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The Associations Between Large Mammal Abundance, Elevation, and Tick Capture Rate in the Big Belt Mountains

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Abstract

The Rocky Mountain wood tick, *Dermacentor andersoni,* is the primary tick vector of human pathogens like Colorado tick fever and Rocky Mountain spotted fever in the Rocky Mountain Region. Drag sampling was conducted to investigate the association between large mammal abundance, elevation, and tick capture rate in the Big Belt Mountains near Helena, Montana during suspected peak tick activity in May and June. Soil temperature and type, climate, humidity, aspect, slope, and the availability of hosts have been shown to be factors that determine tick distribution. Multiple factor regression, using elevation as a covariate, found that even after accounting for elevation, the relative large mammal abundance was significantly negatively associated with the number of ticks observed per hour. It seems likely that overgrazing by large mammals, such as deer and elk, causes a trophic cascade that negatively affects small mammals and, therefore, tick populations, due to a lack of vegetation. The majority of observed ticks were found at elevations between 1323-1761 m. It is unclear exactly why the majority of ticks are found within a specific elevation range, but it may be determined by climatic conditions found within a particular elevation range such as average daily maximum temperature and humidity.

Introduction

The Rocky Mountain wood tick, *Dermacentor andersoni,* is the principle vector of human pathogens like Colorado tick fever, Rocky Mountain spotted fever, and tularemia (Eisen 2007). Populations of *D. andersoni* have been found in the western

United States, southern British Columbia, Alberta, and Saskatchewan (Dergousoff *et al*. 2013). As human populations in the Rocky Mountain region continue to grow there is a greater risk of human exposure to tick borne pathogens because of the increase in human activities taking place in likely tick habitat. It is essential to determine where these ticks reside and what factors influence their distribution in order to better understand the potential risk to humans. Factors that affect tick distribution are: soil temperatures and type, climate, humidity, aspect, slope, and the availability of hosts (James *et al.* 2006). Exactly how these factors affect tick distribution and the risk of human exposure to tick borne diseases is still unclear (Eisen *et al.* 2007). The most recent *D. andersoni* studies have focused on Colorado tick populations. Using data from the early 20th century, James *et al.* (2006) found that Montana had the greatest number of established populations of *D. andersoni* in the country between 1921 and 1941; yet no recent studies have looked at the factors influencing their distribution in Montana. Once we better understand their distribution and the factors that determine it, preventative measures can be employed to reduce human exposure to *D. andersoni* and the diseases they potentially carry.

D. andersoni is a parasitic arachnid with four unique stages of life: egg, six-legged larvae, eight-legged nymphs, and eight-legged adults (Johnson 2010). The entire life-cycle usually takes three years to complete (Johnson 2010). James *et al.* (2006) showed that each mobile stage has a unique host, with larvae and nymphs preferring small mammals, while adults prefer larger mammals like deer and elk. The host-seeking stage is called questing (Dergousoff *et al.* 2013). *D. andersoni* peak questing periods occur between mid-April to mid-June in Colorado (Eisen *et al.* 2008).

Ticks are a vector for many pathogens and transmit pathogens easily because they require a blood meal during each stage of their life; blood meals are necessary for egg production (Seraji-Bozorgzad and Tselis 2013). Ticks are able to transmit pathogens to subsequent life stages and can also pass them to the next generation of ticks through their eggs (Seraji-Bozorgzad and Tselis 2013). Tick-borne human diseases have been steadily increasing worldwide and in order to effectively treat them, early detection is imperative (Seraji-Bozorgzad and Tselis 2013). Two common tick-borne diseases in the Rocky Mountain Region are Colorado Tick Fever (CTF) and Rocky Mountain Spotted Fever (RMSF) (Seraji-Bozorgzad and Tselis 2013). RMSF continues to be a significant source of sickness and death because it is often not recognized (Seraji-Bozorgzad and Tselis 2013). The symptoms of RMSF can appear between 2-14 days after tick exposure and in 40% of reported cases, patients did not note a past tick bite (Seraji-Bozorgzad and Tselis 2013). It is critical patients are aware of the bite because a punctual diagnosis is crucial for effective treatment. Physicians will often avoid testing for tick-borne diseases unless there is a high level of suspicion, so communicating travel history is important. Seraji-Bozorgzad and Tselis (2013) show Colorado Tick Fever to be endemic to the Rocky Mountain region of North America. The greatest disease activity of CTF is reported in May-July and it is the second most common arbovirus in the United States after West Nile virus (Seraji-Bozorgzad and Tselis 2013). *D. andersoni* is the main vector for CTF and adult ticks are most likely to transmit the disease to humans (Seraji-Bozorgzad and Tselis 2013). CTF is difficult to diagnose because it presents nonspecific symptoms that may include: fever, chills, headaches, photophobia, myalgia, abdominal pain, diarrhea, vomiting, and splenomegaly (Seraji-Bozorgzad and Tselis 2013). In most cases the symptoms are resolved in seven days without treatment and death is rarely reported (Seraji-Bozorgzad and Tselis 2013).

The objective of the present study was to explore the association between host availability, elevation, and tick abundance. Efforts were focused on capturing adult ticks with drag-sampling techniques as this method most realistically mimics the movement of animals and humans through the environment (Eisen *et al.* 2008). The relative abundance of large mammals was used to determine host availability at each site. Relative large mammal abundance was determined using 30 meter random transects and pellet counts. Eisen (2007) found host-seeking ticks are consistently found between elevations of 1800-2500m and peak abundance occurs at elevations between 2200-2400m. Four drainages in the Big Belt Mountains in Montana, each with five sites, were sampled once a week between early-May and late-June of 2014 to determine abundance of both ticks and mammals. Multi-factor regression analyses were performed to determine the effect of large mammal abundance and elevation on tick capture rate.

There may be a negative association between the abundance of adult *D. andersoni* and habitats with abundant elk populations (Eisen *et al.* 2008). Grass is the known vegetation of choice for adult ticks when questing (Eisen *et al.* 2008). It is possible that abundant ungulate populations result in an overgrazed habitat that has less grass available for questing ticks. Therefore, I hypothesize that increased relative mammal abundance will lead to decreased numbers of *D. andersoni*. Furthermore, I hypothesize that peak *D. andersoni* abundance will occur between 1800-2500m because Eisen (2007) found this range to contain the most host-seeking ticks in Colorado.

Materials and Methods

Tick and large mammal sampling began in early-May and continued through late-June. This time period was chosen because Eisen *et al.* (2008) showed peak questing activity to occur during this period in Colorado. Four separate drainages in the Big Belt Mountains, east of Helena, Montana, were sampled weekly during suspected peak tick activity (Figure 1). Each drainage had five fixed sites; ranging from 1116m to 2102m. The change in elevation between each subsequent site was kept as constant as possible. Sites were chosen based solely on their general vegetation characteristics, as vegetation has been shown to be a good predictor of tick abundance (Eisen *et al.* 2008). General vegetation characteristics included the presence of large open grassy areas or abundant shrubbery. I was unable to sample the high elevation sites early in the season due to unfavorable road conditions and snow cover. Sampling efforts were restricted to a particular ecosystem at each site; for example, if a site contained both riparian and coniferous-dry ecosystems, sampling was confined to one or the other. Each week the starting site was rotated from high to low elevation within each drainage to minimize a possible temporal factor; if I sampled a low elevation site first one week, I would sample it last the next week.

Drag sampling methods were used to capture questing ticks. The apparatus was made of a one by one meter piece of white flannel attached to a PVC T-bar. White flannel was used so I could easily spot the dark ticks on the material. The apparatus was dragged over ground cover and shrubs and was checked every 20s-30s for ticks. Ticks found on clothing within the search time were also counted. All captured ticks were immediately stored in 100% ethanol for later identification. Each site was sampled for one person-hour each week. The coordinates and elevation of each site were described with a GPS using North American Datum 1983 (Table 1).

Fecal pellet counts were used to determine relative large mammal abundance. It is difficult to accurately quantify the true number of large mammals at twenty different locations, so relative abundance was used to compare large mammal abundance across sites. Using a random number table, ten random 30 m transects were sampled at each site. For each transect, I walked the distance and counted the scat piles of large mammals; piles within approximately half of a meter of the tape measure were counted. Each pile was marked with spray paint to ensure it would not be counted in subsequent weeks. Mean scat counts from each site were used to determine relative large mammal abundance. Sites with an increased mean scat count, when compared to other sites, were considered to have more large mammals present. Regression analysis was used to determine if the scat index and elevation were correlated. Subsequent multiple factor regression analyses were performed to test the correlation between elevation, scat index, and tick capture rate. Elevation was included as a covariate before testing for the effect of scat index

Results

The objective of the study was to explore the association between relative large mammal abundance, elevation, and tick capture rate. Preliminary regression analysis indicates a significant negative correlation between the scat index and elevation (Table 2, Figure 2). Regression also revealed a non-linear association between tick capture rate and elevation (Table 2, Figure 3). Multiple factor regression, using elevation as a covariate, found that even after accounting for elevation, the scat index was significantly negatively correlated with the number of ticks observed per hour (Figure 4).

Discussion

This study found elevation and large mammal abundance to be significant factors that contribute to a decreased number of host-seeking *D. andersoni.* Therefore, I accept my first hypothesis that increased large mammal abundance can lead to decreased *D. andersoni* numbers. Similarly, Eisen *et al.* (2008) showed that elk abundance was negatively correlated with tick abundance in Rocky Mountain National Park in Colorado. Grass is the preferred substrate for questing ticks, so it is possible that overgrazing by ungulates results in decreased questing of *D. andersoni* (Eisen *et al.* 2008). Ungulates eat grass and other vegetation and therefore reduce the substrate available for the ticks to quest.

It is possible that overgrazing by ungulates can cause a trophic cascade that affects the abundance of small mammals and ticks (Eisen *et al.* 2008). A decrease in vegetation may result in fewer small mammals such as rabbits and ground squirrels, because there is no food or cover for them. The absence of small mammals may mean that the early life stages of the tick, larvae and nymphs, have no host upon which to survive.

One concern regarding the results is that I did not account for the presence of cattle at the sampling sites. None of the sites I sampled had cattle when I was present, but there were many piles of cow dung visible at the majority of the sites. It is hard to speculate exactly how cattle affect tick abundance because there was no apparent correlation between presence or absence of cows and tick abundance. Additional studies are needed to determine the role cattle play in tick abundance.

I reject my second hypothesis that the majority of ticks would be found between 1800-2500 meters. The relationship between ticks collected and elevation was parabolic; with the majority of ticks found between 1323-1761 meters. This is a decreased and narrower elevation range than that found by Eisen (2007) in Colorado (1800-2500m). However, this is not surprising because the mountains in Montana are generally colder than those in Colorado (when compared to similar elevations) because they are located further from the equator. Therefore, I would expect the average temperature to be lower in Montana when compared to similar elevations in Colorado. Eisen *et al* (2008) sampled sites with elevations between 2200-2620m in Colorado that all yielded adult *D. andersoni*. The average daily maximum temperature in April-May at these sites was 11.2 ^{o}C. In the present study, no sample sites fit into this elevation range, so an exact comparison cannot be made. However, four sites were sampled in Montana with elevations between 1998-2102m; no ticks were captured at any of these sites. The average daily maximum temperature in April-May at these Montana sites was 10.5 ^{o}C. Consequently, since no ticks were found at higher elevation sites in the Big Belt Mountains, it is reasonable to conclude that sites in Montana with elevations comparable to those sampled in Colorado would have a lower average maximum temperature. It is likely the ticks are found at lower elevations in Montana because of this temperature difference. The majority of *D. andersoni* collected in the present study were found between elevations of 1323-1761m; the average daily maximum temperature in April-May at these sites was 13.9 ^{o}C. It is possible that elevation itself is not what drives tick distribution, but rather the specific microclimates found at particular elevations determine where ticks reside.

Eisen (2007) found there to be an increase in *D. andersoni* questing when there was a stretch of several days in a row that exceeded a maximum temperature of 5 ^{o}C. Eisen (2007) also found that questing activity began to rapidly decline when maximum temperatures reached 20 ^{o}C for several days in row and relative humidity fell below 20%. Eisen (2007) concluded the peak questing period of *D. andersoni* in Colorado to occur when the daily maximum temperature is consistently between 16-19 ^{o}C and the relative humidity is greater than 20%. It is likely these climatic conditions slightly vary annually depending on winter and spring conditions. Determining peak questing period was not the objective of this study, but it is likely temperature and humidity are important factors that determine peak questing periods. Future, in depth studies are needed to determine the climatic conditions that may be used to predict peak questing periods in Montana. It would be beneficial to describe peak questing periods in Montana; so that people could be informed when they are at the greatest risk of exposure to *D. andersoni*.

Future, but similar studies need to be conducted in other parts of the state to test or examine factors that influence large mammal abundance and elevation on tick abundance. My colleague, Tyler Jacobsen (2014) found there to be greater numbers of *D. andersoni* on south and east facing slopes when compared to north and west facing slopes. Studies also need to examine other factors that affect tick distribution such as; soil temperature and type, climate, humidity, slope, and vegetation characteristics. As humans begin to encroach deeper into tick habitat it is essential we understand the factors that affect tick distribution; so that we can assess the risk of human exposure and eventually make a plan to reduce exposure to dangerous tick pathogens.

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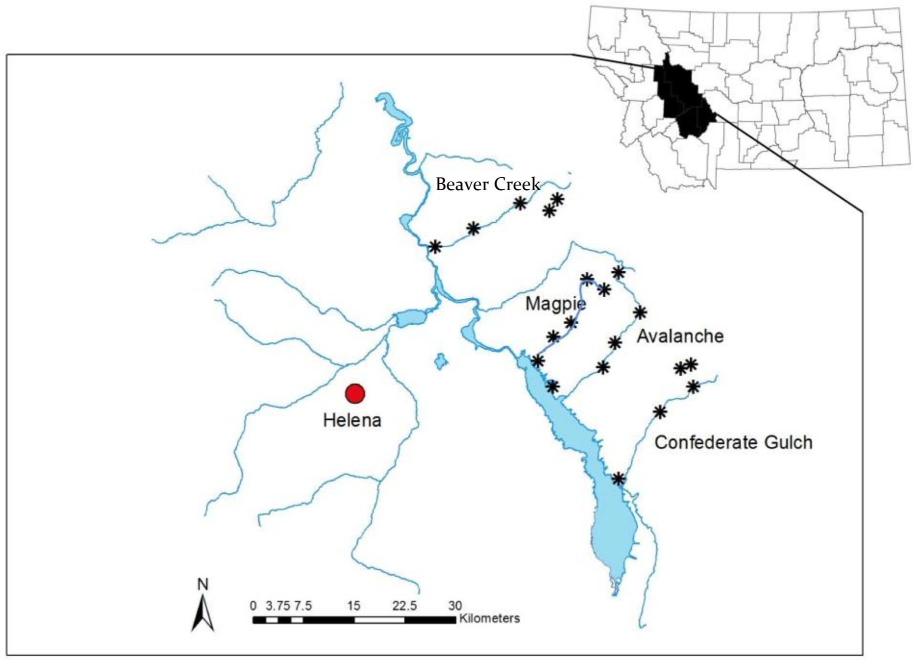

Figure 1- Four drainages (Beaver Creek, Magpie, Avalanche, and Confederate Gulch) in the Big Belt Mountains near Helena, MT were sampled weekly in the late spring/early summer of 2014. The drainages contain five sample sites each; elevation increases eastward.

Table 1- Coordinates and elevation of 20 permanent sites

Drainage	Site	Longitute	Latitude	Elevation (m)
Beaver Creek	a	-111.888001	46.791357	1116
Beaver Creek	b	-111.815959	46.817094	1219
Beaver Creek	c	-111.726069	46.852218	1385
Beaver Creek	d	-111.654811	46.858799	1761
Beaver Creek	e	-111.669293	46.843518	2002
Magpie Gulch	a	-111.684325	46.643799	1166
Magpie Gulch	b	-111.655774	46.675837	1328
Magpie Gulch	c	-111.621496	46.695861	1402
Magpie Gulch	d	-111.593061	46.753844	1622
Magpie Gulch	e	-111.559766	46.740594	2102
Avalanche Gulch	a	-111.653419	46.610204	1164
Avalanche Gulch	b	-111.557871	46.637847	1323
Avalanche Gulch	c	-111.536484	46.670754	1419
Avalanche Gulch	d	-111.488804	46.71133	1530
Avalanche Gulch	e	-111.533335	46.764125	1998
Confederate Gulch	a	-111.522861	46.490287	1161
Confederate Gulch	b	-111.446186	46.580173	1388
Confederate Gulch	c	-111.382769	46.61488	1620
Confederate Gulch	d	-111.388718	46.644684	1875
Confederate Gulch	e	-111.408309	46.638861	2086

Table 2- Results of regression analyses.

Model	R-Squared	p-value
Scat=Elevation	0.32	0.008
Ticks=Elevation+Scat	0.45	0.006
Ticks=Elevation		0.002
Ticks=Scat		0.009

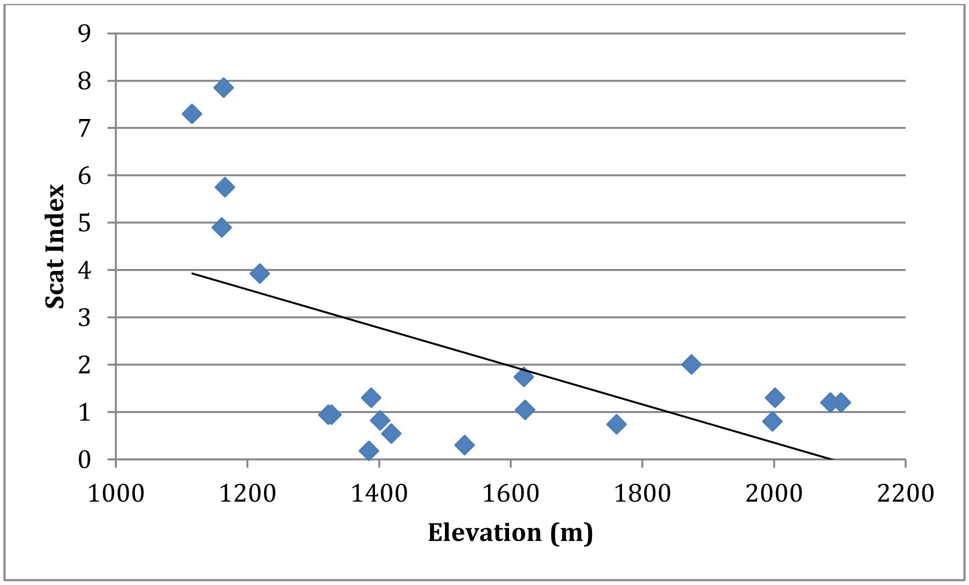

Figure 2-Preliminary regression analysis indicates a significant negative association between the scat index and elevation.

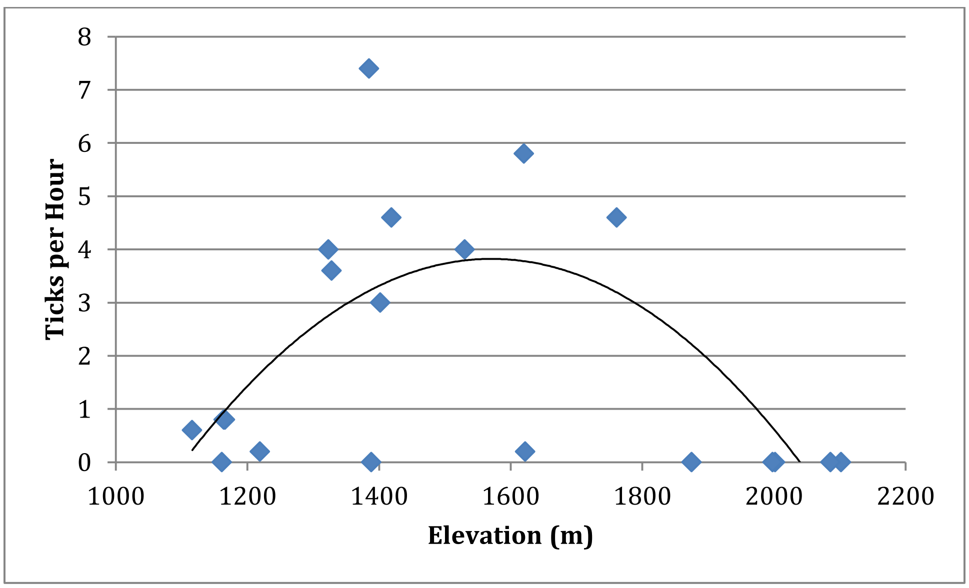

Figure 3- Visual representation of multi-factor regression analysis between tick capture rate and elevation. The majority of ticks observed occurred approximately between the elevations of 1300-1800 meters.

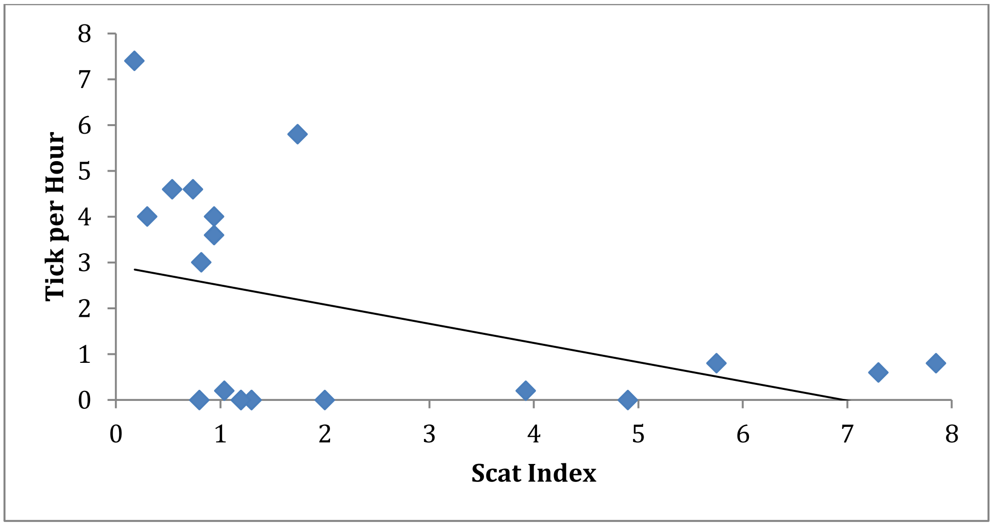

Figure 4-Visual representation of multi-factor regression analysis between tick capture rate and the scat index. When elevation was accounted for, the scat index was still significantly negatively associated with the number of ticks observed per hour.