bauchi used either traditional medicine, in 32 % and 40 % of cases, respectively, or conventional medicine, in 55 % and 29 % of cases, respectively. Traditional medicine was usually used as a first-line treatment more because it was immediately available on site in the farm than because of its expected effectiveness. Conventional medicine was usually reserved for more serious cases, particularly those that did not respond to traditional treatment, provided that farmers have access to it (availability nearby and affordable price). Despite the extensive use of the veterinary services in Kano, farmers still used traditional medicine to control diseases (33 % of cases). In Plateau, farmers mentioned the importance of good husbandry practices, such as heating the pens with burning charcoal. In Bauchi and Kano, some farmers practiced depopulation methods such as slaughter or emergency sale, meaning that they sold or slaughtered more animals during disease outbreaks compared to normal time, to minimise overall loss of animals to disease.

3.3.5. Morbidity, mortality and case fatality rate associated with PPR-like diseases

Data related to the epidemiological indicators calculated based on farmers' perceptions in the three states are presented in Table 4 and Fig. 4.

In Plateau State, morbidity due to *zawo* was perceived to be higher in goats (75 %) than in sheep (65 %) ($p = 0.04$), while in Bauchi and Kano States no significative difference was observed between species for any of the indicators of the PPR-like diseases.

For goats, the impact of *zawo* in Plateau State was perceived to be greater than in Kano State, and to a lesser extent than in Bauchi State. Morbidity in Plateau State (75 %) was higher than in Bauchi State (61 %) ($p = 0.008$) and Kano State (59 %) ($p = 0.0001$). Perceived mortality rates in Plateau State (36 %) and Bauchi State (28 %) were higher than in Kano State (20 %) ($p = 0.0002$ and $p = 0.01$ respectively). Case fatality rates in Plateau (67 %) and Bauchi (62 %) States were reported to be higher than in Kano State (47 %) ($p = 0.001$ and $p = 0.01$, respectively). For sheep, the impact of *zawo* also appeared to be more detrimental in Plateau and Bauchi States than in Kano. Mortality was perceived to be higher in Plateau State (35 %) and Bauchi State (27 %) than in Kano State (15 %) ($p = 0.0004$ and $p = 0.002$, respectively). Case fatality rate was also significantly higher in Plateau State (64 %) and Bauchi State (63 %) than in Kano State (44 %) (respectively $p = 0.04$ and $p = 0.003$).

3.3.6. Rapid test for the detection of PPR virus

Farmers reported the presence of animals with PPR-like clinical signs in five villages in Bauchi and four villages in Kano. Results of the rapid test conducted on all animals with clinical signs present at the time of the FGD (up to five) are presented in Table 5. In Bauchi, among 13 animals affected with *zawo* across four villages and tested, three animals tested positive for PPR. They were all combining respiratory and digestive clinical signs. The single animal affected with *huhu* was tested and found positive, and the single one affected with *mura* was found negative. In Kano, among the nine animals affected with *mura (1), zawo (2)* or *huhu (6)*, only two of those affected with *huhu* were found positive, in the same village.

4. Discussion

Our study revealed a wide range of diseases of concern for small ruminant smallholder farmers in Plateau (35 diseases), Bauchi (35) and Kano (24). Contrary to what is described in the literature (Sinn et al., 1999), we did not observe a great difference of results between the reported experiences of female and male farmers regarding diseases. To describe these diseases, farmers use clinical manifestations (diarrhoea, cough, etc.), physiological conditions (sudden death, weakness, etc.) or organs affected (lung disease, liver disease, etc.) as observed in other studies (Catley, 2006; Queenan et al., 2017; Jones et al., 2020). Following the results of the 104 FGDs, four main diseases were identified that exhibit clinical characteristics similar to PPR. *Zawo* was overwhelmingly considered the disease most likely to be PPR in Plateau (85 % of cases) and Bauchi (61 %). However, in Kano, *zawo* was identified as likely to be PPR in only 45 % cases. *Zawo*, which means diarrhoea, was identified in 67 % of the cases, and *hanta*, which means liver, was reported in 7 % of the cases. Both of these were most often associated with diarrhoea, but also frequently associated with respiratory clinical signs (nasal discharge, cough, dyspnoea). *Huhu* (reported in 17 % of the cases), meaning lung, and *mura* (9 % of the cases), meaning catarrh, were both dominated by respiratory signs (coughing, dyspnoea), but digestive signs were also reported in 50 % of the cases.

According to the farmers, the diseases most suggestive of PPR can occur all year round but with a highest incidence during the wet season and, to a lesser extent, at the end of the dry season. This is consistent with the seasonal occurrence of PPR as described in the literature. Outbreaks of PPR are often attributed to changes in weather, that is, at either the end of the dry season or the onset of the rainy season, or during the wet months (Ezeokoli et al., 1986; Okoli, 2003; Abubakar et al., 2009). The end of the dry season is associated with cooler temperatures and Harmattan, which are conducive to the persistence of the

[4] The Harmattan season is between the end of November and the middle of March, characterised by the dry and dusty north-easterly trade wind of the same name, which blows from the Sahara over West Africa.

Table 4
Morbidity, mortality and case fatality rate perceived by farmers for the most frequent PPR-like diseases in Plateau, Bauchi and Kano States.

		Plateau		Bauchi		Kano			
		Zawo		*Zawo*		*Zawo*		*Huhu*	
		Sheep	Goat	Sheep	Goat	Sheep	Goat	Sheep	Goat
Morbidity	min.	26 %	18 %	18 %	26 %	28 %	41 %	33 %	27 %
	max.	91 %	94 %	100 %	82 %	91 %	73 %	91 %	73 %
	med.	70 %	80 %	69 %	65 %	40 %	64 %	65 %	60 %
	mean	65 %	75 %	60 %	61 %	49 %	59 %	61 %	55 %
Mortality	min.	2 %	4 %	3 %	4 %	2 %	6 %	8 %	5 %
	max.	74 %	71 %	50 %	45 %	24 %	27 %	31 %	36 %
	med.	42 %	36 %	27 %	31 %	16 %	23 %	17 %	13 %
	mean	35 %	36 %	27 %	28 %	15 %	20 %	16 %	15 %
Case fatality rate	min.	10 %	22 %	21 %	6 %	10 %	23 %	33 %	23 %
	max.	85 %	100 %	82 %	87 %	79 %	69 %	75 %	80 %
	med.	74 %	72 %	67 %	65 %	39 %	49 %	50 %	42 %
	mean	64 %	67 %	63 %	62 %	44 %	47 %	52 %	49 %

virus in the environment and its likelihood of transmission. Furthermore, animals that have endured a long period of drought are weakened and more vulnerable to viral infections (Mantip et al., 2019). At the beginning of the wet season, animals are released from the pens where they were kept during the dry season and experience close contact with animals from other herds, which is conducive to the circulation of the virus. In addition, transhumant farmers usually return in the middle of the wet season (June and July) in this part of the country; their animals represent a further risk of introduction of the PPRV in the sedentary flocks of the area (Ijoma et al., unpublished results). During the rainy season, high humidity may also increase the persistence of PPRV in the environment and the likelihood of its transmission (Cao et al., 2018). Year-round kidding, which causes a constant introduction of susceptible animals, in association with intense commercial animal movements throughout the year, could explain the perennial occurrence of outbreaks (Mantip et al., 2019).

In terms of the prevention and control of PPR-like diseases, practices were fairly uniform among communities within the same state. In Kano State, where small-ruminant farming is predominant among agricultural activities, farmers seemed to be more aware of the importance of good husbandry practices to prevent diseases (hygiene and housing quality, biosecurity rules, etc.). This can be explained by the fact that farmers in this state were more exposed to awareness campaigns in relation to animal health management (good husbandry practices, disease reporting) conducted by the authorities and aid programmes. The use of veterinary services, whether for disease prevention or treatment, is much more marked in Bauchi and Kano States than in Plateau State. This discrepancy is probably due to the reported poor coverage of public and private veterinary services in Plateau State. While the use of traditional medicine is common in all three states, it is more common in Bauchi and Kano, where the use of traditional medicine is deeply rooted in the culture of the Hausa and Fulani, the most predominant ethnic groups (Abubakar et al., 2007). In Plateau and Bauchi States, farmers mentioned depopulation practices for sick animals through method such as salvage sales or slaughter for consumption. These practices can increase the risk of spreading the disease within the animal population, as well as posing a zoonotic risk if such animals are infected with pathogens transmissible between animals and humans. While PPR is a disease that can be effectively controlled by vaccination, this practice was not frequently used in any of the three states.

The morbidity and mortality rates described by farmers were compatible with those described in the literature for endemic areas where part of the population has acquired immunity during previous outbreaks of the disease (Diallo, 2003; Baron et al., 2016). Goats are generally considered more susceptible to the disease than sheep (Truong et al., 2014; Wernike et al., 2014). However, in this study a higher morbidity rate in goats than in sheep was only significant in Plateau.

This study has identified a wide range of terms suggestive of PPR, with temporal and spatial variations. For two of the identified diseases (*zawo* and *huhu*), the limited rapid tests conducted confirmed that they were indeed associated with PPRV. The four diseases most likely to be PPR (*zawo*, *mura*, *huhu* and *hanta*) displayed predominantly either digestive or respiratory clinical signs. When several PPR-like diseases were identified in a given FGD, seasonal calendars showed that they occurred concomitantly or successively. This suggests that these four diseases could potentially all be caused by PPRV, but that farmers use different terms depending on the relative severity of clinical signs and the predominance of the digestive or respiratory form (Catley et al., 2012; Jost et al., 2007; Queenan et al., 2017; Jones et al., 2020). The results of this study also suggest that the terms used for PPR-like diseases may be used for other predominantly respiratory or digestive diseases with different aetiologies than PPRV. According to the farmers, the leading cause of *zawo* is the consumption of fresh grass growing at the beginning of the wet season. This may simply reflect the fact that grass growth coincides with an increase in the incidence of PPR, or it may suggest that *zawo* was used to refer to other predominantly digestive diseases that appear with the change in food diet, in particular enterotoxaemia, which is favoured by the consumption of fresh grass. Additionally, *zawo* was mainly described at the beginning of the rainy season, where small ruminants are also highly exposed to infection with *Haemonchus* parasites, which causes haemonchosis including clinical signs of acute and severe diarrhoea. Similarly, the clinical signs associated with *mura* and *huhu* may also be suggestive of pasteurellosis, which usually occurs at the same time. Although the low sensitivity of the rapid test may have led to false negative results, the fact that PPRV was not systematically detected with this test in animals that were manifesting one of these PPR-like diseases corroborates this hypothesis. Finally, the fact that the names of the PPR-like diseases refer to clinical signs, conditions or organs affected and that they were associated with a wide variety of clinical signs - not always commonly described in cases of PPR - also suggests that they may be used to describe co-infections.

These results highlight the richness of information that can be collected using such participatory epidemiology, and its potential to contribute to the epidemiological knowledge of diseases and to the development of interventions better adapted to local needs and settings. They make it possible to identify the diseases of great concern to the farmers, the terms they use to refer to these diseases, the clinical manifestations that alert them to the occurrence, and their general disease management practices. All this information is useful for subsequently developing interventions that meet farmers' needs (prevention and control programmes focusing on diseases that are a priority for farmers) and that are correctly contextualised (surveillance system using case definitions based on clinical signs suggestive of PPR for farmers, awareness campaigns using the terminologies used to develop appropriate and comprehensive messages, etc.). However, this study also highlighted the complexity and ambiguity that may exist in the local terminology for diseases and that need to be taken into consideration when using those terms for disease prevention and control. For instance,

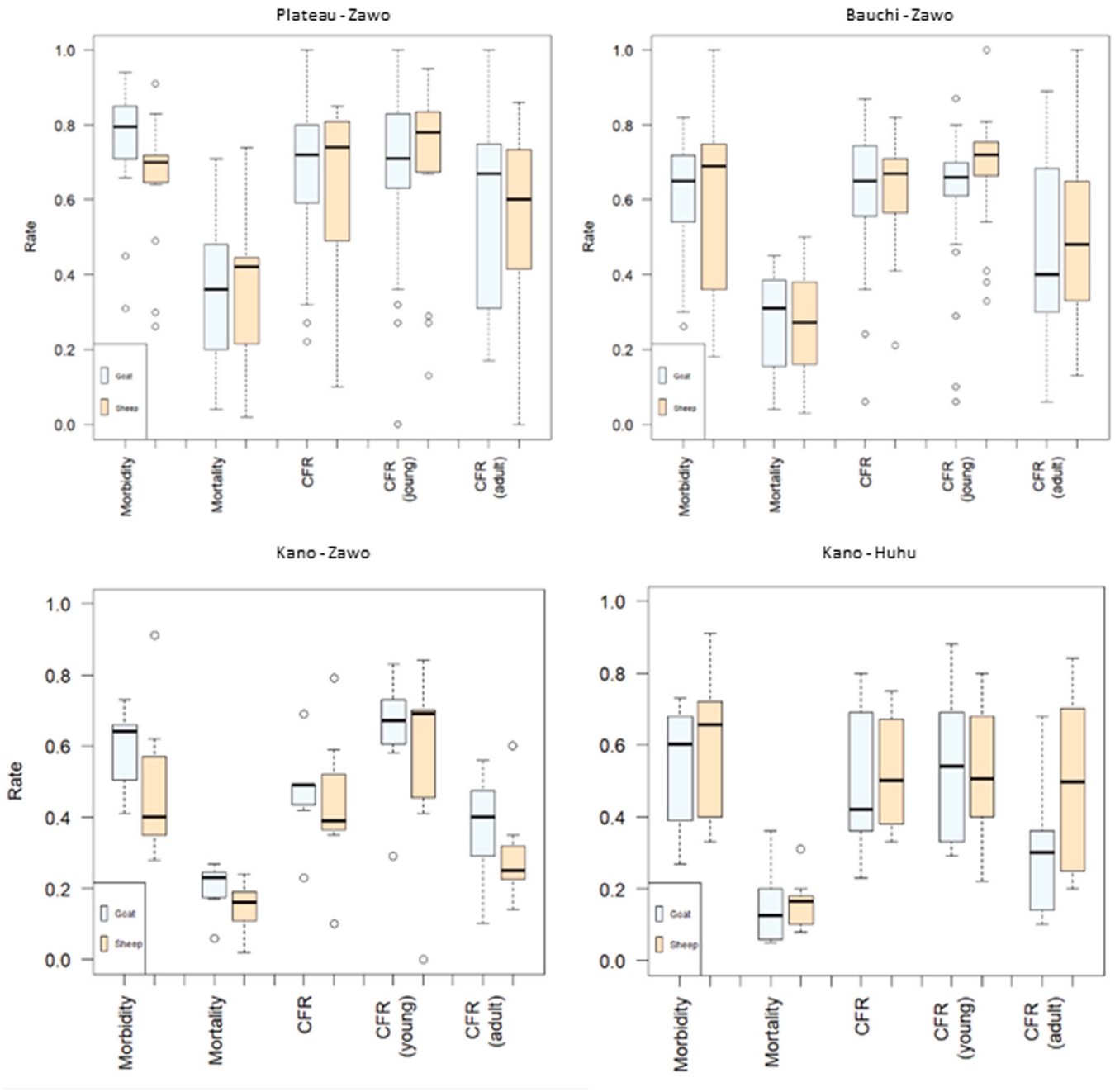

Fig. 4. Morbidity, mortality and case fatality rate of the most common PPR-like diseases in Plateau, Bauchi and Kano States.

when vaccination campaigns against PPR are implemented, it is crucial to inform farmers that vaccination will not prevent all cases of *zawo* in their herds, as some cases may be due to other aetiological agents. A miscommunication on this point could result in farmers losing confidence in PPR vaccination in the future. Regarding epidemiological surveillance, validation of PPR-like disease cases with laboratory tests is necessary to confirm PPR cases before incorporating them in a surveillance system (Queenan et al., 2017; Jones et al., 2020).

In addition to improving the knowledge of diseases and their management, participatory epidemiology also helps to create a climate of trust between scientists and farmers, because information is gathered through active, non-judgemental listening in a spirit of co-learning between the two parties (Bordier et al., 2024). Although the participatory dimension of this study remains limited, it has enabled the development of relations among researchers, authorities and farmers in a geographical area and has produced knowledge about diseases of concern for farmers that can subsequently be mobilised to define prevention and control measures that take account of farmers' perceptions and are more readily accepted. Following the FGDs, and up to now, farmers have repeatedly called the research team to seek for assistance to manage disease events or to purchase PPR vaccines. Researchers organised feedback meetings with the communities to disseminate the knowledge that was produced with the FGDs and to discuss ways of improvement for animal disease management, with a focus on PPR and vaccination. These outcomes are conducive to the future construction of a common research agenda and the appropriation of knowledge production by local communities, through a more emancipating and empowering participatory approach (Fischer and Chenais, 2019).

A comparison of the results with those of the serological survey revealed discrepancies. While eight villages in Plateau and one in Bauchi

Table 5
Results of the rapid tests conducted on animals displaying clinical signs of PPR-like diseases at the time of the FGD.

State	Village	Animals tested					
		Species	Gender	Age	Clinical signs	PPR-like disease	Test result
Bauchi	1	Sheep	Female	> 18 months	ocular discharge, nasal discharge	Zawo	Negative
		Goat	Female	< 6 months	ocular discharge, nasal discharge, diarrhoea	Zawo	Positive
		Goat	Female	< 6 months	ocular discharge, nasal discharge, diarrhoea	Zawo	Positive
		Goat	Female	6–12 months	ocular discharge, nasal discharge, diarrhoea	Zawo	Positive
		Goat	Female	> 18 months	ocular discharge, nasal discharge, diarrhoea	Zawo	Negative
	2	Sheep	Male	12–18 months	ocular discharge, nasal discharge, diarrhoea	Zawo	Negative
		Sheep	Female	12–18 months	ocular discharge, diarrhoea	Zawo	Negative
		Sheep	Female	> 18 months	nasal discharge, diarrhoea	Zawo	Negative
		Sheep	Female	> 18 months	ocular discharge, diarrhoea	Zawo	Negative
		Goat	Male	< 6 months	ocular discharge, nasal discharge	Zawo	Negative
	3	Goat	Female	> 18 months	ocular discharge, nasal discharge, diarrhoea	Zawo	Negative
		Goat	Female	> 18 months	ocular discharge, nasal discharge, diarrhoea	Zawo	Negative
	4	Goat	Female	> 18 months	ocular discharge, nasal discharge, diarrhoea	Huhu	Positive
		Goat	Male	6–12 months	ocular discharge, nasal discharge, diarrhoea, coughing	Mura	Negative
	5	Goat	Male	6–12 months	nasal discharge	Zawo	Negative
Kano	1	Sheep	Male	6–12 months	ocular discharge, sneezing, coughing, conjunctivitis	Mura	Negative
	2	Goat	Female	> 18 months	diarrhoea, pyrexia	Zawo	Negative
		Goat	Female	6–12 months	diarrhoea	Zawo	Negative
	3	Sheep	Female	12–18 months	ocular discharge, nasal discharge, coughing, diarrhoea, lacrimation	Huhu	Positive
		Sheep	Male	> 18 months	nasal discharge, coughing, pyrexia	Huhu	Positive
		Goat	Male	> 18 months	nasal discharge, coughing	Huhu	Negative
		Goat	Female	12–18 months	ocular discharge, nasal discharge, coughing	Huhu	Negative
	4	Goat	Male	6–12 months	mouth erosion	Huhu	Negative
		Goat	Male	6–12 months	nasal discharge, diarrhoea, coughing, mouth erosion	Huhu	Negative

were seronegative for antibodies against PPR, FGDs had identified recent outbreaks suggestive of being PPR in these villages. On one hand, this may be explained by a lack of specificity in the FGDs' protocol to select PPR-like diseases (in particular the case definition used to select diseases suggestive of PPR) and the use of non-specific terms by farmers to refer to PPR. On the other hand, the statistical robustness and the quality of laboratory results used for the serological survey can also be questioned. This discrepancy between the two sources of information underlines the value of mixed approaches, such as in this case combined epidemiological surveys based on both local knowledge and on biological sampling, which make it possible to assess the validity of the results obtained and identify potential bias (Coffin-Schmitt et al., 2021). Mixed approaches strengthen reliability and credibility of the conclusions. Indeed, the detection of inconsistencies or discrepancies can help identify methodological problems or sources of error specific to each approach, based on which solutions can be proposed to improve the validity of the results. In the specific context of our study, reliability of the results could be improved by increasing the number of animals tested in the field with the rapid test and to confirm all positive results with a PCR test. In addition, all animals tested negative in the field but showing evident clinical signs of a PPR-like disease should be sampled for laboratory confirmation. Consideration could also be given to testing animals for other diseases that may be confused with PPR, in order to refine the differential diagnosis between all the PPR-like diseases.

5. Conclusion

This large-scale epidemiological survey deepens our understanding of the epidemiology and management of PPR in small ruminants in Plateau, Bauchi, and Kano States. Such qualitative epidemiology studies, relying on farmers' knowledge, perceptions and perspectives, provide valuable information that may not be captured by a conventional epidemiological approach based solely on biological tests. By employing different tools to collect this information, we can validate our findings through comparison across different data sources.

This study identified the terms that farmers are most likely to use to describe PPR, namely: *zawo*, *mura*, *hanta* and *huhu*. For each of these diseases, the associated clinical signs, seasonality and health impact were identified, along with the management measures implemented. Using biological tests, some cases of *zawo* and *huhu* were confirmed to be caused by PPRV. Reported morbidity and mortality rates are consistent with those commonly observed in endemic countries. The disparities observed between the studied states and sometimes within communities underline the importance of developing disease prevention and management measures that are tailored to local settings. Only measures that have been co-constructed with farmer communities, in a co-learning process between scientists and farmers, and that meet the basic needs of the latter, will have a chance of being accepted and implemented.

In the context of the national eradication of PPR in Nigeria, vaccination must be emphasised, as it remains largely unused in many communities despite its crucial role.

Ethical clearance

The Animal Use and Care Committee of the National Veterinary Research Institute granted ethical clearance for the study, including the surveys and FGDs, with permission number NVRI/AEC/02/113 A/22. In the study areas, permission was obtained from all relevant authorities before field data collection. Additionally, written informed consent was obtained from study participants and the data generated was kept confidential.

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Declaration of Competing Interest

The authors declare no competing interests.

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Supplementary materials

Supplementary file 1. Interview guide to conduct the focus group discussion with farmers.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2025.106633.

Data availability

The dataset generated during the current study is available at: https://dataverse.cirad.fr/privateurl.xhtml?token=719004d2-2fb1-405a-b25e-7e87034b6619.

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