Available online at www.sciencedirect.com
SCIENCE DIRECT
Preventive Veterinary Medicine 65 (2004) 17–30
PREVENTIVE VETERINARY MEDICINE
www.elsevier.com/locate/prevetmed

Participatory diagnosis of a heat-intolerance syndrome in cattle in Tanzania and association with foot-and-mouth disease

A. Catley[a,b,*], R.T. Chibunda[c], E. Ranga[d], S. Makungu[d], F.T. Magayane[c], G. Magoma[d], M.J. Madege[d], W. Vosloo[e]

[a]*African Union/Interafrican Bureau for Animal Resources, P.O. Box 30786, 00100 Nairobi, Kenya*
[b]*Feinstein International Famine Centre, School of Nutrition Science and Policy, Tufts University, 126 Curtis Street, Medford, MA 02155, USA*
[c]*Sokoine University of Agriculture, P.O. Box 3017, Morogoro, Tanzania*
[d]*Veterinary Investigation Centre, P.O. Box 129, Mwanza, Tanzania*
[e]*Exotic Diseases Division, Onderstepoort Veterinary Institute, Private Bag X05, Onderstepoort 0110, South Africa*

Received 7 August 2003; received in revised form 22 June 2004; accepted 22 June 2004

Abstract

A heat-intolerance (HI) syndrome in cattle in Tanzania was suspected to be associated with previous, clinical foot-and-mouth disease (FMD). A participatory appraisal (PA) method called ‘matrix scoring’ was used to explore livestock-keeper perceptions of association between HI and cattle diseases. A PA method called ‘proportional piling’ was used to estimate herd incidence of FMD and other diseases, herd incidence of HI, and association between HI and other cattle diseases. Use of matrix scoring and proportional piling with pastoral Maasai informants demonstrated association between FMD and HI. With agropastoral Sukuma informants, the matrix-scoring method did not indicate an association between FMD and HI, whereas the proportional piling method indicated a weak association. Results were supported by calculation of positive predictive values for herder diagnosis of HI and FMD. Clinical examination of cattle by veterinarians was used to confirm HI

* Corresponding author. Tel.: +254 20 226447; fax: +254 20 212289.
E-mail address: andy.catley@oau-ibar.org (A. Catley).

doi:10.1016/j.prevetmed.2004.06.007

cases and detection of antibody to non-structural proteins of FMD virus was used to confirm previous clinical FMD.

Keywords: Cattle-microbiological disease virus; Heat intolerance; Foot-and-mouth disease; Participatory epidemiology; Tanzania

1. Introduction

1.1. The heat-intolerance syndrome in cattle in Tanzania

In the late 1990s, a syndrome of heat intolerance (HI) and overgrowth of hair in cattle was reported by workers in Morogoro region, Tanzania (Makene, 1998). Affected cattle spent less time grazing than normal cattle, and more time resting in the shade of trees or wallowing in water. The coat developed a long, thick appearance and affected animals panted during the heat of the day. Cattle with HI lost body condition, and milk production and fertility were reduced. Based on descriptions of foot-and-mouth disease (FMD) by Radostits et al. (1994), it was suggested that HI was a sequel to FMD and was caused by damage to the endocrine system by FMD virus. Soon after the study on HI in Morogoro, workers in the Lake Zone of Tanzania reported that Sukuma farmers were complaining about a disease in cattle which they called *luzwiga* also characterised by heat intolerance and overgrowth of hair (Magoma et al., 2000). That study confirmed that HI cases became pyrexic and developed high respiratory rates as ambient temperature increased from early morning to afternoon.

The first report of FMD in Tanzania referred to an outbreak in Kahama District, Arusha Region in 1927 attributed to type O virus (Anon, 1927). Since then FMD has been reported annually in almost every region of the country and generally is assumed to be endemic in East Africa (Vosloo et al., 2002). Types O, A, SAT-1 and SAT-2 were noted in late 1960s (Rweyemamu, 1970), and SAT-3 was reported in 1996 in Arusha Region. Kivaria (2003) reported FMD in Tanzania due to type C virus. Tanzania has an indigenous-cattle population of ~17 million head (Ministry of Agriculture and Food Security, 2002). Many of these animals are managed using agropastoral and pastoral systems, and the country has extensive (largely unregulated) borders with Burundi, Democratic Republic of Congo, Kenya, Malawi, Mozambique, Uganda, Rwanda and Zambia. Seasonal and trade-related movements of cattle across borders probably help maintain FMD in Tanzania. The country has many African buffalo (*Cyncerus caffer*), which are carriers of FMD virus (Thomson et al., 2003). Contact between cattle and buffalo is common in pastoral and agropastoral areas (particularly in the dry season when animals congregate around watering points).

In Kenya, woolly coats, panting and reduced fertility were noted as complications of FMD (Anon, 1955) and it was suggested that the problem only occurred in high-grade cattle rather than in indigenous African types. More recently, there are reports of HI following FMD outbreaks in cattle in pastoralist areas of Africa. The diseases *juol*, *jul* and *akumol* were noted in Nuer communities in southern Sudan (Blakeway et al., 1996); in Sudan, the disease *ha'ish*, (meaning 'ugly') was similar to HI (Kenyon, personal communication). All these reports are based on ad hoc field observations by veterinarians or on associations between HI and FMD as described by livestock keepers. Although there were no published accounts of the incidence of HI in affected herds, most accounts described the disease in adult or young cattle rather than calves.

1.2. Using participatory appraisal methods to investigate association

Participatory appraisal (PA) methods have been used by veterinarians in Africa since the late 1980s. Guidelines for specific PA methods are available (Mariner and Paskin, 2000) and examples of field research include the use of matrix-scoring scoring to characterise cattle diseases in southern Sudan (Catley et al., 2001) and Kenya (Catley et al., 2002a), and seasonal calendars to depict seasonal variations in disease incidence and vector populations (Catley et al., 2002a, 2002b). A PA method called "proportional piling" was used to estimate cattle disease incidence (Catley et al., 2002a), and Mariner and Roeder (2003) described the use of semi-structured interviews, timelines and mapping when searching for mild rinderpest in East Africa.

We investigated the putative association between acute, clinical FMD and the chronic HI syndrome. We used both conventional research methods and matrix-scoring and proportional piling for exploring livestock keepers' perceptions of the association between HI and acute diseases of cattle, and the incidences of FMD and HI.

2. Methodology

In 2000, FMD was reported from all the major cattle-rearing regions of Tanzania (Pan African Programme for the Control of Epizootics-Tanzania, unpublished data). The main criterion for selection of study locations was evidence that livestock keepers recognised a HI-like syndrome and had requested advice from local veterinarians on how best to solve the problem. A further consideration was the presence of research partners in the locality who were interested in HI and willing to invest time in the study. Our research was conducted with Maasai communities in Morogoro Region and Sukuma communities in Mwanza and Shinyanga Regions. The Maasai are pastoralists who inhabit large tracts of the Rift Valley in Kenya and Tanzania. In recent years, they have expanded their range to Morogoro and Coast regions of Tanzania. The Sukuma are sedentary agropastoralists who rely more heavily on crops than livestock as a source of livelihood.

The methodology involved three main stages. First, matrix-scoring was used in community meetings to assess the ability of groups of livestock keepers to clinically diagnose cattle diseases (including FMD) and to determine whether keepers associated HI with previous acute clinical disease. Second, an historical cohort study was used with the same livestock keepers to compare herds with and without HI. This comparison used proportional piling with individual livestock keepers to further assess association between HI and previous acute clinical disease, and estimate the incidence of HI and FMD in sampled herds. Third, the positive predictive value of herder diagnoses for HI and FMD on a herd level was assessed by clinical examination of herder-diagnosed HI cases, and detection of antibody to non structural proteins of FMD virus.

In each region, local veterinary workers selected villages where HI cases had been reported and where similar livestock-production systems and ecology were observed. In Morogoro Region, research was conducted May 2001 and in Mwanza/Shinyanga Regions, in June 2001.

2.1. Matrix-scoring to assess clinical diagnosis of cattle diseases, and association between HI and previous clinical disease

Local veterinary personnel contacted chiefs and administrators to arrange initial meetings with livestock keepers in selected villages. At these meetings, the objectives of the research were explained and participants were divided into groups for matrix scoring of disease signs. The matrix-scoring method was adapted from the method described by Catley et al. (2001).

In Morogoro Region, interviews with local veterinary workers provided the Maasai names for FMD and four other cattle diseases (*endorobo*/trypanosomiasis, *oltikana*/East Coast fever (ECF), *emwilalas*/contagious bovine pleuropneumonia (CBPP) and *engluwet*/blackleg). The Maasai name for FMD was assumed to be *olukuluku*. The four diseases other than FMD were selected because they appeared to be important problems in Maasai cattle and we assumed that informants would be willing to take time to discuss them. These four diseases acted as controls in the matrix and at no time were informants told that we were interested particularly in FMD.

According to previous knowledge of the four control diseases (trypanosomiasis, ECF, CBPP and blackleg), FMD and HI, we identified eight acute and eight chronic clinical signs of these diseases. These signs were illustrated on pieces of card using simple line drawings (for example, a picture of drooling cow was used to represent the indicator ‘salivation’). To construct the matrix, the five diseases were represented using common objects placed in a row on the ground. The local disease name assigned to each object was explained to the informants and they were asked to repeat back the names to ensure that they understood the meaning of each object. The researchers then selected the acute disease sign ‘coughing’, showed the informants a picture of a coughing cow and explained the meaning of the picture. This explanation included the idea of acute disease signs, being signs that were observed within five days of an animal observed to become sick. Informants then were asked to score the five diseases by dividing a pile of 20 stones to show the relationship between coughing and the diseases. They were instructed to use all 20 stones. They were also advised that if they felt that coughing was not observed in any of the five diseases, they should allocate a score of zero stones to all five diseases.

After this scoring, the researchers prompted the informants to check their scores and confirm that as a group, they agreed that the scores were correct. The scoring procedure was repeated with each acute disease sign in turn and each time the method was used, the disease signs were presented in the same order. We then explained that some diseases caused signs of disease that appeared weeks or months after the animal first became sick.

The chronic signs then were added one-by-one to the matrix and scored using the same procedure with 20 stones.

In Mwanza/Shinyanga Regions, the same matrix-scoring method for acute and chronic disease signs was used but with the Sukuma names for the same five diseases (*bugigi*/FMD, *ndorobo*/trypanosomiasis, *madundo*/ECF, *mabuupu*/CBPP and *lyoho*/ blackleg).

In Morogoro Region, matrix scoring was conducted with nine groups of Maasai informants (each comprising six to 16 individuals) in Dakawa (one group), Chalinze (four groups), Malela (two groups) and Sokoine (two groups) villages. The Kendall coefficient of concordance (*W*) (Siegal and Castellan, 1988) using the *Statistical Packages for the Social Sciences* Version 9.0 Software (SPSS, 1999) was used to assess agreement between informant groups.

In Mwanza/Shinyanga Regions, matrix scoring was conducted with 11 groups of Sukuma informants (8 to 25 individuals) in Kibetilwa, Ng'walalya, Solwe, Sawidi (two groups per village) and Laini (three groups). The Kendall coefficient of concordance (*W*) was used to assess agreement between informant sub-groups, as for the Maasai group.

2.2. Proportional piling to assess association between HI and previous acute clinical disease, and estimate incidence of FMD and HI

Matrix-scoring sessions with each informant group were concluded by the researchers explaining the need to further investigate HI, and visit herds with and without HI cases. Due to time and resource factors, participants were advised that approximately 6 herds per informant group could be visited. Using this informal sampling procedure, Maasai informants identified 23 herds reported to have HI cases and 27 herds reported not to have HI cases (total 50 herds). Sukuma informants identified 6 herds reported to have HI cases and 67 herds reported not to have HI cases (total 73 herds). Proportional piling was conducted with the owners or carers of these herds. These informants had previously conducted the matrix-scoring, as members of the informant groups.

Local definitions of cattle age groups were used. Maasai cattle age groups were *lohok* ($\leq$1 year old), *lenok* or *endawowa* (1–3 years old) and *engeshulapowa* (>3 years old). Sukuma age groups were *ndama* ($\leq$18 months old), *ndogosa* or *kayagamba-kanyabuka* (1.5–3 years old) and *mbogoma* or *nzagamba* (>3 years old).

Using a pile of 100 stones to depict an age group, the informant was asked to divide the stones to show the pattern of 'sick cattle during the last year' and 'healthy cattle during the last year'. The pile of stones representing sick cattle was then sub-divided by the informant to show the pattern of cattle having each of the five diseases (as used in the matrix scoring) plus a category called 'other diseases' (a total of six disease categories). This initial stage of the method is illustrated in Fig. 1.

Each pile of stones representing the six disease-incidence categories then further was sub-divided to show the pattern of cattle dying and surviving for each disease category. This resulted in two piles of stones for each of the five diseases and the 'other diseases' category. The informant then was asked to concentrate on the six piles of stones

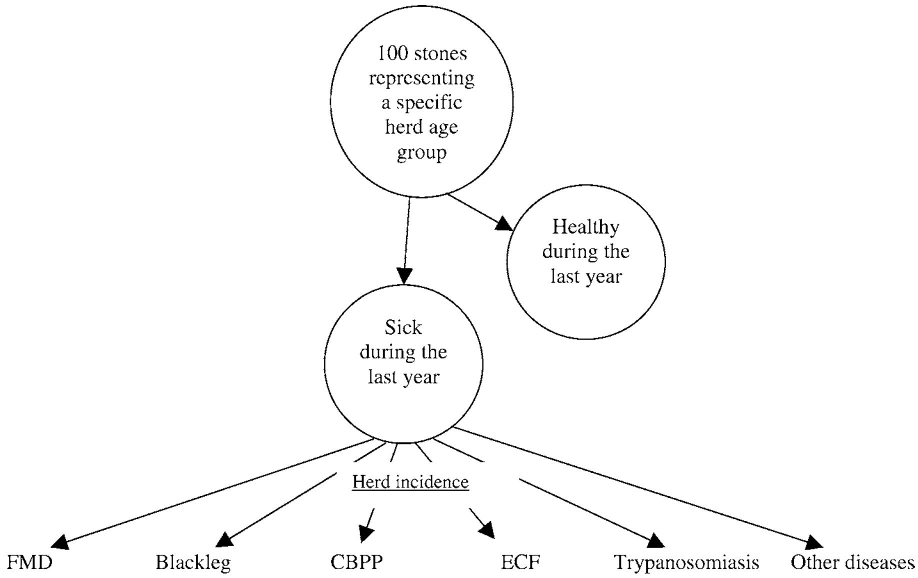

Fig. 1. Diagrammatic representation of the proportional piling method.

representing surviving cattle, and divide these stones to show cattle developing HI versus cattle not developing HI. This aspect of the method was designed to show the relationship between HI cases and previous clinical disease.

Association between HI and FMD was assessed using relative risk in PEPI version 4.0 software (Abramson and Gahlinger, 2001). This software was also used to calculate the difference in the proportion of Maasai and Sukuma informants reporting HI and FMD.

2.3. Positive predictive values of herder diagnosis

2.3.1. Inspection of herds by veterinarians to diagnose HI

We visited the 50 Maasai and 73 Sukuma herds whose carers conducted the proportional piling and matrix-scoring, and who reported the absence or presence of HI cases. Cases of HI diagnosed by livestock keepers were cross-examined by a veterinarian in the 23 Maasai herds and 6 Sukuma herds. In the 27 Maasai and 67 Sukuma herds where no HI cases were reported, the herd was observed by a veterinarian and any suspect HI cases were examined. The positive predictive value of herder diagnosis of HI at herd level was calculated using PEPI version 4.0 software (Abramson and Gahlinger, 2001).

2.3.2. Foot-and-mouth disease serology

In the same Maasai and Sukuma herds, blood samples were collected from cattle and examined for antibody to 3ABC non-structural proteins of FMD virus by enzyme-linked immunosorbent assay (ELISA) (Chekit-FMD-3ABC, Intervet). This antibody is only detected in animals reported to have shown clinical signs of FMD (Mackay et al., 1998; Kitching, 2002) and persists for up to 395 days post infection (Vosloo, unpublished data). The 3ABC ELISA can be used as a screening test for detecting exposure to FMD virus and carrier animals, on a herd basis (Kitching, 2002). The sensitivity of the test was reported as 85% and specificity at 99% (Moonen et al., 2004).

In the 50 Maasai herds, 249 samples were collected (range 2–11 samples per herd). In 73 Sukuma herds, 241 samples were collected from 59 herds (range 2–10 samples per herd). Fourteen of the 73 Sukuma herds involved in proportional piling were not sampled due to time and resource constraints. The positive predictive value of herder diagnosis of previous clinical FMD on a herd level was calculated using PEPI version 4.0 software (Abramson and Gahlinger, 2001).

3. Results

3.1. Disease signs and association between diseases and subsequent HI using matrix scoring

Summarised matrix-scoring results for Maasai and Sukuma groups are presented in Table 1. We categorized agreement between informant groups as ‘weak’, ‘moderate’ and ‘good’ according to critical values for W provided by Siegel and Castellan (1988). Therefore, agreement was termed weak, moderate and good if W values were less than 0.26, between 0.26 and 0.38 ($P < 0.05$), and greater than 0.38 ($P < 0.01$ to $P < 0.001$), respectively.

For Maasai informants, high agreement ($W > 0.38$) typically was seen between informant groups for acute and chronic signs. Maasai informants associated the chronic clinical signs of HI with the previous acute clinical signs of FMD. For Sukuma informants, high agreement was evident for 5/8 acute signs (including typical signs of FMD) and 1/8 chronic signs. Sukuma informants did not associate the chronic clinical signs of HI with previous acute signs of FMD, or any other disease.

3.2. Associations between acute diseases and subsequent HI using proportional piling

In the Maasai group, 41 (82%) informants reported FMD and 23 (45%) informants reported HI in their herds. In the Sukuma group, reporting of FMD and HI was significantly lower; 40 (55%) informants reported FMD (95% CI for difference in proportions 10%, 45%) and six (8%) informants reported HI (95% CI for difference in proportions 21%, 55%).

The mean annual incidences of FMD and HI in sampled Maasai herds ($n = 50$) for the period 2000–2001 were 49% and 2%, respectively. The mean incidences of FMD and HI in sampled Sukuma herds ($n = 73$) for the same period were 17% and 0.1%, respectively. In Maasai herds, 12% of cattle showing acute FMD and surviving the disease later developed HI. In Sukuma herds, HI cases developed in 4% of cattle previously showing acute FMD and surviving the disease.

Table 1
Summarised matrix-scoring results from Maasai informants and Sukuma informants, Tanzania (2001)

Sign	Maasai (9 villages)						Sukuma (11 villages)					
	FMD Md (Mn–Mx)[a]	Blackleg Md (Mn–Mx)	CBPP Md (Mn–Mx)	ECF Md (Mn–Mx)	Tryps Md (Mn–Mx)	W[b]	FMD Md (Mn–Mx)	Blackleg Md (Mn–Mx)	CBPP Md (Mn–Mx)	ECF Md (Mn–Mx)	Tryps Md (Mn–Mx)	W[b]
Acute												
Abortion	10.0 (5–14)	0 (0–0)	0 (0–4)	0 (0–4)	6 (3–8)	0.90	0 (0–10)	0 (0–10)	0 (0–20)	0 (0–0)	0 (0–20)	0.16
Coughing	0 (0–1)	0 (0–1)	14 (3–16)	5 (0–15)	2.5 (0–4)	0.79	0 (0–2)	0 (0–0)	15 (0–20)	0 (0–20)	0 (0–15)	0.63
Death	0 (0–3)	3.5 (0–20)	1 (0–5)	7 (0–20)	0 (0–4)	0.53	0 (0–3)	8 (0–20)	5 (0–10)	5 (0–5)	0 (0–8)	0.48
Diarrhoea	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–17)	20 (3–20)	0.77	0 (0–10)	0 (0–0)	0 (0–10)	0 (0–20)	0 (0–10)	0.20
Enlarged LN[c]	0 (0–0)	0 (0–0)	0 (0–0)	14 (12–17)	6 (3–8)	1.00	0 (0–0)	0 (0–0)	0 (0–0)	20 (20–20)	0 (0–0)	1.00
Lameness	17.5 (10–20)	2.5 (0–10)	0 (0–0)	0 (0–0)	0 (0–0)	0.87	10 (5–10)	10 (0–15)	0 (0–0)	0 (0–0)	0 (0–0)	0.93
Reduced milk	14 (7–20)	0 (0–0)	0 (0–0)	4 (0–4)	0 (0–10)	0.60	5 (0–20)	0 (0–5)	2 (–0–5)	0 (0–10)	0 (0–10)	0.35
Salivation	14 (6–20)	0 (0–0)	1 (0–8)	4 (0–6)	0 (0–2)	0.78	20 (10–20)	0 (0–3)	0 (0–0)	0 (0–5)	0 (0–5)	0.86
Chronic HI												
Cow seeks shade	20 (14–20)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–6)	0.95	0 (0–5)	0 (0–5)	0 (0–3)	0 (0–0)	0 (0–0)	0.05
Hirsuitism	20 (20–20)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	1.00	0 (0–0)	0 (0–0)	0 (0–10)	0 (0–0)	0 (0–20)	0.12
Panting	20 (10–20)	0 (0–0)	0 (0–0)	0 (0–4)	0 (0–0)	0.84	0 (0–10)	0 (0–10)	8 (0–20)	0 (0–4)	0 (0–5)	0.28
Reduced fertility	15.5 (0–20)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–9)	0.63	0 (0–0)	0 (0–10	0 (0–10)	0 (0–0)	0 (0–20)	0.09
Wallows in water	20 (15–20)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–5)	0.95	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–2)	0.91
Chronic other												
Hoof overgrowth	20 (20–20)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	1.00	0 (0–20)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0.28
Loss of tail hair	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	20 (20–20)	1.00	0 (0–20)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–20)	0.36
Weight loss	2.0 (0–15)	0 (0–0)	5 (0–20)	0 (0–5)	7.5 (0–20)	0.32	5 (0–10)	0 (0–10)	0 (0–15)	0 (0–0)	0 (0–16)	0.48

[a] Md, median; Mn, minimum; Mx, maximum.
[b] Weak agreement: $W < 0.26$, $P > 0.05$; moderate agreement: $W = 0.26–0.38$, $P < 0.05$; strong agreement: $W > 0.38$, $P < 0.01$.
[c] LN: lymph nodes.

Table 2
Relative risk of heat intolerance observed in herds after acute food-and-mouth disease, Maasai and Sukuma herds, Tanzania[a]

Herd type	Cross-tabulation of HI and FMD herds, stratified by age group				Relative risk (95% CI) of HI observed in herds after acute FMD
			HI (−ve)	HI (+ve)	
Maasai	Calves	FMD −ve	14	0	1.6 (1.3, 2.1)
		FMD +ve	22	14	
	Young stock	FMD −ve	10	0	2.5 (1.7, 3.7)
		FMD +ve	16	24	
	Adults	FMD −ve	9	0	3.7 (2.3, 6.2)
		FMD +ve	11	30	
	All ages	FMD −ve	33	0	2.4 (1.9, 3.0)
		FMD +ve	49	68	
Sukuma	Calves	FMD −ve	67	0	Not calculated[b]
		FMD +ve	6	0	
	Young stock	FMD −ve	48	0	1.1 (1.0, 1.3)
		FMD +ve	22	3	
	Adults	FMD −ve	30	4	1.1 (0.9, 1.3)
		FMD +ve	33	6	
	All ages	FMD −ve	145	3	1.1 (1.0, 1.3)
		FMD +ve	61	10	

[a] During proportional piling HI cases were only observed in cattle previously observed to have FMD. No HI cases were observed in cattle previously suffering from blackleg, CBPP, ECF, trypanosomiasis or other diseases.
[b] No HI cases were reported in calves in Sukuma herds, therefore relative risk of HI observed in herds after acute FMD was not calculated.

Cross-tabulation of herds according to the presence or absence of HI and FMD is presented in Table 2.

3.3. Positive predictive value of herder diagnosis

Positive predictive values for herder diagnoses of FMD and HI are presented in Table 3.

4. Discussion

4.1. Methodological issues

4.1.1. Matrix scoring

During matrix scoring, higher agreement was evident between Maasai compared with Sukuma informant groups (Table 1). For example, compared to the Maasai, Sukuma informants disagreed over their scores for the indicators ‘diarrhoea’ and ‘abortion’. In part,

Table 3
Positive predictive values for herder-diagnosis of foot-and-mouth disease and heat intolerance, Maasai and Sukuma herds, Tanzania

Disease	Cross-tabulation of disease in herds				Positive predictive value (%) (95% CI) of herder diagnosis
			+ve	−ve	
Foot-and-mouth disease, 3ABC ELISA[a]	Maasai diagnosis	+ve	30	11	73 (65, 80)
		−ve	3	6	
	Sukuma diagnosis	+ve	16	24	40 (32, 49)
		−ve	6	13	
Heat intolerance, veterinarian diagnosis[b]	Maasai diagnosis	+ve	22	1	96 (76, 99)
		−ve	0	27	
	Sukuma diagnosis	+ve	5	1	83 (42, 97)
		−ve	0	67	

[a] ELISA for non-structural proteins to FMD virus; sensitivity 85%, specificity 99%.
[b] Herder diagnosis cross-tabulated with results of clinical examination by veterinarians.

this difference might have been due to the very-low reported incidence of trypanosomiasis in Mwanza and Shinyanga Regions compared with Morogoro Region giving Sukuma informants had relatively little experience of this disease. A weakness of the method was that the researchers identified the control diseases in Morogoro (the first study location) where trypanosomiasis was considered to be an important problem. However, the researchers did not check whether trypanosomiasis was also a priority in Mwanza and Shinyanga Regions (the second study locations). Therefore, although some Sukuma informants were aware of trypanosomiasis, this disease was not an appropriate choice for a control disease in Sukuma locations.

The face validity of the matrix-scoring method was assessed by comparison of matrix scoring results with modern veterinary knowledge. For acute signs of disease, there was good agreement between the opinions of Maasai and Sukuma informants, and typical disease signs (as selected by the researchers) in veterinary textbooks. The scoring of trypanosomiasis by Maasai informants matched modern veterinary thinking apart from a very high score assigned to ‘diarrhoea’. Some veterinary texts state that diarrhoea is a sign of trypanosomiasis (e.g. Radostits et al., 1994) but Table 1 implies that the Maasai perceived this to be a major sign of the disease. This result arose because the scoring procedure required informants to use all 20 stones or zero stones for each indicator. Therefore, if only one disease was associated with a particular sign it would receive a score of 20. This is a possible weakness of the method because it can lead to apparent emphasis of a particular sign (or signs) if results are viewed on a disease-by-disease basis, rather than on a sign-by-sign basis. When probed, Maasai informants consistently stated that diarrhoea was only observed in *endorobo*, and not the other diseases in the matrix.

For chronic signs of disease, there were marked differences in the scoring patterns of the Maasai and Sukuma. The Maasai scored the control disease trypanosomiasis as expected, with stones assigned to weight loss and loss of tail hair. Compared to the Sukuma, the Maasai consistently scored FMD for those signs associated with heat intolerance. In terms of face validity, the Maasai scores matched a textbook description of chronic manifestations of FMD (Radostits et al., 1994) and reports of 'chronic FMD' from other pastoral areas. Sukuma informant groups did not associate the signs of HI with FMD (or any other disease) during matrix scoring. However, during proportional piling, far fewer Sukuma informants reported HI compared with Maasai informants. Therefore, it is likely that fewer Sukuma informants had actually observed HI relative to Maasai informants.

Because the matrix scoring method was used with informant groups and consensus of opinion was encouraged, it is possible that the views of a relatively small number of Sukuma informants who knew about HI were 'over-ruled' by the majority who had not observed the disease. If this was the case, it indicates that a standardised matrix-scoring method with informants groups might be less appropriate in situations where knowledge about a particular problem resides with a small number of informants (for example, for a disease of very low incidence). This problem might have been overcome by categorising informants into those people who had observed *luzwiga* cases in their herds and those who had not. The method could then be repeated with these two informant categories.

4.1.2. Proportional piling

The proportional-piling method was a useful, indirect way to explore perceptions of links between FMD and HI. Regarding prior knowledge of the researchers' interest, only after scoring all six-disease categories for incidence was an informant asked to think specifically about HI. Furthermore, the logical division of stones into sick and healthy animals, followed by further division to show patterns of specific diseases and 'other diseases' meant that it was impossible for an informant to backtrack and suddenly assign a large number of stones to a particular disease.

Both questionnaires and proportional piling are subject to recall bias. Researchers often assume that this type of bias is a particular problem with respondents who do not keep written records of herd management and disease events, because people simply forget what happened at a certain time. However, there are a number of reports of pastoralists' ability to provide very detailed verbal accounts of past disease events, covering the entire lifespan of their stock (McDermott et al., 1987; Akabwai, 1992; Iles, 1994; Kaufmann, 1998).

4.2. Associations between HI and FMD

Proportional piling indicated herd-level association between acute FMD and the subsequent appearance of HI (Table 2), with relatively stronger association in Massai compared with Sukuma herds. However, reported herd incidence of HI and FMD was significantly lower in Sukuma herds. Only 73 Sukuma herds were examined and the estimated incidence of HI was 0.1%.

Positive predictive values of Maasai herder's diagnoses of FMD and HI indicated strong ability to diagnose these diseases, but provide no direct evidence of association between the two diseases. Compared with the Maasai, Sukuma herders were less able to provide a positive diagnosis of FMD at herd level. This finding suggested that proportional piling with Sukuma informants was compromised by relatively weak ability to diagnose FMD.

Available information on the 3ABC ELISA suggests that after acute FMD, antibody persists for up to 395 days (Vosloo, unpublished data). It is possible that in our study, the 3ABC ELISA detected some antibody caused by exposure to FMD virus before the 12-month period covered by the proportional piling method. In this situation, calculation of positive predictive values of herder diagnosis by comparing proportional piling and 3ABC results would not be appropriate.

4.3. Incidence estimates

In the sampled Maasai and Sukuma herds, 12% and 4%, respectively of cattle showing clinical signs of FMD and surviving the disease later developed HI. According to Maasai informants, cattle affected with HI neither recovered clinically nor returned to their previous level of production. These findings indicate that losses due to HI should be included in assessments of the economic impact of FMD in pastoral and agropastoral herds.

4.4. Outcomes of the research

As a result of the research, illustrated information leaflets were designed to explain the association between FMD and HI to livestock keepers. The leaflets focussed on clinical recognition of HI. Also, as some herders attempted to treat HI using modern drugs such as antibiotics and anthelmintics, or indigenous methods such as local brews, the leaflet advised that any treatment was unlikely to be successful and culling affected cattle was the best option.

5. Conclusions

This research demonstrated that PA methods can be adapted to explore associations between acute and chronic manifestations of disease. However, when the incidence of a disease is low, methods used with groups of informants may not reveal knowledge held by a few individuals. In such situations, methods focussing on individual informants are preferred. The research findings supported the hypothesis that HI is associated with FMD in indigenous Maasai and Sukuma cattle in Tanzania.

Acknowledgements

This research depended on the contributions of Maasai and Sukuma communities in Morogoro, Mwanza and Shinyanga Regions, Tanzania. The researchers acknowledge the support of Dr. J.T. Musiime, Acting Director, African Union/Interafrican Bureau for Animal Resources, Professor D. Kambarage, Sokoine University of Agriculture and Dr. A.

Kondela, Mwanza Veterinary Investigation Centre. Prof. G. Scott and Dr. P. Rossiter provided advice on the older literature on FMD. Michael Thrusfield and Jeffrey Mariner commented on the draft manuscript. The research was funded by the Department for International Development, United Kingdom.

References

Abramson, J.H., Gahlinger, P.M., 2001. Computer Programs for Epidemiologists PEPI, Version 4.0, Sagebrush Press, Salt Lake City.

Akabwai, D.M.O., 1992. Extension and Livestock Development: Experience from among the Turkana pastoralists of Kenya. Pastoral Development Network Paper 33b, Overseas Development Institute, London.

Anon, 1927. Annual Report of the Tanganyika Department of Veterinary Services, 1927. Dar es Salaam.

Anon, 1955. Notes on animal diseases. VIII. Foot-and-mouth disease. East African Agric. J. XX (3), 140–144.

Blakeway, S., Linquist, B.J., Adolph, A., 1996. Nuer Ethnoveterinary Knowledge. A Resource Manual, UNICEF Operation Lifeline Sudan Southern Sector Livestock Programme, Nairobi.

Catley, A., Irungu, P., Simiyu, K., Dadye, J., Mwakio, W., Kiragu, J., Nyamwaro, S.O., 2002a. Participatory investigations of bovine trypanosomiasis in Tana River District. Kenya. Med. Vet. Entomol. 16, 1–12.

Catley, A., Osman, J., Mawien, C., Jones, B.A., Leyland, T.J., 2002b. Participatory analysis of seasonal incidences of diseases of cattle, disease vectors and rainfall in southern Sudan. Prevent. Vet. Med. 53/54, 275–284.

Catley, A., Okoth, S., Osman, J., Fison, T., Njiru, Z., Mwangi, J., Jones, B.A., Leyland, T.J., 2001. Participatory diagnosis of a chronic wasting disease in cattle in southern Sudan. Prevent. Vet. Med. 51 (3/4), 161–181.

Iles, K., 1994. The progeny history data collection technique: a case study from Samburu District, Kenya. RRA Notes 20, 71–77.

Kaufmann, B., 1998. Analysis of pastoral camel husbandry in Northern Kenya. In: Hohenheim Tropical Agricultural Series. Margraf-Verlag, Weikersheim.

Kitching, R.P., 2002. Identification of foot and mouth disease virus carrier and subclinically infected animals and their differentiation from vaccinated animals. Revue Scientifique et Technique Office International des Epizooties 21 (2), 531–538.

Kivaria, F., 2003. Foot and mouth disease in Tanzania. Vet. Quart. 25 (2), 72–78.

Mackay, D.K.J., Forsyth, M.A., Davies, P.R., Berlinzani, A., Belsham, G.J., Flint, M., Ryan, M.D., 1998. Differentiating infection from vaccination in foot-and-mouth disease using a panel of recombinant non-structural proteins in ELISA. Vaccine 16 (5), 446–459.

Ministry of Agriculture and Food Security, 2002. Livestock Statistics. Republic of Tanzania, Dar es Salaam.

Magoma, G., Samuel, S., Kondela, A., Madege, M., Makungu, S., 2000. A preliminary clinical investigation of a condition known as *luzwiga* in the Lake Zone of Tanzania. In: Annual Scientific Conference of the Tanzania Veterinary Association, Arusha, 3rd to 5th December 2000.

Makene, V.W., 1998. Heat intolerance associated with foot and mouth disease in cattle: occurrence, behaviour and physiological parameters. M.Sc. thesis, Sokoine University of Agriculture.

Mariner, J.C., Paskin, R., 2000. Manual on Participatory Epidemiology. FAO Animal Health Manual 10. Food and Agriculture Organization, Rome.

Mariner, J.C., Roeder, P.L., 2003. Use of participatory epidemiology in studies of the persistence of lineage 2 rinderpest virus in East Africa. Vet. Rec. 152, 641–647.

McDermott, J.J., Deng, K.A., Jayatileka, T.N., El Jack, M.A., 1987. A cross-sectional cattle disease survey in Kongor Rural Council, Southern Sudan. I. Prevalence estimates and age, sex and breed associations for brucellosis and contagious bovine pleuropneumonia. Prevent. Vet. Med. 5, 111–123.

Moonen, P., van der Linde, E., Chenard, G., Dekker, A., 2004. Comparable sensitivity and specificity in three commercially available ELISAs to differentiate between cattle infected with or vaccinated against foot-and-mouth disease. Vet. Microbiol. 99, 93–101.

Radostits, O.M., Blood, D.C., Gay, C.C., 1994. Veterinary Medicine, eighth ed. Bailliere Tindall, London.

Rweyemamu, M., 1970. Observations on foot-and-mouth disease type SAT2 in Tanzania. Bull. Epizootic Dis. Africa 18, 87–100.

Siegel, S., Castellan, N.J., 1988. Nonparametric Statistics for the Behavioural Sciences, second ed. McGraw-Hill, New York.

SPSS, 1999. SPSS Base 9.0 User's Guide. SPSS Inc., Chicago.

Thomson, G.R., Vosloo, W., Bastos, A.D.S., 2003. Foot and mouth disease in wildlife. Virus Res. 91, 145–161.

Vosloo, W., Bastos, A.D.S., Sangare, O., Hargreaves, S.K., Thomson, G.R., 2002. Review of the status and control of foot and mouth disease in sub-Saharan Africa. Revue Scientifique et Technique Office International des Epizooties 21, 437–449.