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Techne meets Metis: Knowledge and practices for tick control in Laikipia County, Kenya

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ABSTRACT

Prevention of tick borne diseases is often through tick control practices. This article diagnoses tick control practices, knowledge underlying these practices and how knowledge is shared at the wildlife-livestock interface in Laikipia County, Kenya. It identifies diverse land use and tick control practices by different land and livestock owners from a scientific knowledge-based (techne) and context driven experiential knowledge-based (metis) perspective.

Interviews, focus group discussions, observations and documents yielded qualitative data to unravel i) the historical development of tick control in Kenya ii) techne and metis tick control practices within three ranches and among pastoralists in Laikipia County, and iii) status of tick knowledge sharing between stakeholders.

Historical tick control measures date back to about 100 years ago, with increasingly strong veterinary measures over the decades under government control. However, the veterinary control system collapsed around 1991 and livestock owners took tick control into their own hands. All respondents indicated having relevant techne available about tick ecology and tick management practices. To adapt to the changing social, economic and institutional context, they further developed metis, integrating the known techne. Metis and techne complemented each other. Our study reveals that metis is developed within stakeholder groups. The data also suggest that metis practices sometimes develop risky effects to animal, human and environmental health. Knowledge on tick control is mainly shared within a social group, not between groups. We esteem, knowledge sharing between different stakeholder groups (ranchers, pastoralists, DVS) may provide opportunities for better informed decision-making based on fruitful combinations of techne and metis for effective and safe tick management.

1. Introduction

Ticks are a health threat for livestock and people around the world. In cattle, ticks cause diseases which reduce productivity, and lower body weight and milk yield in beef and dairy production systems and can result in high mortality (Randolph, 2000). One of the most important and feared tick-borne diseases is East Coast Fever, caused by the protozoan parasite *Theileria parva* which is transmitted to cattle by ticks. Some tick species are human parasites, being vectors of viral, protozoan and bacterial diseases like lyme disease. In tropical rangelands, where livestock and wildlife interact through shared grazing grounds, tick load burdens and tick species diversity are high compared to temperate regions (Beckley et al., 2016).

Our study was conducted in Laikipia County, in the Kenyan Rift valley, a rangeland ecosystem supporting both wildlife conservation and livestock production in private, government and community owned lands. Through a qualitative explorative study, we studied the understanding of ticks, tick ecology and knowledge used in tick control practices by ranchers and pastoralists, including how this knowledge is generated and shared between stakeholders. By outlining the local tick control practices and knowledge base, we contrasted previous collaborative tick control practices under the DVS and current individual tick control initiatives by livestock owners. In this paper we show the interplay of practices and knowledge systems and how they affect the

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efficacy of tick control under different power institutions. Our research will inform animal health policy, The Cattle Cleansing Act, specifically on acaricide use for tick control. This paper draws attention to knowledge generation and sharing as is witnessed in tick control management over the years. We advance Scott (1998) work on state-steered schemes to improve people's lives, showing that communities can still function beyond failure of state institutions, as metis takes root and is strengthened through communities of practice.

1.1. Problem statement

Rooted in historically contested nature of land use in Laikipia (Lengoiboni et al., 2010; Mizutani et al., 2012), different land tenure regimes and categories of landowners exist, resulting in different land use practices. Different knowledge backgrounds, economic contexts and believe systems make it difficult to negotiate, implement and monitor tick control in the region. Previous studies in Africa and Kenya have focused on tick species identification (Fyumagwa et al., 2007; Latif and Walker, 2004; Walker, 2003), vector-host relations and tick-borne pathogens in domestic and wildlife animals (de la Fuente et al., 2004; Fyumagwa et al., 2007; Lightfoot and Norval, 1981; Norval and Lightfoot, 1982), tick ecology and control measures (Latif and Walker, 2004; Semtner et al., 1971; Spickett, 1994; Wharton et al., 1969), tick-borne diseases and even attempts at developing tick-borne disease vaccines (Dantas-Torres et al., 2012; Minjauw and McLeod, 2003; Oura et al., 2004; Randolph, 2000; Vanwambeke et al., 2010). However, tick control and disease treatment have so far not been successful in reducing tick loads (Mureithi and Mukiria, 2015; Paul et al., 2015; Piesman and Eisen, 2008; Wesonga et al., 2010) hence we need to look further. An important question is what kind of knowledge underlies actual tick management practices and to what extend relevant scientific and/or context-specific experiential knowledge is lacking. The role of experiential knowledge, as compared to generalised scientific knowledge in understanding and explaining tick occurrence and tick control practices is largely lacking in literature, as well as how knowledge and practicesdeveloped are shared.

To prevent tick loads and tick-borne diseases, continuous monitoring, learning, adapting and coordinating practices is required (Paul et al., 2015; Piesman and Eisen, 2008). In this diagnostic study we therefore explore i) what tick and tick management related knowledge is available, ii) how knowledge is shared by stakeholders, and what knowledge and practices related issues should be studied next for developing a tool that facilitates continuous monitoring and learning about ticks and tick control management in Laikipia County.

1.2. Key concepts

The objective of this study is to disentangle knowledge and related practices employed in tick management, including the knowledge underlying these practices, and how people share their knowledge. Knowledge, practices, and knowledge sharing concepts are used to structure the research and analyse the data. We will explain these concepts below.

1.2.1. Knowledge

Knowledge refers to information and skills acquired through experience or education. For a better understanding of (the use of) knowledge different typologies have been developed, such as stock knowledge versus flow knowledge, implicit and explicit knowledge, technological knowledge versus social knowledge and scientific knowledge versus knowledge based on experience. In this study we choose to use the distinction between *techne* and *metis* (Scott, 1998). Techne refers to scientific knowledge that is systematically derived, universal, and organized analytically into verifiable, small, explicit, logical steps (Scott, 1998). Techne normally entails a set of principles or a rational method involved in the production of an object or in the accomplishment of an end. It is communicated through language stored in artefacts and taught as formal instruction, in small explicit logical steps that can be broken down and verified, like a cooking recipe or an explosives preparation, transcending location and context (Kenney, 2010). In this research, techne is identified as the technical know-how needed to deal with ticks and tick-borne diseases (TTBDs). It is knowledge about tick ecology, underlying tick control practices (acaricide use, pasture management and vaccinations) as understood and described in scientific literature and taught in formal training institutes.

Metis concerns site specific, contextualised knowledge generated, repeated and adapted by local users through local observations and experiments over time and space (Agrawal and Gibson, 1999; Davis and Wagner, 2003; Gadgil et al., 2003). Metis represents a wide array of practical skills and acquired intelligence in responding to a constantly changing natural and human environment (Scott, 1998, p. 313) and successfully adapts to a constantly shifting situation. It represents knowledge with "the ability and experience necessary to influence the outcome to improve the odds of a particular instance" (Scott, 1998, p. 318). Metis is used in activities in which "responsiveness, improvisation, and skilful, successive approximations were required" (Scott, 1998, p. 323). Metis results from experience, including both technical and social knowledge in context as well as economic and institutional knowledge, needed to know what motivates people to act in specific ways in specific situations. As we expect that these kinds of knowledge are indeed used to decide about tick management practices we prefer to use the techne - metis typology to emphasis knowledge and skills used in practice, as well as outline the role of context and state power (or lack of it) in mobilising new knowledge. Metis cannot be specified in advance unlike techne which is a cut-and dried set of codified rules in written text. To understand if and what metis is at play, one should experience real-life situations and activities, as metis is developed and expressed through practices. Thus, we give a) an overview of how the two knowledge types evolved over time in contrasting stakeholder groups within the political and economic context of Kenya and, b) an analysis of the dynamic interaction between the two knowledge types.

Central to this research is to find out what knowledge (both techne and metis) is used in tick management practices. Research questions include where the knowledge comes from, how general tick control measures become contextualised tick control practices in Laikipia, and how knowledge is shared within and between different stakeholders. Distinguishing techne and metis knowledge enables us to look at the power dynamics between stakeholders and access to certain knowledge or practice. It allows for the exploration of the role of state in the mobilisation of knowledge,(lack of) integration, and diffusion, e.g. through the implementation of different tick control policies over the years. As we know, techne extension services to livestock owners were stopped after the introduction of structural adjustment policies (SAPS) in early 1990s; hence livestock owners increasingly depended on metis to tackle emerging issues in their changing context.

1.2.2. Practices

As (metis) knowledge is developed and expressed through practices we studied tick control practices. Shove et al. (2012) define practice as combinations of competence (skills and routines), material (things and bodies) and meaning (attached) that are enacted and reproduced. From Gherardi (2012) we learn that a practice denotes a set of activities that form a pattern. The study of practice is associated with the descriptive purpose of depicting the activities that make up a practice. In this research, practices, on the one hand, entail activities related to tick management and treatment of tick borne diseases in livestock, and, on the other hand, activities that influence the presence of ticks, amongst which activities related to land use: where do different categories of animals (livestock and wildlife) meet and thus do ticks get a chance to survive and develop? We use the definition of practice by Shove et al. (2012) to systematically explore the process of transformation showing how practices evolve and change. We use her understanding of practice to isolate patterns in activities of tick control, materials and skills used, as these activities are shaped and enabled by structures of rules and meanings in human (livestock owners) actions (Shove et al., 2012, p. 3).

1.2.3. Knowledge sharing

Knowledge sharing is a process were individuals jointly create new knowledge by mutually exchanging their implicit and explicit knowledge (De Vries et al., 2006; Van Den Hooff and De Ridder, 2004, p. 118). To understand how new knowledge is mobilised in communication we explore the level and nature of interactions between livestock and wildlife managers. We look at the interaction between tick experts (veterinary officers, researchers) as perceived techne knowledge sources, and between livestock and wildlife managers who use techne and develop metis knowledge for tick control.

Knowledge sharing consists of the supply and demand of new knowledge (Ardichvili, 2008) which has elements of flow or transfer from one individual to another. Knowledge sharing occurs at the individual and collective level (in this case within pastoral communities and expert organizations like the department of veterinary services (DVS)), utilizing the resources and capabilities of its members. Knowledge sharing not only affects tacit knowledge but all phases of the knowledge creating process (Wabwezi, 2011). Thus, we explore knowledge sources to understand how information flows from one source (individual or institution) and reaches an end user.

There is formal (for explicit knowledge) and informal (for implicit knowledge) exchange of knowledge, which in our paper we refer to as techne and metis respectively. Informal knowledge is shared in informal networks and in informal communication through informal interactions (Wabwezi, 2011). Wildlife and livestock management knowledge comes from either formal training or from daily experiences of living with wildlife and livestock. By unravelling who talks to whom in what setting, what they talk about and how they communicate (face to face or through use of information technology), we explore interactions in which knowledge (techne and/or metis) is shared. Ultimately this gives insight in what is needed for developing a tool for tick control based on continuous monitoring and knowledge developing and sharing.

1.3. Methods

A case study approach was used for which three private ranches and three surrounding communities were selected in Laikipia county. This approach allows for a qualitative explorative investigation of a phenomenon in context (Cundill et al., 2014) allowing us to understand the use of techne and metis knowledge in Laikipia. We purposely sampled three ranches to explore TTBDs control practices and knowledge in livestock and wildlife. Communities surrounding the ranches were selected to study pastoralists tick control practices, knowledge underlying these practices, and knowledge sharing. We also studied the role of veterinary and livestock officers from the national and county department of veterinary services (DVS) and Kenya Wildlife Service (KWS).

The study applied an interpretive research approach. Interpretive researchers seek to understand human practices, assuming that we live in a world that is understood and enacted in various different ways (Yanow, 2006). The interpretive research paradigm notes that people act on the basis of interpretations that arise from social interaction, which nicely fits our research focus.

1.3.1. Case selection

Laikipia County (9462 km^2) lies within the Kenyan Rift Valley at (37° 2′ E, 0° 6′ N) in a semi-arid and arid agro-ecological zone with variable rainfall, averaging around 820 $mm\,yr^{-1}$ (https://en.climate-data.org/location/11129/). The biome varies from a rangeland savanna to a mountain vegetation at the foot of Mt Kenya. Livestock ranching and community conservation complement the arid to semiarid conditions in Laikipia. As a result, wildlife and livestock meet in the vast landscape in search for water and pasture while the different livestock and wildlife managers interact in a quest to share the ecosystem resources. We selected Laikipia as a study site because of its increased wildlife-livestock pressure and interaction (Benka, 2012). According to residents this leads to high tick borne disease prevalence, specifically East Coast Fever (ECF) (Hughes, 2006). Livestock get this from buffalos who are a reservoir species for the ECF causing protozoan. Increased populations and divergent land regimes give way to grazing practices that spur wildlife-livestock interaction and lead to conflicts between livestock and wildlife owners/managers.

Three major land use practices can be distinguished in Laikipia County: mixed agriculture, pastoral grazing and wildlife conservation. In private conservancies and government ranches, wildlife is either managed in isolation and thus totally fenced off, or in an integrated approach where wildlife is conserved and livestock reared, using rotational grazing of livestock. Private ranches apply pasture management regimes as advised by ecological ranch managers, and tick control practices are regularly executed by trained tick staff. Government ranches host both wildlife and livestock, and apply a less elaborate pasture management system, due to a minimal number or even lack of trained staff.

In community conservancies and lands, both wildlife and livestock management is practiced: management committees led by the council of elders delineate grazing, conservation and settlement area. In wet seasons pastoralists cattle graze close to home whereas in dry seasons they move livestock over large distances, often trespassing other community, private and government lands. However, with coordination and collaborated efforts between community grazing committees and ranchers, pastoralists get grazing access rights to the ranches during dry seasons and invest to rehabilitate their pasture through a holistic management approach. These efforts usually pay off for a while when there are good rains and less invasions by pastoralists from neighbouring counties, and soon diminish with prolonged drought and invasion. This is an example of what Ostrom (1990) describes of local communities working together to conserve resources and how such efforts fail when influenced by external factors of climate and external agents.

1.3.2. Data collection

1.3.2.1. Document analysis. Published scientific literature was reviewed for tick ecology knowledge and universal tick control practices across the world. Country and county policy documents, legislations and departmental reports were analysed to understand the development of tick control in the country in regard to tick and tick-borne disease management.

1.3.2.2. Interviews. Semi-structured interviews were held with key informants (KII) from different actor groups that we identified on basis of being i) livestock owners and /or managers, and ii) experts, working with livestock in tick control and management. In total 22 pastoralists (members of local communities (Maasai, Samburu, Pokot) who derive their livelihood from livestock), 14 ranch herders (people employed to herd livestock within private ranches), 3 veterinary and 4 livestock officers from DVS and KWS, and 4 wildlife managers of local conservation organizations were interviewed as presented in Table 1. We selected interviewees through a mixed method sampling approach (Teddlie and Tashakkori, 2009) employing purposive (land use type) and snowballing sampling (referrals from people interviewed). Interviews were tape-recorded, transcribed and analysed by means of coding, comparing, and contrasting selected concepts and finally identifying patterns. The interviews focussed on knowledge and practices related to ticks and tick borne disease management and knowledge sharing.

1.3.2.3. Field observations. The first author visited ranchers and pastoralists groups to observe tick management activities, including

Table 1
Categories of respondents interviewed.

Stakeholder category	Number	Affiliation
Pastoralist	22	Local communities of Makurian, Naibunga and Segera
Ranch herder	14	Lolldaiga, Ol Pajeta and Ol Jogi conservancies
Veterinary officer	3	DVS, KWS
Livestock officer	4	DVS
Wildlife manager	4	Lolldaiga, Ol Pajeta and Ol Jogi conservancies, KWS
Total	47	

the different tick control measures used. She also participated in the identification of ticks while probing the research groups for tick ecology knowledge. Routinely activities of livestock owners and wildlife managers to control TTBDs are observed to identify knowledge and skills that enable people to perform these activities, as well as the materials used (acaricides, drugs, spray races, hand pumps, etc.). From field observations, we sought to find out what actors involved are actually doing, how they justify their practices, and what knowledge they use for dealing with ticks and tick-borne diseases.

1.3.2.4. Focus group discussions. Three focus group discussions (FGDs) were held with homogenous stakeholder groups: ranchers, and pastoralists within the identified communities. FGDs discussed how communities have historically treated ticks in cattle and managed pasture, citing experiences and learning opportunities from childhood through their youths to adulthood. Discussions were facilitated using semi-structure interview guides, again focussing on tick presence, tick knowledge and tick management, including treatment practices, observed treatment failures, pasture access and grazing patterns throughout the year. The FGDs were also used to identify key-informants to be interviewed and at the same time served as additional validation for responses gathered from interviews.

2. Results

2.1. History of tick control in Kenya

Our understanding and documenting of tick and tick-borne diseases in Africa dates to the early 20th Century. Colonial settler farmers south of the Zambezi River imported non-indigenous cattle breeds from East Africa (George et al., 2008) following a decimation of their herds after the Rinderpest pandemic. A deadly disease, later determined to be East Coast Fever (ECF), was diagnosed in 1902 in southern Africa (Gray, 1902) following the cattle import. The tick species *Rhipicephalus appendiculatus*, a natural but previously un-infected inhabitant throughout this southern African region (Cranefield, 1991; Dolan, 1999; Edmonds, 1922; Lounsbury, 1903) then became infected with *Theileria parva*, the parasite that causes ECF (Dolan, 1999).

Keating (1983) presents the development of tick control practices in Kenya in a review of tick control by chemical ixodicides between 1912 and 1981. The government Department of Veterinary Services (DVS) in Kenya initiated the building of dips along main roads in 1912, and a few farmers who could afford it (mainly white private ranchers), built dips on their farms. By 1913, Kenya had 50 operational dip tanks. Priority in dip construction was given to areas where exotic cattle breeds had been introduced and in areas with high ECF prevalence.

The promulgation of the Cattle Cleansing Ordinance in 1920 defined cattle cleansing areas and dipping of cattle, setting precedence for the handling of cattle and tick control in Kenya. However, failure to advance money to small farmers to build dips rendered it ineffective. In 1927, the Districts were empowered to enforce the Cattle Cleansing Ordinance, officially enforced on 27 April 1937 in the "White Highlands". Full adoption of the Cattle Cleansing Act in 1937 lead to enforcement of tick control measures through building of communal dips (Harambee) for small scale farmers through a 50:50 cost sharing by the Government and District Councils. By 1944 dipping was extended to Traditional African Reserves in Nyeri Reserve and other parts of the country, and by 1960 massive dip construction was fully fledged.

Dip samples were taken by dip attendants and sent to the DVS headquarters to test the strength of particular ixodicides used. Arsenicals (sodium arsenate) were used from 1912 to 1949 but were then banned for being very toxic and persistent in the environment. Organochlorines and benzene hexachlorides were introduced in 1949. In 1954, blue tick *(Boophilus decoloratus)* resistance to arsenic was reported, as was resistance to benzene hexachlorides in many parts of Kenya. In 1959, the carbamates (Sevin) were introduced, subsequently followed by amidines and synthetic pyrethroid acaricides (Norval, 1988).

From 1977 through the 1980s, communal cattle dip management by farmers and local authorities was poor; hence the government took over management to increase effectiveness. 4923 dips were in operation in 1980, as more dips were constructed with acaricides provided by government at subsidised rate. Between 1980 and 1986, the government trained and recruited graduates from its training institutions increasing the technical knowledge in animal health, specifically TTBD control, and trained dip attendants assigned to each dip. At the time, DVS experienced challenges to effectively implement the tick control program (GOK, 2008a, 2008b; Shah and Fernandes, 1986). Although training and absorption of staff to the ministry was well intended for animal health extension services, it failed to deliver, starting about 1987 as government support for DVS dwindled and staff became underfunded. The supply of acaricides to cattle dips became inadequate, with dips seldom being refilled or replenished adequately with acaricides (GOK, 2008b). Livestock morbidity and mortality rates increased and dipping rates decreased further as farmers lost confidence in Government services.

To safeguard their cattle from tick diseases, pastoralists used hand plucking of ticks from cattle's bodies and grass burning as tick control practices. While herding, young boys and herders walked with tins with hot charcoal used to burn plucked ticks. Grass burning was carried out towards the end of the dry season as a pasture management tool, to reduce stem biomass of perennial grasses and as a tick control measure. However, with drought spells becoming longer and uncertain, grass burning led to reduced groundcover and the Maasai council of elders gave a directive to ban grass burning, later supported by the Grass Fire Act law.

Poor government management and budget shortfalls induced the funders' call to adopt the Structural Adjustment Policy in the livestock sector, specifically in provision of animal health care, of which tick control was heavily affected. In 1991 (GoK, 2008b; Wamukoya, 1992), the task of controlling ticks and the management of cattle dips was handed over to farmers and the private sector. Management dip committees formed by the farmer community were ill prepared for the takeover, neither having capacity for tick control, nor dip management expertise. This led to collapse of half of the cattle dips in the country, occasioning the downward spiral of livestock production and upsurge of tick borne diseases, particularly ECF and Anaplasmosis, in the following years (1992–1994). Farmers started applying 'observed' techne from communal dips to home spraying. From 1992 onwards, farmers combined dipping and hand spraying until dipping slowly died out and home spraying became mainstream. Tick control practices evolved within the farmer community as farmers bought acaricides from Agrovets (agricultural and veterinary products markets) and administered drugs to their livestock assisted by paravets. Paravets are technicians trained to give basic, techne-based animal health care and animal production advice to people in their communities.

At the present time, DVS is responsible for testing the efficacy and the safety of acaricides for livestock use. Acaricides are produced and distributed by private companies under regulation, approval and licencing by the Pest Control Products Board (PCPB) Kenya. With increased resistance by different tick species, combined acaricides (mixing two groups) show greater efficacy. Previously, advice on acaricide use was based on the ecological zones in Kenya, described by climate and vegetation variables and observed tick activity by DVS, however this is no longer the case. As extension services and advice from DVS imploded, farmers relied on paravets' advice and trial and error application of acaricides, to find what acaricide treatment gave best desired results. Henceforth, metis practices took root and became more 'dominant' with livestock owners.

To sum up, the historical overview presents two definite periods of tick control development in Kenya; i) pre-structural adjustment policy era between 1912 to 1991 when government through DVS initiated and led tick control program in Kenya and, ii) post-structural adjustment policy era from 1991 to date, when tick control was handed over to farmers and the private sector. Pre- structural adjustment policy era is characterised by government control with extensive development and use of techne knowledge while post-structural adjustment policy era ushers the adaption of metis to techne knowledge as metis becomes dominant. Metis developed as a result of a lack of guidance by DVS: livestock owners and pastoral communities adapted their tick control practices to their different geographic and ecological contexts as well as social and economic capability. In the pre-structural adjustment policy era, we see the role of government in the development and use of techne regarding tick control. Following the government's withdrawal from the tick control program in 1991, tick control practices became integrated with metis know-how and practice-by-doing experimentation. While this allowed for the development of more context-specific practices, it also created a range of potential risks to human, animal and environmental health resulting from inappropriate/irresponsible use of acaricides. Following Scott (1998), we conclude that declining state power in the managing of livestock extension services results in both: a rapid uptake of metis practices and a sudden rise of the profit-driven private sector with potential risk to human, environmental and livestock health as we unravel Acaricide mixes in Laikipia below.

From the history of tick control development in Kenya we can conclude that TTBD control has evolved according to: i) development of tick control knowledge (understanding tick ecology, tick management practices), ii) development of skills, (training of DVS and paravets, farmers learning from DVS and paravets) and iii) contextual changes including institutional changes (i.e. policy on subsidy, payment for tick control). Through time the development and implementation of both techne (scientific knowledge on tick ecology) and metis (continuous adaptation, based on knowledge about social and institutional contexts) has contributed to the evolution of tick management practices. We will now explore how knowledge, skills and context play a role in shaping the current tick control practices in Laikipia County, expounding on the use of techne and metis.

2.2. Stakeholders' understanding of tick ecology

Both interviews and FGDs displayed respondents' understanding of ticks and the environment animated by pastoralists, livestock managers and herders working in ranches. We explored the stakeholders' understandings of tick ecology in relation to tick presence, abundance, identity and tick-borne diseases.

2.2.1. Tick identification

Interviews, FGDs and field observations show that pastoralists, ranchers, herders, livestock and wildlife managers can identify and differentiate various tick species by means of: i) colour, ii) skin patterns, iii) skeleton texture, iv) number of legs, v) colour of legs and v) names, as illustrated in the following utterances:

> "*We generally call ticks masheri. There are different types, the red one is called Lntunturi, there is one with patterns (madoadoa), another one with red legs and other with red and white stripe on the legs. The one with the red legs and the one with patterns are the most poisonous. So people know if they see this, the cattle will be sick. The blue one only sucks blood.*" KII
>
> "*They are different types of ticks. The ticks that bite the snakes and tortoise have a very hard skin. They also have a pattern in black and white. From the colour and pattern we can tell that this is from wildlife and this is from livestock*". FGD

2.2.2. Understanding the tick life cycle

Ranchers, livestock and wildlife managers could identify and differentiate different lifecycle stages of ticks. Pastoralists showed awareness of different tick life cycle stages by distinguishing the egg, larvae and nymph and adult stages. The tick life cycle stages did not have relevance for pastoralists' control of ticks, as for them, these are all ticks. The adult stage was identified more on livestock, the larvae and nymphs were often seen on grass, especially after the rains. Adult ticks and nymphs were differentiated from larvae by the number of legs: six legs for larvae and eight legs for nymphs and adults. Pastoralists narrated that engorged ticks fell off the livestock to the soil, where they would 'give birth' to young ticks. Later they would see the young ticks climbing onto grass blades after the rains questing. This explained pastoralists belief that ticks came from the soil. They did not hold particular importance to the larvae and nymph lifecycle stages.

> "*Number of legs; sometimes you see ticks with 6 legs and others with 8 legs. I think the one with six legs is a baby that is developing to become an adult. This is because, all the big adult ones have eight legs. The ones that you always find on the cows when they suck blood have 8 legs.*" KII

Pastoralists explained seeing the same type of ticks on small mammals and reptiles (snakes, tortoise, rats, etc.) but did not link this occurrence to the different hosts that ticks needs to complete their life cycle. Pastoralists were not aware that ticks reproduce sexually:

> "Then if the eggs are in the soil, ticks come from the soil. So, if you say that ticks mate, that I don't know because, I have never seen a male or female tick and I have never seen ticks mating in my whole life and I have lived with cattle my whole life seeing ticks."

2.2.3. Linking ticks and diseases

Pastoralists and ranchers mentioned a loss of productivity, poor skin health, and diseases as the effects of ticks on livestock. Asked for tick effects on humans, they mentioned tick bites that swell when scratched. One respondent, a rancher, mentioned suffering tick fever with malaria-like symptoms (fever, headaches, night sweats, weak joints). They singled out ECF as a tick-borne disease associated with ticks during the rainy season. To treat TTBDs pastoralists administer drugs bought from the agrovets.

> "*Lipis (ECF). This is the one that I know comes when cows have many ticks. It causes the lymph nodes here (referring to the neck area) to swell. Then if not treated the animal will die.*" KII

Summarily, livestock owners demonstrate an understanding of tick ecology knowledge borne from observation and long experience with livestock. Ticks are identified in context, from what is observed, drawing links to seasons of the years. This shows the embeddedness of metis in society.

2.3. Tick control practices

2.3.1. Ranchers' tick control measures

Ranchers approached the management of TTBDs from three angles: i) pasture management, ii) acaricide application through spraying, and iii) vaccination.

2.3.1.1. Pasture management for tick control. To allocate grazing areas for both wildlife and livestock within the ranches, ranchers used a holistic techne based approach. Ecological monitoring tools were used to know both the quantity and quality of the pasture available across the year. Livestock managers and ecological experts worked together to design pasture consumption by both livestock and wildlife. A rotation cycle across blocks, delineating space for wildlife and tourism as well as livestock production was planned and followed.

Herders recruited by ranchers executed the designed grazing plans. Ranchers employ herders from Maasai, Pokot and Samburu, which are the main pastoral communities of Laikipia County. Herders from the pastoralists communities are favoured as they have experience in dealing with livestock. Ranchers rely on herders' knowledge to effectively and safely graze livestock within the ranch.

> "*I prefer herders from the pastoral communities because they have a natural feel with livestock. They can survive in the forest under harsh conditions and when they come into contact with wildlife like buffalos, they know how to handle that safely. (…) I never get cases of lost cattle from a group with them, they herd the group together*". KII

During dry seasons, ranchers grant pasture access to pastoralists based on contract agreements between ranchers and grazing committees from pastoralist communities. Grazing access contracts state: i) the fee to be charged per head of cattle; ii) number of cattle to bring into the ranch and names of their owners; iii) duration of grace pasture access inside the ranch; iv) delineation of the area to graze and access routes; v) tick control measures to put in place while inside the ranch and vi) number and names of herders to graze the cattle inside the ranch. The committee ensures that livestock grazing inside ranches are cleaned and treated as agreed in the contract.

Different ranches make different arrangements regarding treatment and control of TTBD of pastoralists cattle inside the ranches. One arrangement includes the cost of spraying and treating cattle per head. Another arrangement passes the responsibility to treat and spray cattle inside ranches to the pastoralists who are supposed to use their own drugs, acaricides and hand pumps.

Metis related to grazing develops through understanding of one's physical environment combined with lived experiences in different grazing contexts. Hence, we see herders from pastoral communities in Laikipa highly favoured for their knowledge of the biophysical characteristics of the terrain. In addition, given their pastoral experience they know how to respond should they come into contact with wildlife that raises potential for conflict. Techne is used for pasture management decision making using ecological monitoring tools while its implementation capitalises on the use of metis to herd livestock in pasture grounds.

2.3.1.2. Acaricide use. To control ticks in livestock, ranchers, use acaricides in spray races of wooden and concrete structures that fitted with nozzles to spray cattle from different angles. These spray races are advancements of the dips set in large white owned farms in the early days of tick control development in Kenya. Each cattle herd is sprayed once a week. Ranches have organised cattle in herds of 100–200 heads, assigned to individual herders grazing in different ranch blocks. On spraying days, several groups converge at the nearest spray race, making groups of between 400–1200 heads.

Preparations by the tick team start early in the morning with assembly and transport of materials (water, acaricides, motor pump, etc.) needed to specific dip being used that day. The tick team consists of farm hands that are recruited from the neighbouring pastoral community and are trained on the handling of acaricides and cattle at the dips. Once the right acaricide to water rations have been mixed - a techne requirement - the cattle are guided to walk through the spray race. Mid way through the exercise, more acaricide is added to ensure that the right acaricide concentration is maintained. Each herder is responsible for his own cattle group to successfully walk through the spray race.

Tick teams reported dizziness, headaches, body itches and swelling experienced on spraying days, as consequences of acaricides use to humans. These effects are normally 'treated' with rest, regular painkillers (Panadol) and a glass of milk. Tick team members are not provided with personal protective equipment (like gloves, overalls, masks) nor have they been made aware of the effects of (unprotected and prolonged) exposure to acaricides during trainings.

"Usually I get headaches at the end of the day, and dizziness. I feel that my blood is dirty from the chemicals used. So we take milk to reduce the bad feeling." KII

We see uses of acaricides that combine techne with metis of those implementing the spraying schedules. The tick team members and herders attributed their tick control knowledge to experience from living with livestock as they received minimal instructions upon hiring. Ranches provide techne-based trainings to newly recruited tick team staff on handling and mixing acaricides, and water to get the desired concentration at the mixing tank, in addition to general cleaning and maintenance of the spray race to ensure that spray nozzles are clean and unclogged. The fact that private ranches still have operational cattle dips speaks to the role of the economic context to sustaining a development project against state support.

2.3.1.3. Vaccinations. Vaccination against tick borne diseases such as heart water disease and ECF was reported from ranches. Use of vaccines is limited to large commercial ranches. Vaccines are purchased from the Department Veterinary Services, Nairobi. Vaccination schedules are used depending on the disease to be controlled and as advised by the ranch livestock managers. ECF was noted as the highest cause of mortality in ranch livestock with highest mortality experienced in calves less than one month old. Different ECF management practices were observed, with some ranches using vaccines and others preferring to treat the diseases. At one ranch, initial trials with the Muguga cocktail variant of the ECF vaccine were not successful (death of calves vaccinated reported), therefore the livestock manager resorted to exposing calves to the disease and treating them once symptoms manifested:

> "*The Muguga cocktail of the ECF vaccination was not successful at our ranch. All the calves that were vaccinated died. So, we learnt to treat them our way. We expose them to the diseases then treat it when the symptoms are still manageable. This way when the calves heal, they have acquired immunity against ECF*." KII.

Again, a combination of techne and metis can be observed. The vaccinations are techne based, however from prior experience where calves were lost after vaccinating, livestock managers choose not to vaccinate young calves against ECF. Such adaptation to local experience shows the application of metis.

2.3.2. Pastoralist tick control practices

Pastoral communities in Laikipia control ticks mainly by spraying acaricides to clean their livestock, a techne based practice adapted to suit their needs, motivated by different contextual factors. We present different practices observed and narrated since pastoralists became aware of tick problems and especially after the collapse of communal dips in 1991,the development and uptake of metis took place.

2.3.3. Pasture access and management

Livestock is grazed in different areas across the seasons of the year, depending of pasture availability. In wet seasons, livestock graze close to home, mainly on short savanna grass. As the season gives way to dry conditions, livestock is moved to forest areas, around Mukogodo forest and Mt. Kenya where grass is accessed without a fee. The forest areas are reserve grazing areas usually set aside by the council of elders. Grass burning was outlawed as a tick and pasture management tool. A FGD participant explained:

"*Previously we used burn grass and cowsheds to kill the ticks. However, we no longer burn grass because of population increase and environmental management reasons. It was also banned by the council of elders.*"

As conditions get increasingly dry, pastoralists seek pasture access from private ranches. Ranches included in the study confirmed having signed grazing arrangements with pastoralists living close to them at a reduced fee. Pastoralists interviewed indicated that the highlands and forests with thick vegetation have different tick species that do not easily respond to treatment as compared to ticks found in the plains. Pastoralists specified that during rainy seasons, tick loads are higher than other seasons of the year. Pastoralists are also well aware of regions that are ECF endemic and should thus be avoided and when livestock grazes there, it should be sprayed more frequently (every three days).

"During the rainy season and when we take cattle to the ranches, ticks are there all the time. But there are seasons that Lipis (ECF) is high, especially when we take the cattle inside the ranches". FGD.

Pastoralists use metis to plan where to graze their cattle during the different seasons of the year and to decide on specific tick control methods. Elders use their experiences to plan land use (settlement areas, grazing areas, where to conserve pasture for dry season etc.). After experiencing more ticks and diseases in certain regions of the landscape (in forest and ranches, as compared to plains), pastoralists are better equipped with drugs and acaricides for TTBD treatment as they move within the landscape. Hence, to reduce tick loads and TBDs metis is applied to techne.

2.3.4. Acaricide use for tick control

The grass-burning ban coincided with the period of massive dip construction in Kenya and an increased awareness of ticks and tick-borne diseases by the pastoralists. Communal plunge dips combined with the extension services offered by the DVS in the 1970s–1980s were the main TTBDs control avenues used. When farmers shifted from dipping their cattle at the communal dips to home spraying, they bought acaricides for tick control and drugs for disease treatment from Agrovets. Initially farmers would buy the drugs and call the veterinary officers to treat the animals. But due to reduced budgets and paralysed transport, the veterinary officers could not sustain extension services, thus farmers took up the treatment of their livestock themselves.

Of the community members interviewed, none used spray races or plunge dips. This was due to the collapse or absence of cattle dips in the community areas.

"*Previously we had plunge dips, but they all collapsed. The structures are there, but not in good condition to be used. So we use the hand spray pumps at home*". KII.

Individual application of acaricides started after the implementation of the structural adjustment policies and the transfer of tick control to the community in 1991. The deteriorating quality of services at community plunge dips led to a gradual shift to home hand spraying from 1992. At first, pastoralists bought acaricides from the Agrovet shops, mixed them at home with water in a bath basin, and used a cloth to rub the mixture onto the livestock. Progressively, hand pumps and hand sprayers, (knapsacks) bought from agrovets were introduced. Hand pumps were favoured as they could easily be adapted to available materials; a 20 l jerrycan, a hose reel and a hand pump were cheaper than commercially produced knapsacks and hand pumps. Pastoralists adapted to home spraying, assembling pumps with locally available materials.

"You see, washing with the cloth is not safe, because you are touching the acaricides without protection. Secondly, the application style is also not safe for the animals like young goats. They would be easily affected by the strong smell of the acaricide as you try to clean all parts. So, I feel that a pump is better." FGD

Presently, hand pump sprays are predominantly used within the pastoral communities and among sedentary farmers with improved livestock breeds. Dependent on the season of the year spraying is done every 7–14 days, with a higher frequency during the rainy season. While migrating, pastoralists carry the spray pumps and acaricides with them.

"*We prepare ourselves before calving or when we move our cattle to a new place or the forest by buying acaricides, drugs and syringes that we know we will need. So, I buy them and give them to the herders who will go with the livestock*." KII

Spraying is traditionally done early in the morning before livestock is let out to graze. Livestock is first separated into groups of adult cattle, calves and shoats, and directed into makeshift enclosures called *boo ee kishu*. The acaricide is then mixed with water in jerry cans. One person sprays the acaricide, taking note to spray under the tail, ears and armpits, while the other pumps the mixture. This is repeated for all the separate groups. At home, the family members assist in spraying with the father spraying, while the mother and children pump the mixture and order the livestock. While on transit during migrations, herders (who are mainly Maasai *morans*, young men) will both mix and spray. Here we see integrated use of techne and metis. Pastoralists use their landscape and seasons knowledge to decide the frequency and quantity of acaricide used. Local knowledge of available resources is used in assembling local materials for tick control. This knowledge thus results from trials and errors of metis knowledge.

2.3.5. Acaricide mixes

At the initiation of home spraying, pastoralists used acaricides that they had observed being used at the communal plunge dips, mainly from the Amitraz group. Weak acaricide concentrations used at the communal dips had compromised the efficacy of the acaricides, leading to tick treatment failure and tick resistance upsurge reports emerged. Hence when pastoralists realised that certain acaricides brands had low efficacy, they resorted to trying other acaricide brands to achieve the desired results. Pastoralists judged efficacy by i) number of days livestock would stay without visible tick loads, ii) skin condition after application (smooth versus lumpy) and, iii) failure to get diseases. Pastoralists trialled with different acaricides mixes. and opted for those with desired results. Metis based criteria can be identified here, grounded on trial and error to improve existing methods:

"*Like now if I use Bye Bye [an amitraz acaricide base brand] and spray in the morning, then the livestock goes to graze, and they will come back in the evening with ticks. Even when you use a strong concentration, after two days the ticks will be visible. So Bye Bye is a weak one*."

Double dosage in administering drugs and acaricide concentration was reported by all people interviewed as well as in the FGDs and confirmed in field observation while pastoralists prepared the acaricide mixture:

"*Usually we mix 20 cc of acaricide with 20 litres of water ……. we often add 10 cc to make it stronger, more effective*". KII

Pastoralists mentioned that they mix different classes of acaricides with crop pesticides, herbicides, fungicides and insecticides to boost effectiveness. They mix perceived weak acaricides with perceived strong acaricides and perceived weak acaricide with crop pesticides, herbicides, fungicides and insecticides Farmers believe that mixing of acaricide and crop pesticides is not harmful to their livestock.

"*No, it cannot be bad. It cannot do anything for the animal. You know all this time, I have not seen any negative effect, it has not killed the livestock. If it does not kill, it is not bad*". KII

Pastoralists mixed acaricides with used vehicle engine oil to treat chronic tick infestation in hidden and hard to access body parts of livestock like armpits, ears, and under the tail. They perceived that the oil increased the binding capacity of the acaricide:

> "*When ticks are many, they hide under the tail, and they are difficult to remove. Even with normal spraying they do not fall off. So, we take the concentrated acaricide, a little water and mix it with used vehicle oil, then you apply using a piece of the cloth. The oil is for binding purpose and it makes the acaricide last longer. It will kill the ticks and keep the place dry……for up to a month you will not see ticks there*." KII

Evidently, metis plays a key role in how acaricides are applied. Pastoralists base decisions on tick management practices on specific context-driven knowledge. After the collapse of cattle dips and extension services by the DVS, they relied on their understanding of their environment, and learned from one another in order to successfully deal with ticks.

The FGDs, field observations and KII showed that both pastoralists and ranchers heavily relied on the use of acaricides for reduction of tick loads in Laikipia. Vaccination was frequently used at ranches, while pastoralists used drugs. Tick control practice are chosen in specific situations based on metis, including: i) experience from the past applied to the current context, ii) specific ecological conditions, depending on the season of the year and the location of pastures accessible, iii) the social context, what is permitted and encouraged within the community, and iv) the institutional context, including policy guidelines that are permitted and encouraged. We flag out potentially health risks associated with mixing acaricides, pesticides and insecticides for livestock, consumers and the environment.

2.4. Knowledge sharing

The actors involved in this research developed and shared their knowledge about ticks and tick management strategies with people they meet in formal and informal settings (family, neighbours). Various formal communication and knowledge sharing by ranchers, pastoralists and veterinary officers were identified, using different media technologies and serving different needs for each actor group. This section reviews that type of information shared by actors and how it was shared in an attempt to show the flow of techne and metis knowledge among actors. Knowledge sharing groups presented are actor specific.

2.4.1. Ranchers: Borana cattle breeders society

The Borana cattle breeder's society was formed in 1951 to improve the indigenous East African short horned Zebu to breed cattle with high quality beef productivity. Technical breeding information is currently shared through formal meetings, emails, phone conversations and through national and regional agricultural shows to reach a greater audience. The society partners with researchers and companies that manufacture TTBDs products; drugs and acaricides. Companies and researchers are invited by the society for field visits and lunch meetings where they give talks on either tick resistance or their products. At this meetings, ranchers negotiate access to and fair prices for acaricides and drugs for their livestock.

2.4.2. Pastoralists: serian and grazing committees

Grazing committees are informal networks made up of a chairperson, a treasurer, a secretary and selected members from pastoralists communities. The committees were formed primarily for pasture management and for negotiating pasture access rights with private ranches during periods of drought. Members share information about the health of livestock, reporting any disease symptoms or outbreaks noticed, pasture conditions, and any security intel that members come across.

Pastoralists share livestock health information about diseases and treatments through face to face meetings, informal phone calls and formal meetings organised through the local chief's office. Most information is shared by word of mouth at meet ups referred to as *serian*. *Serian* happens every day when a group of pastoralists meet at local centres, at homes while visiting or even on the way when they meet.

> "*When we meet, talking about livestock follows naturally after greetings and asking about the children. Then next is the cows and any that show symptoms of being sick, any attacks by wild animals or cattle rustling. If anyone reports a disease symptom then we call our friends on phone to ask them about their herds and if they have seen anything strange or worth reporting. That way, we are well aware of any disease outbreak. We also are in a position to advice each other what to do, where to buy the original drugs and if need be, call the veterinary officer (often they call the local Paravets) to come and observe the animal*" (KII)

At grassroots level, the pastoralists are very well connected through informal networks that allow them to share livestock management information. Mobile phones play a big role to reach each other, to pass information or make inquiries. Cattle owners call herders who are migrating with the cattle to get updates on the livestock, and store information as depicted in the quote below

> "*I use my phone for calling, SMS. to store livestock data like the days I am supposed to deworm. I also use the phone to keep track of the herders when they are away in the forest. I have bought mobile phones for them. We communicate every day, morning and evening and get reports on the livestock. He tells me such and such a cow has this problem. We identify them by name and colour. So, when he says the name, I know what cow he is referring to and I direct him what to do*." (KII)

Pastoralists communicate continuously to share their knowledge and skills on tick control as well. By comparing practices and results in conversations, they develop contextualized knowledge - metis - that responds to the needs of pastoralists at the moment at stake. They consult one another to gain new knowledge while those with desired treatment results share that knowledge to empower others. The use of mobile phones shows the importance of communication technology for knowledge sharing in informal setups.

2.4.3. Veterinarians: VET info

Vetinfo is a national reporting system for the government veterinary officers on disease surveillance. It is operated through a google accounts group and managed by the Directory of Veterinary Services Kenya at their Nairobi headquarters. Veterinary officers collect disease surveillance information through common focus groups (markets, crushes, abattoirs, water points) to give weekly reports to the county veterinary officer who prepares a report that is send to the national headquarters. Veterinary officer reported calling particular sedentary pastoralists to get weekly updates to gather their surveillance data, mainly reporting on any disease symptoms observed. Veterinary officers communicate with the Chiefs by phone when mobilising communities for vaccination exercises.

A lack of knowledge and information sharing between government departments was witnessed. Information is solely gathered for internal use, and not made public. Analysis of the weekly reports is used to advice and direct county officers on diseases status and give directives on what measures, if any, need to be implemented, for instance a directive to effect a quarantine in a given area following reported cases of a notifiable disease. However, sharing of diseases and incidence occurrence between the veterinary department and the public health department was non-existent s as illustrated in the following utterance:

> "*There are no proper established channels of communication across the ministerial departments of health, Vet and Wildlife to share information. When the hospitals get human cases, they do not get back to the KWS to tell us what is out there for us to watch out for. (…) A hippo died of anthrax and people ate it and got sick. We only came to know much later that the anthrax was from the hippo when it had died, and two people had died*". KII.

The knowledge sharing groups encountered are actor specific and are 'closed' (share information within a group). Techne knowledge is shared in the ranchers' and veterinary officers' groups in more formalised knowledge flows. Metis is shared with the pastoralists in informal settings and flows. There is both demand and supply of knowledge as stakeholders consult each other to get information and constantly communicate to share knowledge. Mobile phones call, text messages and emails exchange show the role of information technology in the flow and storage of knowledge.

3. Discussion

The results of our study show that all respondents have a lot of techne tick related knowledge available. Pastoralists and ranchers in Laikipia can link ticks to TBDs, especially ECF, and are aware of tick predilection sites, paying attention to ears, neck, armpits, and under tails while spraying. This differs from what Mugambi, Wesonga, and Ndungu (2012) reported about farmers that could not accurately link tick borne diseases to ticks and are content spraying the main body of livestock. Our study results suggests that farmers, from observation and increasing understanding of ticks and their environment have gained relevant techne and metis knowledge over time.

Wildlife and livestock managers in ranches had professional education backgrounds and mainly count on techne knowledge, which they apply to manage both wildlife and livestock. Through carefully planned of tourism and wildlife areas, interaction between wildlife and livestock is minimised. Literature confirms that wildlife, specifically cape buffalos, are natural reservoirs of *T. parva* parasite (Nene et al., 2016) causing ECF to cattle. Ranches therefor apply comprehensive TTBDs management and have high productive livestock, unlike what we observed with pastoralists. Through frequent interaction with tick scientists and companies that produce TTBDs drugs, ranchers and their staff ensure continuous acquisition of techne knowledge about how to deal with TTBD challenges. But for effective tick disease control ranch managers not only need the techne knowledge about TTBD drug effectiveness, but also contextual knowledge about the physical environment and its seasonal changes. The economic and social power of ranchers allows them easy access to techne knowledge as most tick research studies in Laikipia are (purposefully) set up in ranches.

In contrast to the ranches, knowledge exchange between veterinary and livestock officers and pastoralists dwindled since the privatisation of tick control. This means that pastoralists increasingly depend on experiential knowledge, metis, that is acquired through learning by doing. Within pastoral communities, we see a constant flux and mix of techne and metis knowledge, depending on different contextual conditions and the availability of relevant knowledge. Pastoralists use grazing metis to evade ticks, but they need curative measures to control TTBD. After the collapse of communal dips, pastoralists started individual acaricides spraying at home. In the absence of veterinary advice, they consulted the techne of the drug selling Agrovets, and started to experiment and share knowledge about acaricide mixes and their effectiveness within their circle. This supports Lin and Law (2014) work, where in practice people seem to 'hybridise' different forms of knowledge 'without purifying', thereby challenging the idea of state control on knowledge and service delivery. They pick what is beneficial from the types of knowledge and gives them desired results as we see metis easily assimilating elements of techne.

Our findings in Laikipia County are consistent with findings from pastoral communities in Kajiado County, Kenya (Mugambi et al., 2012), and central and western parts of Uganda (Vudriko et al., 2016). For instance, acaricides that contain Amitraz, to which ticks have become more resistant, are seen as 'weak acaricides', hence pastoralists tend to use a higher doses than prescribed. However, pastoralists are not aware of specific Active Ingredients (AI) present in acaricides and how they act to kill ticks, neither how communal grazing coupled with use of acaricides with different AIs increase tick resistance. To increase (perceived) effectiveness, pastoralists tend to create mixes of acaricides with crop pesticides, fungicides, herbicides and insecticides with detrimental effects to their health as well as to the health of their cattle. In the past when DVS operated communal dips (and regulated acaricide use by regions), selective pressure on ticks was uniform in cattle dips due to the use of a single acaricide. Today, with individual pastoralists using acaricides with different AIs and still grazing communally, the development of simultaneous tick resistance is enhanced. It is not clear from literature how AI in different acaricides mixes (including crop pesticides, fungicides, herbicides and insecticides) react to form synergies or antagonisms to increase or decrease efficiency of resulting mixes. An earlier study showed acaricide residues in milk (Kituyi et al., 1997), though it was not evident whether this resulted from milk contamination or absorption through the body. Establishment of acaricide residues in animal products is a possible starting point to flag safety levels of acaricide use. The consequences of acaricide mixes for livestock, human and environmental health need to be studied, documented and communicated.

In order to prevent undesired consequences such as health issues different experts should engage with pastoralists and discuss the effects of their evolving acaricide use practices. Acaricide efficacy and residual tests should be carried out to inform choice of recommended acaricides based on efficiency of AI and context of use. With input of relevant techne, metis capacity to adapt accordingly increases and risky practices are reduced.

Our study evidently demonstrates a need for improved and constant knowledge sharing on ticks, TTBDs and tick management practices. Preventing TTBDs in Laikipia County is a complex endeavour that asks for effectively integrating techne and metis knowledge. Combining knowledge from different stakeholder groups is key, as is the need to continuously update existing knowledge, flagging risky practices and reinforcing good practices.

We found various ways of knowledge sharing in which tick related knowledge is exchanged. In addition to formal meetings and informal face-to-face encounters, mobile phones are widely available and commonly used within and between livestock stakeholders. Scientists and veterinary officers tend to share knowledge with ranchers, hardly reaching to pastoralists. Further study of the communication within and between stakeholder groups is needed to know: what is communicated, among whom, with what frequency and with what effect on the tick management practices of pastoralists, ranchers and other stakeholders? In future research we will use an action research approach to actively involve relevant stakeholders in knowledge development, sharing up-to-date scientific knowledge on tick ecology and tick management as well as contextual experiential knowledge. Ultimately, we aim to explore the potential for i) improved TTBD information flow and ii) coordinated action for safe TTBD control.

While in discussions, pastoralists mentioned other livestock production challenges they grapple with, in addition to ticks, that they would be relieved to find solutions. These include: diminishing pasture, the invasive Opuntia plant (invisible land grabber) that has taken over the pasture lands, poor markets access and pricing, environmental degradation and security threats from cattle rustling and human wildlife conflict.

4. Conclusion

This study provides an exploratory research of the availability and application of knowledge of tick control practices in Laikipia, before and after introduction of the structural adjustment policies. Our findings reveal that the techne knowledge concerning tick ecology and tick management practices date back to the pre-structural adjustment policy period. At this time, state-controlled extension services ensured effective dissemination of uniform practices. Interestingly, in the post-structural adjustment policy period, metis knowledge gained prominence, as it adapted to specific contexts. In our analysis, we showed how metis is developed and integrated with techne.

This integration may however, have potentially risky effects to animal, human and environmental health. We recommend follow up residual tests to prove whether acaricide residuals in the animal tissues and products from study site exceed the Minimum Residue Limit (MRL) for various groups of compounds that constitute the active ingredients of commercial acaricides and pesticides for human, livestock and environmental health.

In addition, several important knowledge gaps have been observed as well, resulting in accelerated tick resistance to active ingredients in acaricides (and crop pesticides, fungicides, herbicides, and insecticides when used in combination). Our results allude that knowledge on tick control is shared within homogenous groups but not between groups: in particular, techne–oriented groups (ranchers, DVS) do not seem to actively interact with metis-oriented groups (pastoralists).

We conclude that improved knowledge sharing between heterogeneous stakeholder groups would provide opportunities for better informed decision-making based on fruitful combinations of techne and metis for effective and safe tick management.

Declaration of interest

The authors declare that there is no conflict of interest.

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References

Agrawal, A., Gibson, C.C., 1999. Enchantment and disenchantment: the role of community in natural resource conservation. World Dev. 27 (4), 629–649.
Ardichvili, A., 2008. Learning and knowledge sharing in virtual communities of practice: motivators, barriers, and enablers. Adv. Dev. Hum. Resour. 10 (4), 541–554.
Beckley, C.S., Shaban, S., Palmer, G.H., Hudak, A.T., Noh, S.M., Futse, J.E., 2016. Disaggregating tropical disease prevalence by climatic and vegetative zones within tropical West Africa. PLoS One 11 (3), e0152560.
Benka, V., 2012. Wildlife, Livestock, and Disease in Laikipia. Pastoralist Observations, Kenya.
Cranefield, P.F., 1991. Science and Empire : East Coast Fever in Rhodesia and the Transvaal.
Cundill, G., Lotz-Sisitka, H., Mukute, M., Belay, M., Shackleton, S., Kulundu, I., 2014. A reflection on the use of case studies as a methodology for social learning research in sub Saharan Africa. NJAS-Wageningen J. Life Sci. 69, 39–47.
Dantas-Torres, F., Chomel, B.B., Otranto, D., 2012. Ticks and tick-borne diseases: a one health perspective. Trends Parasitol. 28 (10), 437–446.
Davis, A., Wagner, J.R., 2003. Who knows? On the importance of identifying "Experts" when researching local ecological knowledge. Hum. Ecol. 31 (3), 463–489.
de la Fuente, J., Naranjo, V., Ruiz-Fons, F., Vicente, J., Estrada-Peña, A., Almazán, C., Gortázar, C., 2004. Prevalence of tick-borne pathogens in ixodid ticks (Acari: Ixodidae) collected from European wild boar (Sus scrofa) and Iberian red deer (Cervus elaphus hispanicus) in central Spain. Eur. J. Wildl. Res. 50 (4), 187–196.
De Vries, R.E., Van den Hooff, B., de Ridder, J.A., 2006. Explaining knowledge sharing: the role of team communication styles, job satisfaction, and performance beliefs. Commun. Res. 33 (2), 115–135.
Dolan, T.T., 1999. Dogmas and misunderstandings in East Coast fever. Trop. Med. Int. Health 4 (9).
Edmonds, C.R., 1922. Diseases of Animals in South Africa. Baillière, Tindall & Cox, London.
Fyumagwa, R.D., Runyoro, V., Horak, I.G., Hoare, R., 2007. Ecology and control of ticks as disease vectors in wildlife of the Ngorongoro Crater, Tanzania. South Afr. J. Wildl. Res. 37 (1), 79–90.
Gadgil, M., Olsson, P., Berkes, F., Folke, C., 2003. Exploring the role of local ecological knowledge in ecosystem management: three case studies. Navigating social-ecological systems: building resilience for complexity and change. pp. 189–209.
George, J., Pound, J., Davey, R., 2008. 18• Acaricides for controlling ticks on cattle and the problem of acaricide resistance. Biol. Dis. Control 408.
Gherardi, S., 2012. How to Conduct a Practice-Based Study: Problems and Methods. Edward Elgar Publishing.
GOK, 2008a. Kenya National Assembly Official Record (Hansard). Government of Kenya, Nairobi.
GoK, 2008b. Ministry of livestock development. Session Paper No 2 of 2008 on National Livestock Policy.
Gray, C.E., 1902. Report Upon Texas Fever or Redwater in Rhodesia. Argus printing and publishing Company, limited.
Hughes, L., 2006. The Ecological Impacts *Moving the Maasai*. Springer, pp. 105–132.
Keating, M.I., 1983. Tick control by chemical ixodicides in Kenya: a review 1912 to 1981. Trop. Anim. Health Prod. 15 (1), 1–6.
Kenney, M., 2010. Beyond the Internet: Mētis, Techne, and the Limitations of Online Artifacts for Islamist Terrorists. Terror. Pol. Violence 22 (2), 177–197.
Kituyi, E.N., Wandiga, S.O., Jumba, I.O., 1997. Occurrence of chlorfenvinphos residues in cow's milk sampled at a range of sites in western Kenya. Bull. Environ. Contam. Toxicol. 58 (6), 969–975.
Latif, A., Walker, A., 2004. An Introduction to the Biology and Control of Ticks in Africa. International Consortium on Ticks and Tick Borne Diseases (ICTTD-2) project.
Lengoiboni, M., Bregt, A.K., van der Molen, P., 2010. Pastoralism within land administration in Kenya—The missing link. Land Use Policy 27 (2), 579–588.
Lightfoot, C.J., Norval, R.A.I., 1981. Tick problems in wildlife in Zimbabwe. 1. The effects of tick parasitism on wild ungulates. South Afr. J. Wildl. Res. 11, 41–45.
Lin, W.-y., Law, J., 2014. A correlative STS: lessons from a Chinese medical practice. Soc. Stud. Sci. 44 (6), 801–824.
Lounsbury, C.P., 1903. Ticks and African Coast fever. Transvaal Agric. J. 2 (5), 4–13.
Minjauw, B., McLeod, A., 2003. Tick-borne Diseases and Poverty: The Impact of Ticks and Tick-Borne Diseases on the Livelihoods of Small-Scale and Marginal Livestock Owners in India and Eastern and Southern Africa.
Mizutani, F., Kadohira, M., Phiri, B., 2012. Livestock–wildlife joint land use in dry lands of Kenya: A case study of the Lolldaiga Hills ranch. Anim. Sci. J. 83 (6), 510–516.
Mugambi, J., Wesonga, F., Ndungu, S., 2012. Ticks and tick-borne disease control in a pastoral and an agro-pastoral farming systems in Kenya. Livest. Res. Rural Dev. 24, 1–8.
Mureithi, D., Mukiria, E., 2015. An Assessment of Tick-Borne Diseases Constraints to Livestock Production in a Smallholder Livestock Production System: a Case of Njiru District, Kenya. Int. J. 43.
Nene, V., Kiara, H., Lacasta, A., Pelle, R., Svitek, N., Steinaa, L., 2016. The biology of Theileria parva and control of East Coast fever – Current status and future trends. Ticks Tick. Dis. 7 (4), 549–564.
Norval, R., 1988. Tick control in relation to the epidemiology of theileriosis. Paper presented at the theileriosis in Eastern, Central and Southern Africa. Proceedings of a Workshop on East Coast Fever Immunization.
Norval, R., Lightfoot, C., 1982. Tick problems in wildlife in Zimbabwe. Factors influencing the occurrence and abundance of Rhipicephalus appendiculatus. Zimbabwe Vet. J.
Ostrom, E., 1990. Governing the Commons: the Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge.
Oura, C., Bishop, R., Wampande, E., Lubega, G., Tait, A., 2004. The persistence of component Theileria parva stocks in cattle immunized with the 'Muguga cocktail'live vaccine against East Coast fever in Uganda. Parasitology 129 (01), 27–42.
Paul, S.M., Alison, H., Sarah, H., Beard, C.B., 2015. TickNET—a collaborative public health approach to tickborne disease surveillance and researchemerging infectious disease journal. Emerg. Infect. Dis. J. 21 (9), 1574. https://doi.org/10.3201/eid2109.150301.
Piesman, J., Eisen, L., 2008. Prevention of tick-borne diseases. Annu. Rev. Entomol. 53, 323–343.
Randolph, S.E., 2000. Ticks and tick-borne disease systems in space and from space. Adv. Parasitol. 47, 217–243.
Scott, J.C., 1998. Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed. Yale University Press.
Semtner, P.J., Howell, D., Hair, J.A., 1971. The Ecology and Behavior of the Lone Star Tick (Acarina: Ixodidae) I. The relationship between vegetative habitat type and tick abundance and distribution in Cherokee Co., Oklahoma. J. Med. Entomol. 8 (3), 329–335.
Shah, A., Fernandes, K., 1986. Kenya-Animal Health Services Project. World Bank.
Shove, E., Pantzar, M., Watson, M., 2012. The Dynamics of Social Practice: Everyday Life and How It Changes. SAGE.
Spickett, A.M., 1994. Tick ecology. Int. J. Parasitol. 24 (6), 845–849.
Teddlie, C., Tashakkori, A., 2009. Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences. Sage.
Van Den Hooff, B., De Ridder, J.A., 2004. Knowledge sharing in context: the influence of organizational commitment, communication climate and CMC use on knowledge sharing. J. Knowl. Manag. 8 (6), 117–130.
Vanwambeke, S.O., Šumilo, D., Bormane, A., Lambin, E.F., Randolph, S.E., 2010. Landscape predictors of tick-borne encephalitis in Latvia: land cover, land use, and land ownership. Vector-Borne Zoonotic Dis. 10 (5), 497–506.
Vudriko, P., Okwee-Acai, J., Tayebwa, D.S., Byaruhanga, J., Kakooza, S., Wampande, E., et al., 2016. Emergence of multi-acaricide resistant Rhipicephalus ticks and its implication on chemical tick control in Uganda. Parasit. Vectors 9 (1), 4.
Wabwezi, A., 2011. The Role of Knowledge Sharing in Fostering Innovation in Higher Education: a Case Study of Tallinn University. Høgskolen i Oslo. Avdeling for journalistikk, bibliotek-og informasjonsvitenskap.
Walker, A.R., 2003. Ticks of Domestic Animals in Africa: a Guide to Identification of Species. Bioscience reports Edinburgh.
Wamukoya, J., 1992. The status of tick infestation of livestock and tick control methods in Kenya. Int. J. Trop. Insect Sci. 13 (4), 665–670.
Wesonga, F., Kitala, P., Gathuma, J., Njenga, M., Ngumi, P., 2010. An Assessment of Tick-Borne Diseases Constraints to Livestock Production in a Smallholder Livestock Production System in Machakos District. Kenya. .
Wharton, R., Harley, K., Wilkinson, P., Utech, K., Kelley, B., 1969. A comparison of cattle tick control by pasture spelling, planned dipping, and tick-resistant cattle. Crop Pasture Sci. 20 (4), 783–797.
Yanow, D., 2006. 27 qualitative-interpretive methods in policy research. Handbook of Public Policy Analysis. pp. 405.