Preventive Veterinary Medicine 113 (2014) 447–456

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

Wildlife–livestock interactions in a western rangeland setting: Quantifying disease-relevant contacts

Heinrich zu Dohna[a,*], Dannele E. Peck[b], Bruce K. Johnson[c], Aaron Reeves[d], Brant A. Schumaker[e]

[a] School of Veterinary Medicine, University of California, Davis, CA, USA
[b] Department of Agricultural & Applied Economics, University of Wyoming, Laramie, WY, USA
[c] Oregon Department of Fish and Wildlife, LaGrande, OR, USA
[d] Department of Production Animal Health, University of Calgary Veterinary Medicine, Calgary, Alberta, Canada
[e] Department of Veterinary Sciences, University of Wyoming, Laramie, WY, USA

ARTICLE INFO

Article history:
Received 9 October 2013
Received in revised form
12 December 2013
Accepted 12 December 2013

Keywords:
Wildlife–livestock contacts
Spatial statistics
Spatio-temporal point processes
Rangeland systems

ABSTRACT

Disease transmission between wild ungulates and domestic livestock is an important and challenging animal health issue. The potential for disease transmission between wildlife and livestock is notoriously difficult to estimate. The first step for estimating the potential for between-species disease transmission is to quantify proximity between individuals of different species in space and time. This study estimates second-order statistics of spatio-temporal location data from radio-collared free-ranging deer, elk and cattle in northeast Oregon. Our results indicate, that when observed simultaneously, elk and cattle occur in closer proximity to each other than what would be expected based on general space use of these species. The same is true for deer and elk but not for deer and cattle. Our analysis also demonstrates that average distances between cattle and elk are largely driven by rare events of close co-mingling between the species, which extend over several hours. Behavioral causes for these co-mingling events are currently unknown. Understanding the causes for such events will be important for designing grazing practices that minimize wildlife–livestock contacts.

1. Introduction

Disease transmission between wild ungulates and domestic livestock is an important and challenging animal health issue. Diseases are generally easier to control in livestock than in wildlife populations, so an introduction or spillover of a disease into wildlife can severely impact the livestock industry's control efforts (Miller et al., 2013). Bovine brucellosis, for example, was introduced to North America via domestic cattle and later spilled over into wild bison (*Bison bison*) and elk (*Cervus elaphus*) populations. Although it has been eradicated from the U.S. cattle population, it still persists in wild bison and elk, and poses a continuous economic threat to rangeland cattle producers (Dobson and Meagher, 1996; Meagher and Meyer, 1994; Schumaker et al., 2012). Eradication of bovine tuberculosis and Johne's disease in the United States has also been complicated by spillover into wildlife (O'Brien et al., 2011; Sleeman et al., 2009).

Control of the last foot-and-mouth disease outbreak in the US was hampered by spillover of the disease into wildlife (Keane, 1927). If a highly contagious foreign animal disease, such as the foot-and-mouth disease virus, were introduced to the U.S. livestock system again, a spillover into wildlife (or a direct introduction to wildlife with the potential for spillover into livestock) would complicate control efforts and increase the risk of the disease becoming endemic. A prolonged outbreak or newly endemic

* Corresponding author. Current address: American University of Beirut, Lebanon. Tel.: +961 1 350000x3916; fax: +961 1 350 000x3888.
E-mail addresses: hb54@aub.edu.lb, heinrich.dohna@gmail.com (H.z. Dohna).

0167-5877/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.prevetmed.2013.12.004

situation could be catastrophic for the U.S. livestock industry (Boisvert et al., 2012; Highfield et al., 2010a,b; Ward et al., 2007). To minimize these economic consequences, it is crucial to understand how often livestock and wildlife interact closely enough to potentially transmit disease (Highfield et al., 2010a,b).

Rangeland systems are conducive to inter-species disease transmission because grazing livestock may easily encounter abundant wildlife over shared forage, cover, water, and mineral resources. Livestock graze three million km^2 of rangeland, pasture and forest in the U.S. (Mitchell, 2000). Roughly 2.12 million km^2 of rangeland and pasture occur west of the Mississippi River (Conner et al., 2001), eighty-percent of which is in the Rocky Mountain and Pacific Coast regions, or the 'western U.S.' (Mitchell, 2000). Rangelands in the western US, whether privately or publically owned, support diverse and abundant wildlife populations as well, including roughly 2.5 million mule deer (*Odocoileus hemionus*), 1 million elk, and 700,000 pronghorn antelope (*Antilocapra americana*) (Binfet and Lutz, 2003; Hoffmann et al., 2008; Rocky Mountain Elk Foundation, 2011).

Interactions between these wild ungulates and cattle are unique in rangeland systems compared to conventional systems. Cattle in conventional production systems are typically confined to fenced-in pastures or enclosed barns, and observed frequently by their owners. Cattle in rangeland systems, in contrast, range freely over hundreds or thousands of hectares, with limited supervision and ample opportunity to encounter wild ungulates in their shared habitats. Wildlife–livestock interactions in these settings are driven by many factors. Elk, mule deer and cattle select habitats with different attributes (Ager et al., 2005) and this habitat selection varies by season. In winter, for example, wild ungulates in mountainous regions might move to lower-elevations in search of native winter range (Coupal et al., 2004), where they could encounter cattle occupying private winter pastures and feed lines. In summer, rangeland cattle might be moved to higher-elevation public grazing allotments (Holechek and Herbel, 1982), where they could encounter wild ungulates occupying native summer range.

Wildlife biologists have developed a large body of literature on cattle–elk–deer interactions. Much of this research addresses questions about habitat use and resource competition, rather than disease transmission (Ager et al., 2005; Coe et al., 2005; Loft et al., 1993; Stewart et al., 2002; Torstenson et al., 2006). Forage competition between cattle, elk, and mule deer has been studied intensively at the U.S. Forest Service's Starkey Experimental Forest and Range in northeast Oregon, USA, particularly during spring, summer and fall. Previous work at this location has focused on wildlife responses to roads and traffic (Coe et al., 2005; Lyon, 1983; Rowland et al., 2000; Thomas et al., 1979; Witmer and DeCalesta, 1985), and patterns of resource selection by elk and mule deer in the presence or absence of cattle-grazing (Ager et al., 2005; Coe et al., 2005; Stewart et al., 2002). Results suggest that larger ungulate species generally displace smaller species (Coe et al., 2005; Stewart et al., 2002). It is unclear, though, how this displacement affects the risk of interspecific contact. Physical displacement might not preclude disease-relevant interactions. When cattle displace elk, the distance between them might remain small enough for transmission to occur. No previous studies have quantified the number of close contacts between domestic and wild ungulates at Starkey Experimental Forest and Range or analyzed the fine-scale spatiotemporal characteristics of such interactions.

A handful of studies have estimated parameters that describe livestock–wildlife interactions in the context of disease transmission (Brook and McLachlan, 2009; Richomme et al., 2006). These studies have shown that contacts between livestock and wildlife can be quite common, especially when livestock herds are unguarded (Richomme et al., 2006) or close to forested and/or protected areas (Brook and McLachlan, 2009). Moreover, there is evidence for some wildlife species that the propensity to associate with livestock varies between individuals and seasons (Berentsen et al., 2013). However, none of these studies have provided a detailed analysis of the spatio-temporal distribution of interspecific distances.

Detailed knowledge of the spatio-temporal distribution of livestock–wildlife distances is necessary to quantify the risk of interspecific disease transmission. Comparing the observed distribution of distances with expectations under various null hypotheses facilitates extrapolation of results to other settings. For example, if the distribution of distances between wildlife and livestock individuals does not differ from the expectation for random locations, one could easily extrapolate distributions of interspecific distances to any population densities. Second-order statistics of spatio-temporal point processes provide a framework to conduct such an analysis. Second-order statistics of point processes characterize the distribution of distances between points and can be used to detect spatial clustering or repulsion at different scales (Cressie and Wikle, 2011; Diggle et al., 1995; Lotwick and Silverman, 1982; Ripley, 1981).

In this study, we apply the theory of second-order statistics of spatio-temporal point processes to analyze two years of location data from free-ranging cattle, elk and mule deer in the Starkey Experimental Forest and Range in northeast Oregon (Rowland et al., 1997; Wisdom et al., 2005). Our study has three objectives: (i) characterize the distribution of distances between individuals of different species; (ii) characterize intra- and inter-annual variation in distances; and (iii) test to what degree distances between wildlife and livestock are driven by habitat selection or behavioral effects, such as attraction or avoidance. Our overarching goals in quantifying spatio-temporal interactions between cattle, elk and mule deer are to: (1) facilitate epidemiologists' efforts to incorporate interspecific contacts into mathematical models of disease spread, and (2) provide management-relevant insights about close encounters between cattle and wild ungulates that could lead to disease transmission.

2. Methods

2.1. Study area

Data were collected within the U.S. Forest Service's Starkey Experimental Forest and Range (Starkey), which