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Short Communication

Q Fever Risk Across a Dynamic, Heterogeneous Landscape in Laikipia County, Kenya

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Abstract: Two hundred fourteen serosamples were collected from four livestock species across five ranches in Laikipia County, Kenya. Serological analysis for *Coxiella burnetii* (the causative agent for Q fever) showed a distinct seroprevalence gradient: the lowest in cattle, higher in sheep and goats, and the highest in camels. Laikipia-wide aerial counts show a recent increase in the camel population. One hundred fifty-five stakeholder interviews revealed concern among veterinary, medical, ranching, and conservation professionals about Q fever. Local pastoralists and persons employed as livestock keepers, in contrast, revealed no knowledge of the disease. This work raises questions about emerging Q fever risk in Laikipia County and offers a framework for further integrative disease research in East African mixed-use systems.

Keywords: Q fever, *C. burnetii*, Laikipia County, Kenya, Livestock, Camels, Zoonotic pathogen

Central Kenya's Laikipia County has high levels of biodiversity and diverse land use practices, ranging from pastoralism to commercial ranching, agriculture, habitat conservation, ecotourism, and research (Frank et al. 2005). Following four confirmed cases of Q fever in American students returning from Laikipia County (personal communication, Dr. Daniel Rubenstein, July 9, 2010), and reports of Q fever in humans and livestock in other parts of Kenya (Knobel et al. 2013), we utilized complementary methodologies to document seroprevalence in four of the county's livestock species and evaluate local knowledge, attitudes, and practices concerning the disease.

Caused by the bacterial pathogen *Coxiella burnetii*, Q fever has multiple transmission modes and occurs globally in both humans and animals. Humans are infected via inhalation (Waag 2007), contact with infected body fluids (Rahimi et al. 2011), consumption of infected animal products (Brougui et al. 2005), and exposure to tick vectors (Aitken et al. 1987; Faix et al. 2008). Likely underreported due to its asymptomatic nature, acute Q fever infection

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has a spectrum of presentations in humans, ranging from non-specific hepatitis or flu-like symptoms to various reproductive problems (Kargar et al. 2013; Spickler et al. 2010). In a minority of cases, Q fever can lead to conditions such as repeated abortions, chronic fatigue syndrome, and often-fatal endocarditis (Arricau-Bouvery and Rodolakis 2005). The bacteria infect a broad range of mammalian hosts, including cattle, goats, sheep (Brougui et al. 2005; McQuiston and Childs 2002), camels (Marrie 1990), and wildlife species (Madariaga 2005). Evidence from the Middle East and Central Africa indicates relatively high camel Q fever seropositivity (Doosti et al. 2014; Schelling et al. 2003). However, little is currently known about the pathogen's ecology or prevalence across sub-Saharan Africa (Steinmann et al. 2005).

From July through September 2011, our field team collected 214 sera samples from four livestock species (cattle, goats, sheep, and camels) across five ranches (Mpala, Segera, Ol Pejeta, Ilmotiok, and Lekiji) in Laikipia County (Table 1). Sampling was dictated by logistical feasibility and diversity of land management practices. Kenya's Ministry of Livestock Development and Central Veterinary Laboratories analyzed the sera samples using an ELISA CHEKIT Q fever test kit (IDEXX, Westbrook, Maine).

In August 2010, July through August 2011, and July 2012, we conducted 155 semi-structured interviews with area residents about their knowledge, attitudes, and practices regarding Q fever. These included local and regional conservation professionals ($n = 15$); human healthcare providers ($n = 11$) and veterinary practitioners ($n = 14$); rangeland management experts ($n = 13$); local pastoralists from the Ilmotiok ($n = 42$) and Tiemamut ($n = 22$) communities adjacent to Mpala Research Centre and Ranch; and livestock keepers, predominantly from pastoralist backgrounds, on Mpala Ranch itself ($n = 38$). Interviews with pastoralists and livestock keepers covered a range of topics, including but not limited to diseases observed to have the greatest impact on livestock herds, perceived causes of disease, changes in livestock numbers and species over time, and interactions between livestock and wildlife.

Laikipia County's population is dispersed across a variety of landscapes that can be seasonally inaccessible. Many people live and own livestock in one location, but work in distinct land management types (DePuy 2011; Yurco 2011). Given these considerations and the small size of these communities (~50–300), interviewees were selected through key informants and snowball sampling among professional, residential, and kinship networks.

Across ranches within Laikipia County, there is a spectrum of livestock–wildlife interaction, with fenced wildlife sanctuaries excluding livestock at one end, and fenced commercial cattle ranches excluding wildlife at the other. One of our sites, Ol Pejeta, resembles these rare extremes through the use of electric fencing to largely segregate wildlife and livestock within its distinct ranch and sanctuary zones. Our other five sites represent more common mixed ranching-and-wildlife conservancy operations (Kinnaird and O'Brien 2012). Three are community based (Ilmotiok, Lekiji, and Tiemamut) with lower rates of livestock-wildlife interaction and mixed species livestock herds (sheep, goats, cattle, and camels). Two others are commercial ranches (Mpala and Segera) where cattle sometimes share grazing land with wild ungulates (zebra, antelope)

Table 1. 2011 serological data by site and livestock species.

	Cattle[a]		Sheep[b]		Goat[b]		Camel[c]	
	% Sero+	*N*	% Sero+	*N*	% Sero+	*N*	% Sero+	*N*
Ol Pejeta	0	24	–	–	–	–	–	–
Segera	3	30	–	–	–	–	–	–
Ilmotiok	0	10	13	8	40	10	–	–
Lekiji	–	–	20	15	31	16	–	–
Mpala (adults)	4	49	–	–	–	–	46	52
Mpala (young)	–	–	–	–	–	–	5	20

[a] Age range was 1.5–2 years in Ol Pejeta sample; 2–4 months in Segera; 4–8 months in Ilmotiok; and 3–9 years for Mpala adults.

[b] Age range in all sheep and goats was 1.5–8 years. All positive samples were from sheep and goats >2 years. All male goats ($N = 5$) and all male sheep ($N = 8$) sampled were negative.

[c] Young were defined as those less than 6 months.

and large herbivores (elephants, hippos). Mpala was the only location sampled with a large resident camel herd.

We observed a distinct *C. burnetii* seroprevalence gradient in livestock: the lowest in cattle, higher in sheep and goats, and the highest in camels (Table 1). Results show low seroprevalence in young and adult cattle across four sites. Among young cattle studied in three sites (Ol Pejeta, Segera, Ilmotiok), overall seroprevalence was under 2%. Adults observed at Mpala had a similarly low seroprevalence of 4%. Most of our sample sites were contiguous, with little environmental variation from site to site; low prevalence figures across age groups suggest minimal confounding factors by ranch or age.

The suggested seroprevalence disparity between adult cattle and other species is worth additional investigation. Where we collected data on sheep and goats, we found intermediate levels of *C. burnetii* seroprevalence, with an average of 31 and 40% for goats and 20 and 13% for sheep in Lekiji and Ilmotiok, respectively. In combination, the seroprevalence of goats ($P = 0.047$) and sheep ($P = 0.001$) at these two sites was significantly higher than in the cattle sampled at two other sites (Segera and Mpala). The pattern of seroprevalence persisted in Ilmotiok where all three species were sampled, suggesting that location is not a confounding factor. Likewise, at the one site where we collected data for camels (Mpala), we found high levels of seroprevalence, particularly in adults (46%). This level was significantly higher ($P < 0.001$) than the seroprevalence observed in adult cattle at the same location (4%). All comparisons were assessed using a t test.

While ranchers value camels for steady milk production and resistance to drought conditions, high Q fever seroprevalence among camels may signal a health risk across wild, domestic, and human species in Laikipia County and beyond via regional supply chains and national markets. Kinnaird and O'Brien have compiled their unpublished camel data from Laikipia-wide aerial counts between 1982 and 2010 (Table 2); these show a pronounced influx of camels in the early 1990s, leading to a well-established population that continues today. Although camel populations remain concentrated in Kenya's arid northern and northeastern regions, nearly all of the country's camel-owning commercial ranches are based in Laikipia County (Musinga et al. 2008). Laikipia County's urban center, Nanyuki, also holds the country's only camel milk processing plant. Our interview data showed several of Laikipia County's small-scale tourism operations are incorporating camels as part of the wildlife safari experience. Interviews with residents of two pastoralist communities indicated that, despite small numbers of pastoralists having camels in their mixed herds at present, the number of camels in their ranches has grown over the past decade (Benka 2012).

Table 2. Three-year moving average of camel population from aerial counts within Laikipia County.

Year	*N*
1982	708
1985	625
1987	1,262
1990	2,463
1991	3,004
1992	3,142
1994	3,712
1997	3,860
1999	4,225
2001	4,105
2003	3,286
2005	3,053
2008	3,171
2010	3,380

Education for prevention of Q fever could be needed. Our 58 interviews with area professionals included personnel from the Kenya Wildlife Service, Mpala Research Centre, Ol Pejeta Conservancy, and Laikipia Wildlife Forum; commercial ranchers; medical doctors and clinic staff; and veterinary professionals based in Nanyuki and nearby rural areas. Most expressed both awareness and concern about Q fever in humans and animals. However, interviews with livestock-based pastoralists living on community ranches and livestock caretakers at Mpala Ranch revealed no explicit knowledge of Q fever. In contrast, the majority of this interview cohort conveyed familiarity with and concern about other livestock and zoonotic diseases, including Brucellosis, Contagious Caprine Pleuropneumonia, Contagious Bovine Pleuropneumonia, and Anthrax (Benka 2012).

Any outreach or education efforts related to Q fever awareness and prevention will require interdisciplinary and cross-cultural work in understanding how this and other disease cycles in the region are embedded in livestock management practices within economically and ecologically heterogeneous landscapes. Our results are the first to document that at least some of the livestock in the Laikipia County region has been exposed to Q fever, but research gaps remain. Knowledge disparities documented here are only the beginning of relevant understanding for effective intervention. For instance, pastoralists' lack of familiarity with this potential pathogen could be linked to the absence of a specific word for "Q fever" in local dialects.

Prevalence disparities also beg further study. Innate biological differences between species could shape susceptibility to *C. burnetii* infection, although past case studies show significant variation in Q fever prevalence within a single species, complicating biological determinist hypotheses (Kargar et al. 2013). Environmental differences offer a second explanatory framework for prevalence disparities among livestock species (Deem et al. 1993). Mixed ranching-and-conservancy operations where wildlife and livestock mix differ from contexts where livestock or wildlife predominates. Smaller community ranches contain different populations, densities, and overlap of livestock and wildlife than do large commercial ranches and may show different patterns of Q fever exposure. Finally, variations in veterinary practices could also influence differences in *C. burnetii* seroprevalence. Highly capitalized ranches engage in more regular and comprehensive acaricidal dipping regimes than do community ranches. All use antibiotics with varying frequency and varying adherence to manufacturer recommendations (Benka 2012). This could plausibly affect Q fever transmission.

Our findings constitute the first definitive evidence of Q fever as a relevant public health and veterinary concern in Laikipia County, Kenya. Preliminary results show promise for the modeling of biological, environmental, veterinary-medical, or rangeland management-based determinants of seroprevalence disparity. Given the diverse livestock management regimes, local interest in improving ranching conditions, and many specialists in arid landscape management, Laikipia County presents an ideal system for further study of Q fever disease ecology. More attention is needed to the occupational risks and knowledge levels associated with the different livestock and wildlife species compositions and care regimens, and to varied rangeland management in Laikipia County's ranches as these factors affect the incidence of this pathogen there and throughout East Africa.

Future Q fever research should include human ecology and political economy in the study of pathogen ecological cycles. Such an integrative approach attends to the ecological and socio-economic variations that shape human exposure to zoonotic disease, delivering nuanced models of transmission dynamics and delineating viable courses of action for disease detection and prevention.

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