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RESEARCH OPINIONS IN ANIMAL & VETERINARY SCIENCES

Analysis of small ruminants' pastoral management practices as risk factors of Peste des petits ruminants (PPR) spread in Turkana District, Kenya

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Abstract

Peste des petits ruminants (PPR) is an emerging viral disease spreading throughout Kenya and East Africa causing major losses in the small stock. This study is an attempt to evaluate small stock management practices in Turkana pastoral system, Kenya as predictors of PPR outbreaks. Information on the social practices and the occurrence of PPR outbreaks was obtained by participatory techniques. The small stock management practices, evaluated as factors, in a previous study were simultaneously analyzed with seasons and administrative divisions as the independent risk factors for the presence or absence of PPR outbreaks in 142 *Adakars* (villages) as the dependent variable. Analyses were carried out for the years 2009 and 2010 combined as one data set and considered as longitudinal repeated data. In the analyses, the presence or absence of PPR outbreaks was the dependent variable. Data were further analyzed separately disaggregated by season where the presence or absence of PPR outbreaks in a season was considered as the dependent variable. All analyses utilized multivariable logistical regression analyses. In the longitudinal analysis, season was the only significant factor associated with PPR outbreak. Disaggregating the data by season revealed that certain seasonal-specific livestock management activities increased the risk of reporting PPR outbreaks: (1) sharing water sources leading to social aggregation of young stock in one point (Factor 3) (odds ratio (OR) = 2.0) in season 2 (wet season) of 2009; (2) sick dams left to nurse their young kids/lambs (Factor 7) (OR=1.62) in the same season in 2010. The finding of diverse risk factors in the same seasons across years suggests temporal heterogeneity in the distribution and occurrence of the determinants of PPR in the Turkana ecosystem. The study discusses the implications of these findings on disease control.

Keywords: Participatory risk assessment, social ecology, temporal heterogeneity, Peste des petits ruminants, Turkana

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Introduction

Peste des petits ruminants (PPR), a viral disease of small ruminants have become an increasingly important trans-boundary disease following eradication of rinderpest (Elsawalhy et al*.,* 2010). Peste des petits ruminants disease is endemic in Africa, Middle East and Asian countries and is a major contributor to poverty in the rural pastoral communities due to its morbidity and mortality burdens on small ruminants (Diallo, 2006; Banyard et al., 2010; Munir et al., 2013). The PPR virus spreads through close contact between susceptible and infected animals. The infective contacts within and between herds are suspected to be influenced by various factors that are seasonal and context-specific. The PPR ecology detailing PPR virus life cycle, host and non-host factors that determine host receptivity and susceptibility to PPR virus has been

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documented (Gopilo 2005; Dufour, 2010; Munir et al., 2013;). Literature is scarce on social and political ecology of PPR disease. However, it is known that PPR disease outbreaks are associated with social, cultural and economic activities that promote host contacts such as livestock trade, cultural festivals, husbandry practices (Ohta, 1982) as well as nomadism, environmental and climatic factors (Food Agricultural Organization FAO 2009; Garrett et al., 2013). These factors are known to have seasonal variability. Generally it is thus becoming increasingly evident that human factors, more so the cultural activities, play a great role in the emergence and reemergence of the infectious animal diseases (Newcastle, 2012; Robbins, 2012). In pastoral societies where the survival strategies develop around the use and accumulation of animals, cultural activities play a particularly important role in livelihood sustainability. Some of the cultural activities such livestock raids and exchange of animals in marriage ceremonies among others activities, increases the probability of susceptible herds contacting infection from incoming infected animals (Sollod and Knight, 1982). Therefore, a better understanding of social and cultural aspects of small stock management practices thought to elevate risk of introduction and spread of PPR, become in large, a part of designing solutions to the social ecological challenges of PPR occurrence in the Turkana District (Cumming, 2010). This would entail carrying out a PPR disease risk analysis that focuses on risk identification and risk assessment (MacDiarmid, 1991). This study, therefore, attempts to evaluate the small ruminant management practices by Turkana herders as predictors of PPR outbreak through integration of risk assessment and participatory methodologies (Grace et al., 2008). The purpose of the study was to aid future designing of contextual-specific interventions in the disease control policies (Mariner et al., 2012)..

Materials and methods

Study area

The study was carried out in six administrative divisions of Turkana District namely Loima, Orropoi, Kakuma, Lokichogio, Kaaling and Kibish. The district is located in the extreme north west of Kenya (Figure 1). Turkana District covers an area of 77,000 km^2 with a human population of 849,277 (Kenya National Bureau of Statistics (KNBS), 2010). The district is characterized by arid and semi-arid lands covered with grass and sparse thorny shrubs (Olang, 1984). The central, eastern and southern parts of the district consist of low-lying vast plains, with isolated rocky mountainous and hilly ranges surrounded by several seasonal rivers. The area to the west bordering Uganda and Sudan to the north consists of mountainous ranges

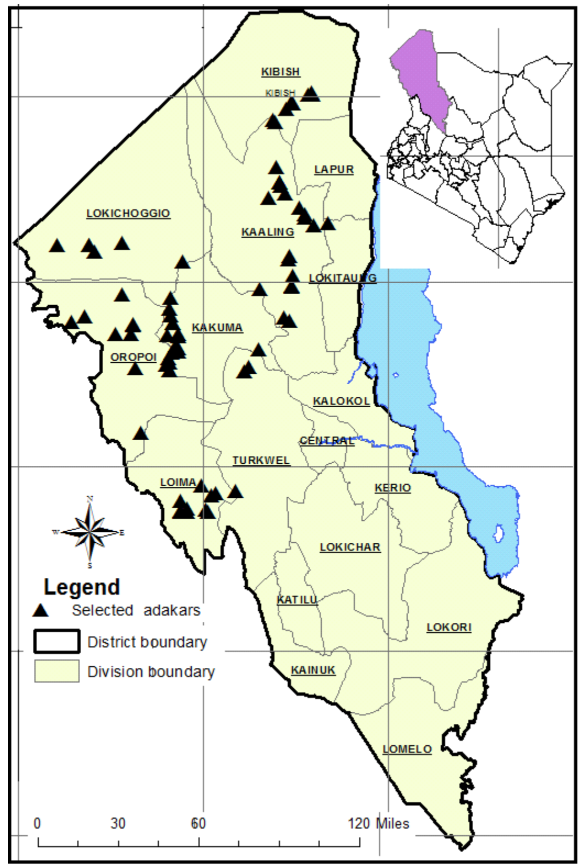

Fig. 1: Map of Turkana study sites (Kihu et al., 2012)

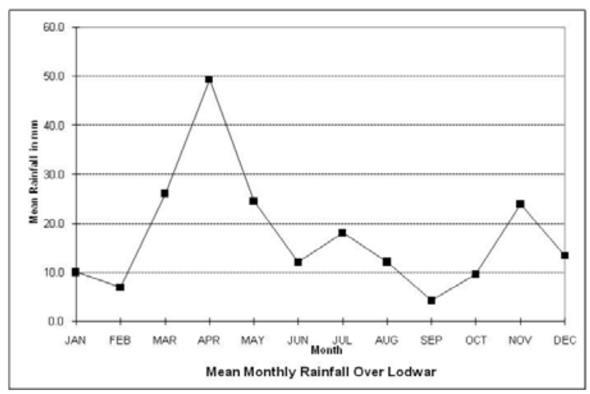

Fig. 2: Mean monthly rainfall over Lodwar showing MAM and OND seasons (Savatia 2011)

where elevations vary from 1800 – 2100 meters above sea level. The latter areas comprise the main grazing lands. The mountains are the sources of numerous seasonal streams, which feed into the Turkwell and Kerio rivers that end up draining into Lake Turkana (Aemun, 2006). The district's woody vegetation is found on the escarpments, mountains areas, along the Turkwell and Kerio rivers and within the other numerous seasonal watercourses (Amuyunzu et al., 1991). Generally, the district experiences both temporal and spatial rainfall variability as well as frequent droughts and famines (Ouma et al., 2012). Results from times series plot indicate that Turkana District has two distinct rainfall seasons: long rains (*Akiporo*) that fall between March, April and May (MAM) and short rains (*erupe*) that are experienced between October, November and December (OND) (Figure 2) (Savatia, 2011). The annual rainfall ranges between 100 to 600 mm per year (Little et al., 1999).

Four distinct climatic seasons are identified in the Turkana district though description of two key seasons is more prevalent; the wet season (*akiporo*) expected in April to June and dry season (*akamu*) expected in October to January. The other two non-conspicuous seasons but described by Turkana people are early rainy showers (*Akicheres*) expected in February and March; and the end of wet season (*Ait*) expected in July to September. Temperatures range from a low of 24 ºC to a high of 38 ºC with a mean of 30 ºC (Arid Lands Resource Management Project (ALRMP), 2009 unpublished data).

Approximately 70% of the populations in Turkana district are nomadic or semi-nomadic pastoralists deriving their livelihood from extensive livestock production. Recently, the small ruminant population was reported to be 3,517,151 sheep and 5,994,861 goats (KNBS 2010). Sheep, goats and camels are commonly grazed in the plains while cattle are grazed on the mountainous ranges where there are grass pastures in most seasons.

Sampling Unit and sample size

The sampling unit was an *Adakar*. An *Adakar* entails a cluster of often-related Turkana households that pursue similar socio-economic activities such as search for pasture, water and security, under a trusted leader (Bett et al., 2009). An *Adakar* is, thus, more or less synonymous to a herd. The number of households in each *Adakar* varies from 40 to a 100 with an average of 70 households per *Adakar* (African Medical and Research Foundation (AMREF), 2012 unpublished data; Akabwai, 1992). Using households' population (KNBS 2010) for all the six administrative divisions in this study, a total population of 535 *adakars* was estimated using the average number of households per *Adakar* at 70. All the *Adakars* were allocated numbers and using the random number generator in Microsoft Excel® and the study sample of 142 *Adakars* were selected by simple random sampling proportionate to population size of each administrative division (Table 1).

Data collection

Risk assessment questionnaire

The risk assessment questionnaire had three sections, section I enquired on herd history of PPR, while section II enquired on variables that could be associated with PPR exposure focusing on seasonality of some management and cultural activities. Section III of the risk assessment questionnaire was based on a Likert scale approach whose data were analyzed by factor analysis and results published (Kihu et al., 2012). We used the factor analysis results to carry out risk factor analysis in this paper.

Table 1: *Adakars* and household population and the sample sizes of *Adakars* by division, Turkana District, Kenya

Division	*Adakars* population	Household population	Number of sampled *Adakars*
Loima	76	5288	20
Orropoi	118	8265	32
Kakuma	87	6040	22
Lokichoggio	121	8505	33
Kibish	42	2935	11
Kaaleng	91	6392	24
Total	535	37445	142

Focus group discussions

The participatory risk assessment entailed oral administration of the questionnaire to a small group of about 5 to 15 respondents being representatives and key informants that formed a focus group discussion (FGD) for each *Adakar* interviewed. The scale items were translated in local Turkana language and discussed and clear meaning in local language agreed for ease of scoring by the respondents. The interviewer with the help of local Turkana language interpreter led a discussion on each question following which an agreed scoring was pointed out and recorded for each variable based on agreement reached between the respondents in their group discussion.

Data management and analysis

After selection of a final factor analysis model (Kihu et al., 2012), standardized factor scores with an approximately zero mean and unit variance were calculated using regression scores method for *Adakars* that were interviewed (DiStefano et al., 2009). These scores were subsequently evaluated as predictors in a model-based logistic regression analysis to determine whether they were associated with the occurrence of PPR outbreaks during 2009 and 2010. Treating the management factor scores as longitudinal repeated data by season, multivariate logistic analysis was carried out with the presence or absence of PPR outbreaks as the dependent variable. The data was further disaggregated by season in each study year and univariate and multivariate logistic analyses was carried out with the presence or absence of PPR outbreaks in a season as dependent variable. Likelihood ratio test (LRT) ($P<0.05$) was done to test the significance of a variable in the multivariable regression analysis.

Results

Descriptive analysis
Seasonal characteristics

Treating data as longitudinal data, the study covered 142 *Adakars* (villages) in the 6 administrative divisions highlighted above in Turkana District. The data was collected for two years 2009 and 2010 and each year was divided into four seasons. The Turkana community described the four seasons in their local calendar year namely *Akicheres, Akiporo, Ait* and *Akamu* (Table 2). In each year studied, for each of the 142 *Adakars*, there were 4 seasons leading to a total of 568 observations per year. In disaggregating the data by season, each of these seasons had a binary outcome of PPR outbreak occurrence or not. An outbreak was defined as an observation by herders of PPR clinical signs in several small ruminants in a household herd (*awi*) or *Adakar* herd within the study period. In this analysis, each of the four seasons had 142 observations (from 142 *adakars*) and each season was treated independently resulting in four models for each year.

Distribution of PPR outbreak occurrences by divisions

Overall 131 (23.1% [95% confidence interval (CI): 19.9%, 26.7%]) observed PPR outbreaks were reported to have occurred throughout the four seasons in the year 2009. There was no significant difference in the proportion of observed outbreaks among divisions (p=0.871). In the year 2010 there were 133 (23.4% [95% CI: 20.1%, 27.1%]) observed PPR outbreaks that were reported to have occurred throughout the four seasons. Similar to the year 2009, there was no significant difference among divisions (p=0.693). Therefore, distribution of the reported observed disease outbreaks across the divisions was similar between the two years (Table 3).

Upon disaggregating data into seasons, most outbreaks were reported to occur in the dry season (*Akamu*) followed by wet season (*Akiporo*). However, more cases were reported in the dry season of 2010 compared to the same season of 2009. The first season (*Akicheres*) recorded the lowest outbreaks in both years. Moreover, a significant difference in outcomes between

Table 2: Description of seasons and months and their characteristics by the Turkana community in relation to the conventional calendar months and seasons (Aemun, 2006)

Turkana Season	Conventional equivalent of seasons	Turkana months in a season	Conventional equivalent months	Turkana interpretation of the month	Seasonal climate and ecological characteristics
Akicheres	Early rains Season 1	*Lodung'e*	February	To put off, as of fire: the dry season ends	Very hot and dry, no pastures and water. First signs of long rains, clouds. Some areas get early showers. Most small stock grazing on mountain ranges within *Adakar* herd
		Lomaruk	March	Cloud formation: life comes back with formation of clouds.	
Akiporo	Long Rains Season 2	*Titima*	April	Growth: growth of grasses and greening of trees.	Long rains, plenty of green pasture and water, shrubs are green and seasonal rivers flowing with flood water. Small stock grazing on the plains dispersed as household (*awi*) herds.
		Yelyel	May	Flowering process: crops (millet) and plants flower	
		Lochoto	June	Mud/cow dung: The colour of grasses turn to dark green	
Ait	Start of Dry season Season 3	*Losuban*	July	Rituals; ceremonies. Grass begins to wither.	Start of dry season. Water available in pans and sand dams. The pasture are maturing and drying into standing hay.
		Lotiak	August	To divide: separation of rains and dry season.	Small stock in household (*awi*) herds grazes along the river beds to access both pasture and water. Migration starts in such for water.
		Lolongu	September	Hunger starts to bite. Trees shed leaves	
Akamu	Dry season Season 4	*Lopo*	October	Cook wild foods	It is dry and hot with extreme high temperatures. Pastures and water in plains are depleted. Community mining water from dry river beds. Trees shed leaves and fruits Scare pastures and water available only on mountain ranges and river beds near mountains. Small stock grazed within *Adakar* herds that migrate to highlands.
		Lorara	November	Fall: wild berries and pods drop	
		Lomuk	December	Cover: shrubs may green due to short rain	
		Lokwang'	January	White: bare rangeland	

Table 3: Distribution of PPR outbreak observations by divisions

Division and year	Outbreak present		Outbreak absent		Total
	n	%	n	%	n
2009					
Kakuma	30	23.4	98	76.6	129
Kibish	17	25.0	51	75.0	68
Kaaleng	32	24.2	100	75.8	132
Loima	23	24.0	73	76.0	96
Loki	18	18.0	82	82.0	100
Oropoi	11	25.0	33	75.0	43
Total	131	23.1	437	76.9	568
2010					
Kakuma	32	25.0	96	75.0	128
Kibish	17	25.0	51	75.0	68
Kaaleng	34	25.8	98	74.2	132
Loima	22	22.9	74	77.1	96
Loki	17	17.0	83	83.0	100
Oropoi	11	25.0	33	75.0	44
Total	133	23.4	435	76.6	568

n= number of observations of presence or absence of PPR outbreaks

seasons in each division for five divisions was found (Table 4). Similar to 2009, there was a significant difference in outcomes between seasons in all divisions in 2010 (Table 5).

Description of management factors

Data on Turkana small ruminant's management variables was collected from the 142 *Adakars* in the same questionnaire that collected data for seasonal disease outbreak occurrences. Factor analysis of the management variables as described in Kihu et al (2012) resulted in factor model listed below with their associated factors (Table 6).

The relationship between the management variables and factors is shown in the values in the table which represent correlation coefficients between management variables and management factors. Coefficient correlation is the factor loading that denotes correlation between variables and factors that has been extracted from the data and are derived from computed correlation matrix comprising the inter-correlations between all variables. Correlation coefficients greater than 0.3 shows that variables related to each other and they share common factors (Tabachnick and Fidell, 2007). However, for this study, only variables with coefficient correlations greater than 0.4 were included in the factor analysis model for interpretation.

Analysis of small ruminants' pastoral management factors as predictors of PPR outbreaks

Treating the data as longitudinal repeated data by season

Treating the management factor scores as longitudinal repeated data by season, a multivariate logistic regression analysis was carried out to assess the association between outcome (PPR outbreaks occurrence or not) on one hand and the factors, season and divisions, independently, on the other. For the two years studied, the result showed that there was no management factor that was significantly associated with outcome (Table 7). Division as a variable was not associated with the outcome as well. Accounting for correlation of responses by division showed that inclusion of division random effect did not provide a better fit than the standard logistic regression (p=1) (data not shown). However season was significantly associated with the outcome in both years (p=0.00) (Table 7). From the results, PPR outbreaks were more likely to be reported in all other seasons compared to the early rains season for every one unit increase in factor score in both years. However, this was more striking in the dry season of 2010 and least striking during the start of the dry season of 2010 (Table 7).

Disaggregation of data by season

Univariable analysis

This section provides the results of univariate logistic analysis when the outcome was disaggregated by season, i.e. outcome in a particular season was the dependent variable. In this analysis, a total of eight models (four seasons each for two years) were derived with the level of significance set at $p \leq 0.1$.Variables that were significant at ($p \leq 0.1$) were further offered to a multivariate logistic analysis whose level of significance was set at $p \leq 0.05$.

At least one variable was independently associated with the outcome in each season. However, activities grouped into "*introduction of new animal into the herds*" factor (Factor 2) were not associated with PPR outbreaks in any season.

During the early rains season (season 1) of 2009, activities grouped into "*nomadism and transhumance*" factor (Factor 5) were more likely to be associated with PPR outbreaks for every one unit increase in the factor score (Table 8). During the long rains season (season 2) of 2009, three variables were significant, though independently, associated with reporting of PPR outbreaks: for every one unit increase in the factor score, (1) activities grouped into "*indiscriminate mixing of vulnerable groups with high risk groups within herds*" factor (Factor 1) were less likely to be associated with PPR outbreaks; (2) activities grouped into "*sharing watering sources leading to concentration of young stock in one point*" Factor (Factor 3) were more likely to be associated with PPR outbreaks and (3) all divisions were more likely to report PPR outbreaks compared to the reference (Loima) division. However, for the latter, Kibish Division reported the highest PPR infection risk relative to the reference (Loima) division (Table 8). During the dry season (season 4) of 2009 when more PPR outbreaks were reported relative to

Table 4: PPR disease outbreak disaggregated by season in 2009

Seasons	N	*Akicheres* Early Rains Season 1		*Akiporo* Long rains Season 2		*Ait* Start of dry season Season 3		*Akamu* Dry season Season 4	
Division		n	%	n	%	n	%	n	%
Kaaleng***	33	1	3.0%	8	24.2%	4	12.1%	19	57.6%
Kakuma***	32	0	0.0%	6	18.8%	5	15.6%	19	59.4%
Kibish***	17	0	0.0%	9	52.9%	0	0.0%	8	47.1%
Loima***	24	3	12.5%	1	4.2%	5	20.8%	14	58.3%
Loki	25	2	8.0%	5	20.0%	3	12.0%	8	32.0%
Oropoi**	11	0	0.0%	2	18.2%	3	27.3%	6	54.5%
Total	142	6	4%	31	21.2%	20	14.1%	74	52.1%

N=Total reported observations; n = the number of observations reported as outbreaks; *** P≤0.001; ** P≤0.05; *P≤0.1 = denotes the level of statistically significant difference of the outcomes between seasons in each division.

Table 5: PPR disease outbreak disaggregated by season in 2010

Seasons	N	*Akicheres* Early rains Season 1		*Akiporo* Long rains Season 2		*Ait* Start of dry season Season 3		*Akamu* Dry season Season 4	
Division		n	%	n	%	n	%	n	%
Kaaleng***	33	0	0.0%	7	21.2%	1	3.0%	26	78.8%
Kakuma***	32	1	3.1%	2	6.3%	2	6.3%	27	84.4%
Kibish***	17	1	5.9%	5	29.4%	0	0.0%	11	64.7%
Loima***	24	0	0.0%	1	4.2%	2	8.3%	19	79.2%
Loki***	25	1	4.0%	1	4.0%	1	4.0%	14	56.0%
Oropoi**	11	1	9.1%	2	18.2%	1	9.1%	7	63.6%
Total	142	4	2.8%	18	12.7%	7	5.0%	104	73.2%

N=Total reported observations; n = the number of observations reported as outbreaks; *** P≤0.001; ** P≤0.05; *P≤0.1 = denotes the level of statistically significant difference of the outcomes between seasons in each division.

other seasons, activities grouped into "*sharing watering sources leading to concentration of young stock in one point*" factor (Factor 3) were less likely to be associated with PPR outbreaks for every one unit increase in the factor score (Table 8).

Unlike during the early rains season (season 1) of 2009, in 2010, activities grouped into "*local culture of borrowing and loaning of livestock*"factor (Factor 6) were more likely to be associated with PPR outbreaks for every one unit increase in the factor score (Table 8). During the long rains season (season 2) of 2010, two variables were significant, though independently, associated with reporting of PPR outbreaks: for every one unit increase in the factor score, (1) activities grouped into "*sick dams left to nurse their young kids/lambs*" factor (Factor 7) were more likely to be associated with PPR outbreaks and (2) four divisions were more likely to report PPR outbreaks compared to the reference (Loima) division whereas one division was less likely to report the outbreaks compared to the reference division. Similar to 2009 during the long rains season, Kibish Division was the area more likely to report the outbreaks relative to Loima Division (Table 8). During the start of dry season (season 3) of 2010, activities grouped into "*local culture of borrowing and loaning of livestock*" factor (Factor 6) were less likely to be associated with PPR outbreaks for every one unit increase in the factor score (Table 8). During the dry season (season 4) of 2010 when more PPR outbreaks were reported relative to other seasons, three variables were significant, though independently, associated with reporting of PPR outbreaks: for every one unit increase in the factor score, (1) activities grouped into "*indiscriminate mixing of vulnerable group with high risk group within herds*" factor (Factor 1) were less likely to be associated with PPR outbreaks, (2) activities grouped into "*sick dams left to nurse their young kids/lambs*" factor (Factor 7) were less likely to be associated with PPR outbreaks and (3) four divisions were less likely to report PPR outbreaks compared to the reference (Loima) division whereas one division was more likely to report the outbreaks compared to Loima Division (Table 8).

Multivariable analysis

In the final multivariate logistic analysis with significance level set at p≤0.05, only activities practiced in the long rainy season and dry season were significant. In the year 2009, activities grouped into "*sharing watering sources leading to concentration of young stock in one point*" factor (Factor 3) were more likely to be associated with PPR outbreaks during the long rainy season whereas the same activities were less likely to be associated with the outbreaks during the dry season for every one unit increase in the factor score. In the year 2010, activities grouped into "*sick dams left to*

Table 6: The seven factors extracted from 49 variables of PPR risk assessment

Factor 1: Indiscriminate mixing of vulnerable group with high risk group within herds		
Q3.25	Sick adults stock watered on same troughs with older kids/lambs	.860
Q3.23	Older kids/lambs share the same watering troughs with older animals	.718
Q3.18	Older kids/lambs graze alongside wild herbivores.	.708
Q3.38	Extent of watering young goats/sheep at separate water holes	-.684
Q3.41	Sick young goats/sheep watered in communal water holes	.657
Q3.26	Sick adult stocks grazed along with older kids/lambs	.625
Q3.36	Frequency young sheep and goats graze along with wild herbivores	.609
Q3.40	Sick young sheep/goats separated from other	-.526
Q3.62	Traders graze their animals alongside herds on their way to the markets	.468
Q3.39	Young goats/sheep share the same watering troughs with older animals	.447
Q3.22	Extent of watering older kids/lambs at separate water holes	.436
Factor 2: Introduction of new animal into the herds		
Q3.44	Frequency of young goats/sheep returned home after failed market sale	.873
Q3.61	Frequency of adult goats/sheep returned home from failed market sale	.769
Q3.47	Extent of goats/sheep sourced from markets used to restock herds	.650
Q3.29	Extent of young goats/sheep bought from markets used to restock herds	.570
Q3.45	Extent of introduction into herds goat/sheep gifts from ceremonies	.538
Q3.30	Extent of young goats/sheep got through raids used to restock herds	.520
Q3.13	Extent of kids/lambs bought from markets used to restock herds	.502
Q3.33	Young goats/sheep grazed in common pasture	-.465
Q3.48	Extent of adult goats/sheep got from raids used to restock herds	.465
Factor 3: Sharing watering source leading concentration of young stock in one point		
Q3.21	Extent of watering older kids/lambs at separate times	.681
Q3.7	Extent of watering young kids/lambs at separate times from other stock	.582
Q3.22	Extent of watering older kids/lambs at separate water holes	.544
Q3.37	Extent of watering young goats/sheep at separate times	.528
Q3.8	Extent of watering young kids/lambs at separate water holes	.506
Q3.14	Extent of older kids/lambs got through raids used to restock herds	-.478
Q3.13	Extent of kids/lambs bought from markets used to restock herds	-.405
Factor 4: Foreign stock from across international borders grazing in local pastures		
Q3.53	Extent of herds from neighboring countries graze in local pastures	.923
Q3.54	Extent of herds from neighboring countries watering in local pastures	.871
Q3.33	Young goats/sheep grazed in common pasture	-.445
Q3.12	Sick adults stocks are grazed along with young kids/lambs	-.408
Factor 5: Nomadism and transhumance		
Q3.43	Frequency of young goats/sheep lost through raids returned back	.830
Q3.60	Extent of young goats/sheep got through raids used to restock herds	.686
Q3.5	Young kids/lambs moved with other animals during transhumance	.582
Q3.30	Extent of young goats/sheep got through raids used to restock herds	.469
Q3.19	Older Kids/lambs moved with other animals during transhumance	.436
Factor 6: Local culture of borrowing and loaning of livestock		
Q3.28	Extent of exchange of young goats/sheep on loans	.665
Q3.46	Frequency of exchange of adult goats/sheep/ on loan	.615
Factor 7: Sick dams left to nurse their young kids/lambs		
Q3.11	Sick adult stock are watered on same troughs with young kids/lambs	.887
Q3.9	Young kids/lambs share the same watering troughs with older animals	.476
Q3.12	Sick adults stocks are grazed along with young kids/lambs	.444

nurse their young kids/lambs" factor (Factor 7) were more likely to be associated with PPR outbreaks during the long rainy season for every one unit increase in the factor score. During the dry season in the year 2010, activities grouped into "*indiscriminate mixing of vulnerable group with high risk group within herds*" factor (Factor 1) and activities grouped into "*sick dams left to nurse their young kids/lambs*" factor (Factor 7) were less likely to be associated with PPR outbreaks for every one unit increase in the factor score. During the same dry season in 2010, four divisions were less likely to report PPR outbreaks compared to the reference (Loima) division whereas one division was more likely to report the outbreaks compared to Loima Division (Table 9).

Discussion

Turkana community has come to associate PPR outbreaks with seasonality, a narrative that is given in almost all *Adakars* in discussions about PPR. This is the reason why seasons were the core question

Table 7: p-values obtained from multivariable logistic regression analysis of treating data as repeated longitudinal data for years 2009 and 2010

Variable	Levels	Year	OR	OR [95% CI]	P-value
Factors	Factor 1	2009	0.94	[0.76, 1.15]	0.55
		2010	0.938	[0.534,1.147]	0.53
	Factor 2	2009	1.04	[0.85, 1.29]	0.66
		2010	1.068	[0.867,1.316]	0.53
	Factor 3	2009	1.04	[0.85, 1.29]	0.65
		2010	1.047	[0.850,1.289]	0.66
	Factor 4	2009	0.98	[0.81,1.20]	0.65
		2010	0.999	[0.821, 1.216]	0.99
	Factor 5	2009	1.01	[0.82, 1.24]	0.91
		2010	1.035	[0.840, 1.274]	0.75
	Factor 6	2009	1.00	[0.80, 1.24]	0.98
		2010	0.959	[0.771, 1.191]	0.70
	Factor 7	2009	1.01	[0.82, 1.24]	0.88
		2010	1.001	[0.816, 1.229]	0.99
Season	Long rains (season 2)	2009	6.33	[2.5,15.7]	0.00*
		2010	5.008	[1.65,15.200]	0.00**
	Start of dry season (season 3)	2009	3.71	[1.4, 9.5]	
		2010	1.789	[0.512,6.251]	
	Dry season (season 4)	2009	24.66	[10.2, 59.5]	
		2010	94.421	[32.672,272.872]	
Division	Oropoi	2009	1.06	[0.46, 2.42]	0.86*
		2010	1.12	[0.49, 2.58]	0.67**
	Kakuma	2009	0.97	[0.52, 1.81]	
		2010	1.12	[0.60, 2.09]	
	Kibish	2009	1.06	[0.51, 2.18]	
		2010	1.12	[0.54, 2.32]	
	Kaaleng	2009	1.01	[0.55, 1.88]	
		2010	1.17	[0.63, 2.16]	
	Loki	2009	0.70	[0.35, 1.39]	
		2010	0.69	[0.34, 1.40]	

Factor 1: Indiscriminate mixing of vulnerable group with high risk group within herds; Factor 2: Introduction of new animal into the herds; Factor 3: Sharing watering source leading concentration of young stock in one point; Factor 4: Foreign stock from across international borders grazing in local pastures; Factor 5: Nomadism and transhumance; Factor 6: Local culture of borrowing and loaning of livestock; Factor 7: Sick dams left to nurse their young kids/lambs; Early rains season (season 1) and Loima division are the reference variable levels; *: LRT P-value for variable for year 2009; **: LRT P-value for variable for year 2010.

investigated in this study. Expectedly, season was the only significant factor identified when data was treated as repeated data within a year for the two years (2009 and 2010) investigated. Seasonality represents a very broad variable influencing diverse drivers of livestock infectious disease occurrence including biological drivers (pathogen transmission dynamics), weather patterns, market dynamics, cultural activities leading to changes in host social behavior, movement patterns, contact rate patterns and cultural ceremonies emanating from management decisions from owners. These are important factors that aid the transmission of PPR virus from infectious to susceptible stock (Wosu et al., 1990; Singh et al., 2004; I Saeed et al., 2010). To highlight the importance of seasonality, the distribution of PPR cases was similar in seasons across the two years. Infection risk was reported to be highest during the dry season followed by the long rainy season.

Additionally, this study further investigated the relationship between the occurrences of PPR outbreaks within a season and decoded the internal disease risk information on socio-cultural practices within the Turkana community previously analyzed using factor analysis. Interestingly, the different factors representing diverse risk factors were independently related with the occurrence of PPR outbreaks in different seasons. Even more remarkably, the same factors were not necessarily related with the occurrence of PPR outbreaks in the same seasons across years. This suggests temporal heterogeneity in the distribution and occurrence of determinants of PPR infection. In other words, over time, the importance and the strength of the effect of a given factor on the occurrence of PPR outbreaks changed. For instance, independently, during the early rainy season nomadism and transhumance and the local culture of borrowing and loaning of livestock were associated with PRR outbreaks in 2009 and 2010. Whereas indiscriminate mixing of infectious stock and susceptible stock within herds and sharing watering source leading to concentration of young stock in one

Table 8: Univariable logistic regression of factor scores on reported PPR outbreaks in adakars in Turkana District in 2009 and 2010

Year	Season	Variable	Variable level	OR	OR [95% CI]	P-value
2009	Early rains	Factor	Factor 5	3.52	[1.08, 11.40]	0.036
	Long rains	Factor	Factor 1	0.65	[0.44, 0.97]	0.036
			Factor 3	2.02	[1.31, 3.13]	0.002
		Division	Oropoi	7.67	[0.59, 99.48]	0.012
			Kakuma	4.76	[0.53, 42.37]	
			Kibish	25.86	[2.82, 237.55]	
			Kaaleng	7.36	[0.85, 63.48]	
			Loki	5.75	[0.62, 53.43]	
	Dry season	Factor	Factor 3	0.68	[0.47, 0.99]	0.038
2010	Early rains	Factor	Factor 6	4.20	[1.07, 16.48]	0.039
	Long rains	Factor	Factor 7	1.62	[1.03, 2.56]	0.038
		Division	Oropoi	7.67	[0.59, 99.48]	0.032
			Kakuma	1.39	[0.12, 16.30]	
			Kibish	9.58	[1.00, 91.62]	
			Kaaleng	6.19	[0.71, 54.19]	
			Loki	0.96	[0.05, 16.24]	
	Start of dry season	Factor	Factor 6	0.28	[0.10, 0.76]	0.013
	Dry season	Factor	Factor 1	0.69	[0.45, 1.06]	0.093
		Factor	Factor 7	0.66	[0.45, 0.96]	0.028
		Division	Oropoi	0.26	[0.05, 1.44]	0.07
			Kakuma	1.57	[0.40, 6.19]	
			Kibish	0.48	[0.12, 1.96]	
			Kaaleng	0.98	[0.27, 3.55]	
			Loki	0.33	[0.09, 1.18]	

Factor 1: Indiscriminate mixing of vulnerable group with high risk group within herds; Factor 3: Sharing watering source leading concentration of young stock in one point; Factor 4: Foreign stock from across international borders grazing in local pastures; Factor 5: Nomadism and transhumance; Factor 6: Local culture of borrowing and loaning of livestock; Factor 7: Sick dams left to nurse their young kids/lambs; * Loima division: reference variable level

Table 9: Multivariable logistic regression of factor scores on reported PPR outbreaks in *Adakars* in Turkana District in 2009 and 2010

Year	Season	Variable	Variable level	OR	OR [95% CI]	P-value
2009	Long rains	Factor	Factor 3	2.02	[1.31, 3.13]	0.001
	Dry season	Factor	Factor 3	0.68	[0.47, 0.99]	0.040
2010	Long rains	Factor	Factor 7	1.62	[1.03, 2.56]	0.049
	Dry season	Factor	Factor 1	0.53	[0.32, 0.88]	0.020
		Factor	Factor 7	0.66	[0.43, 1.00]	0.045
		Division	Oropoi	0.25	[0.04, 1.45]	0.049
			Kakuma	1.02	[0.24, 4.28]	
			Kibish	0.16	[0.03, 0.82]	
			Kaaleng	0.61	[0.15, 2.48]	
			Loki	0.19	[0.05, 0.74]	

Factor 1: Indiscriminate mixing of vulnerable group with high risk group within herds; Factor 3: Sharing watering source leading concentration of young stock in one point; Factor 7: Sick dams left to nurse their young kids/lambs; * Loima division: reference variable level

point were independently associated with the occurrence of outbreaks during the long rainy season in 2009, only activities related to sick dams left to nurse their young kids/lambs were associated with the outbreaks in the same season in 2010. However, spatial effects were associated with disease occurrence during the long rainy season in both 2009 and 2010. Completely different factors were associated with the occurrence of the outbreaks during the dry season: Sharing watering source leading to concentration of young stock in one point only in 2009 and independently indiscriminate mixing of vulnerable group with high risk group within herds, sick dams left to nurse their young kids/lambs and division in 2010. This temporal heterogeneity of significant factors could be attributed to the highly mobile nature of Turkana pastoralists leading to temporal interaction between the socio-cultural practices and the geographical, environmental, climatic and economic variability.

In the final multivariate logistic regression model, sharing watering source leading concentration of young stock in one point had both risk effects during the long rainy season and a protective effect during the dry season in 2009. During the long rainy season the small ruminants migrate from the mountains to the plains in search of the abundant fresh grass and the presence of water puddles in all places. The small ruminants are unrestricted in their movements and all age groups are allowed to graze together since the movements within the pastures are close to the homesteads. In addition, during long rainy season, other *Adakar* herds may share the same grazing pastures in the plains necessitating the transient mixing of herds (Ohta, 1982). Sharing watering source leading concentration of young stock in one point during the dry season was unexpectedly associated with lowered risk of PPR outbreaks in 2009. This could be due to two reasons (a) other factors, not captured in the study could be responsible for the occurrence of the many outbreaks during this season, (b) during dry season the pastures and water availability in the plains is diminished forcing the *Adakar* herds to migrate from the plains to the mountain ranges or to the neighboring countries. The drought in 2009 was very severe and thus no herds from foreign lands could have been enticed as there were no pastures to share within Turkana plains and mountains (ALRMP, 2009). Similar to 2009, activities related to “sick dams left to nurse their young kids/lambs” had both risk effects during the long rainy season and protective effects during the dry season in 2010. During long rainy season, small stock grazes close to homestead and there is general mixing of all groups and sometimes herds. As discussed earlier sick dams are allowed to nurse their young ones due to lack alternative management occasioned by lack of labor. Kids and lambs born by immunologically naïve mothers and older lambs and kids that are above five months may not have maternal immunity or could have lost protective maternal antibodies against PPR and thus were at risk when they are nursed from their sick mothers or graze along with other sick adults. During the dry season in 2010, indiscriminate mixing of vulnerable group with high risk group within herds was significantly inversely associated with the occurrence of outbreaks. During the dry season the animals are herded into *Adakar* herds which are more likely to keep by themselves away from others as competition for pasture and water intensifies. As the dry season becomes intense most of the new born kids and lambs do not survive and even the older kids and lambs succumb earlier to vagaries of drought. Such situations were witnessed from August 2010 to December 2010 (ALRMP, 2010 unpublished data). Thus as the *Adakar* herds becomes close to other intruders herds and with lose of young stock to drought PPR outbreaks become fewer since only adult that are likely to be immune that survive.

Association between division and the occurrence of outbreaks during the dry season of 2010 suggests spatial heterogeneity in the disease occurrence. This observation may reflect differences in ecological factors across the district within the season. Though spatial statistics were not applied to this data, we deduced that spatial heterogeneity could play a critical role in the evolution of PPR outbreaks.

It is inexplicable that some of the management practices that would have been expected to increase risk were not captured by the final logistic regression model. This does not necessarily imply that the factors that were not significant were not important in the transmission of PPR. Factors associated with the observation of clinical cases during outbreak may be quite different from those associated with the prevalence of infection (Warensj□ et al., 2006; Berghaus et al., 2005). As previously noted, PPR disease is relatively new to the Turkana pastoralists in Kenya. The clearest picture of the PPR disease to the Turkana pastoralist is described as that of dramatic epidemic that killed their sheep and goats in 2006 and 2007. Thus as the disease become endemic such dramatic PPR outbreaks affecting both species and all ages of small ruminants may diminish. This would mean that there are possibilities of misreporting the PPR disease as it is likely to present itself in a different epidemiological picture varying from their original experience with the disease. As such, a participatory risk assessment was considered in this study as data collection method because Turkana community has a large proportion of illiterate pastoral community living in remote arid and semi arid northwest of Kenya and there was scanty official diagnostic information on PPR for this region despite outbreaks originating from the region. However, the Turkana community have gained a wealth of indigenous knowledge on the PPR from last epidemic that could only be gathered through participatory appraisal methods (Mariner and Paskin, 2000; Catley and Mariner, 2002).

The limitations observed in this study relate to the subjective decision making involved in factor analyses and participatory data relating to observation of PPR outbreaks as well as the cross-sectional nature of the study (Esmaillzadeh et al., 2007). However the factor analysis described in Kihu et al. (2012) was thoroughly analyzed and key statistics assessed for factorability of the correlation matrix. Factors scores derived through factor analysis of participatory risk assessment were used as new variables in logistic regression models thus minimizing the multicollinearity problem (Quain et al., 2004; Edefonti et al., 2010;). Use of focused group discussion during data collection minimized subjective nature of the participatory appraisal data collected through triangulation of responses from other members in the *Adakar* focused group discussions therefore the data collected largely reflected the disease knowledge within that *Adakar*.

Conclusion

Occurrence of PPR outbreaks in Turkana District could have resulted from an interaction between socio-cultural and spatial factors with evidence of seasonal trends. However, the situation is made more complex by lack of consistency in factors associated with the occurrence of the disease in a season over time. This complexity calls for a systems approach in understanding and predicting incidence and impacts of the disease in the region. As such, control and eventual eradication of PPR in areas such as Turkana region may provide a challenge to conventional control methods. Concerted control efforts that incorporate application of both conventional methods and targeted control measures based on area specific participatory epidemiological surveillance may stem spread of the disease.

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