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Assessing Vegetational and Climatic Influences on the Distribution of Dermacentor andersoni in Western Montana

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Abstract

Both on the micro and macro levels human risk to the host-seeking adult stage of *Dermacentor andersoni* is poorly understood (Eisen *et al.* 2007). Due to the difficulties associated with identifying, quantifying, and evaluating the many ecological variables that determine an organism's ideal niche, there is some contradiction among the primary literature, as to a reliable, conclusive point regarding seasonality and distribution of a given species of tick (Schaalje & Wilkinson, 1985). *D. andersoni is* the most important North American tick in regards to disease transmission (Mail, 1942). In brief, *D. andersoni* is the principle vector of Rocky Mountain Spotted Fever, Colorado Tick Fever, Tularemia, and Tick Paralysis (Mail, 1942). Due to the life cycle of the Ixodid tick, its overwintering habits, and its variance in required vertebrate hosts/appropriate vegetative substrates, the most plausible factors which might indicate elevated probability of tick presence are soil type, ground cover (leaf litter), brush cover, and mammal presence. Eisen *et al.* (2007) found climatic factors to be better overall determiners of tick presence than either topographical or vegetational features. Variables found to be most informative in reporting tick presence were mean annual values for minimum temperature, mean annual values for maximum temperature, base 10 °C growing degree-days, and median length of annual freeze free period, while the uninformative variables were mean annual values for precipitation, snowfall, and relative humidity (Eisen *et al.* 2007). Flag sampling was conducted throughout the Helena valley and various sites in western Montana. Climatic variables and landscape ecology were assessed through a combination of field-testing and GIS provided data in an effort to determine whether or not there are

any easy identifiers that can serve as tools to ascertain the presence or absence of ticks in a given location.

Introduction

Dermacentor andersoni, the Rocky Mountain wood tick, is common throughout the Rocky Mountain States and Southwest Canada. *D. andersoni* is the most important North American tick in regards to disease transmission as it is the principle vector of Rocky Mountain Spotted Fever, Colorado Tick Fever, Tularemia, and Tick Paralysis (Mail, 1942). Thus, *D. andersoni* poses very serious health threats to those enjoying outdoor forms of recreation from early March to late June (Yoder *et al.* 2003)

D. andersoni is an Ixodid (hard-bodied) tick that is a three-host parasite requiring a blood meal from a vertebrate host to molt between larval, nymphal and adult stages of development (Fielden & Lighton, 1996). Adult ticks emerge in early spring while the larval and nymphal ticks are active in the late summer, typically July and August (Fielden & Lighton, 1996). The adult tick takes a blood meal, and upon repletion, detaches from the host and lays eggs, presumably under rocks or in burrows (Fielden & Lighton, 1996). The larvae emerge from eggs and seek a blood meal from a small vertebrate host in order to molt; if one is not obtained they will overwinter as larvae (Fielden & Lighton, 1996). The main difference between stages is the size of the host, with smaller stages feeding on smaller vertebrate hosts such as rodents and lagomorphs (Fielden & Lighton, 1996). The nonparasitic periods between molting and feeding may account for more than 98% of the total life cycle (Clark, 1970; Fielden & Lighton, 1996). Due to the three-host life cycle of *D. andersoni* the tick has a high capacity for disease replication and transmission, making the Ixodid tick a good reservoir and vector, emphasizing the importance of understanding the ecology of this arthropod.

The tick overwinters by entering a state of diapause either in the soil, under leaf litter or rocks, or in rodent burrows. Few ticks have ever been recovered while they are in this stage so there is little information available on the details of this process (Mail, 1942). Mark and recapture experiments show that unfed adult ticks are able to survive at least two winters, possibly more (Eads & Smith, 1983). Determining the factors that favor overwintering is likely a valuable key in predicting the presence of *D. andersoni* in a particular area.

The host-seeking behavior of a tick is termed questing. A tick ascends a piece of vegetation, places its two forelegs in the air, and waits until signaled by either CO_2, vibrations, scent, or passing shadows to wave its arms and attach to any available passing substrate (Garcia, 1965). Questing alone is not the extent of tick movement and CO_2 baiting experiments have shown ticks possess the ability to preferentially ascend and descend vegetation and relocate near a CO_2 source, showing especially high mobility on warm, sunny days (Yoder *et al.*, 2007; Garcia, 1965). Mark and recapture studies have resulted in ticks being recaptured up to 400 m away from the original capture site (Eads & Smith, 1983). This demonstrates the mobile capacity of the organism and the potential for range expansion further warranting the surveillance of tick distributions.

Big Sagebrush (*Artemesia tridentata*) is a good general indicator of tick presence, albeit not as a substrate, but rather due to a shared climatic preference between the shrub and the tick (Eisen *et al.* 2008). Grass is a favored substrate for questing ticks because most hosts of adult ticks are grazers (Eisen *et al.* 2008). In Ravalli Co. Montana, Clark *et* *al.* (1970) found that adult *D. andersoni* occur primarily in alpine meadows, further supporting the role of grass as a preferred substrate. However, some collections occurred on the sparse vegetation of a talus field, with neither adequate grass for questing, nor suitable soil for overwintering (Clark *et al.*, 1970). This shows the variability of ecotypes occupied by this tick, further elucidated by discrepancies in the literature. This reveals the need to further explore the principle factors influencing tick presence.

In Colorado, high tick abundance has been linked with shallow soils, moderate shrub cover, abundant exposed rock and rock interstices, steep slopes, relatively abundant pine, and abundant log litter (Carey *et al.* 1980). McLean *et al.* (1981) found south/west facing slopes with mixed grass-brush-conifer vegetation a good indicator of tick presence, which was supported by Schaalje & Wilkinson (1985), Eisen *et al.* (2007), and Yoder *et al.* (2007). Eisen *et al.* (2007) suggested that this model was elevation dependent, and reported preliminary results proposing a shift in tick localities from south/west facing slopes to north/east facing slopes at lower elevations where southern exposures may be too hot and arid. Due to this proposed shift, Eisen *et al.* (2007) found that climatic factors were better overall determiners of tick presence than either topographical or vegetative features. The most informative variables in reporting tick presence were mean annual values for minimum and maximum temperature, base 10 °C growing degree-days, and median length of annual frost-free periods. The uninformative variables were mean annual values for precipitation, snowfall, and relative humidity (Eisen *et al.* 2007). Tick presence was positively associated with mean annual maximum and minimum temperatures of 10 °C and -3 °C, respectively, and with growing degree-days of 650 (Eisen *et al.* 2007). In Colorado, ticks were present from early March until late June with the length of their active period lasting anywhere between 84 and 104 days (Eads & Smith, 1983; Eisen, 2007). *D. andersoni* adults exceeded 50% of their peak activity when temperatures were between 16-19 °C and relative humidity was greater than 20% (Eisen, 2007). This period ranged from 43-52 days, and peak activity occurred in mid-April (Eisen, 2007). These data suggest that the distribution of *D. andersoni* can be assessed through mean annual climatic data and if this model is applicable to the entire range of *D. andersoni,* similar findings should be observed in Montana.

Human risk to the host-seeking adult stage of *D. andersoni* is poorly understood (Eisen *et al.* 2007). Due to the difficulty associated with identifying, quantifying, and evaluating the many ecological variables that determine an organism's ideal niche, there are contradictions in the literature which fail to report consistent conclusions on the factors influencing the presence and distribution of a given species of tick (Schaalje & Wilkinson, 1985). If there are easily identifiable, quantifiable variables that could be used to ascertain tick presence in the field by hikers, vacationers, and campers, this information could be used to drastically limit human exposure to many tick-borne pathogens.

The life cycle and host-seeking behavior of *D. andersoni* suggest that locations suitable for encountering a tick in the human-biting adult stage must provide favorable overwintering conditions and proper vegetation to carry out host-seeking. I hypothesize that if overwintering is a crucial factor in tick persistence, and increasing densities of the ground, shrub, and canopy layers create more favorable overwintering conditions, then tick encounter should be positively associated with increasing vegetation densities. Secondly, I further hypothesize that if a crucial factor in tick presence is climate then there should be an association with floral species, because vegetation is also dictated by climate.

Material and Methods

Flag sampling of ticks was conducted throughout the Helena valley and various sites in south-western Montana (Fig. 1). At each site GPS coordinates were taken using NAD-83 datum, and field climate data were taken with a Kestrel 3000 pocket weather meter. The flagging apparatus was constructed from a T-bar PVC pipe with a one meter by one meter flannel cloth attached to the end. One man-hour was designated as the standard sampling time. Within this man-hour the site was sampled in roughly 100 meter transects, as terrain would allow. Ticks removed from clothing were counted the same as ticks removed from the flagging apparatus. There were a total of 77 sample sites (Table 1, Fig. 1). Sampling was conducted from early May to late June. Sites were sorted into two groups, ticks present and ticks absent, consisting of 35 and 42 sites, respectively.

Qualitative vegetation measurements were made in the field to catalogue composition and density of the canopy, shrub, and ground layers. Densities were categorized from 0-100% by increments of 25%. Composition was determined by ranking the top three dominant species of each layer, except the ground layer which was categorized by grasses, forbs, or other.

Data analyses were performed on the following vegetative variables to ascertain any significant influence on tick presence: percent canopy cover, percent shrub cover, percent ground cover, top three tree species present, and top three shrub species present. Tree species observed were Ponderosa Pine (*Pinus ponderosa*), Lodgepole Pine (*Pinus contorta*), Douglas Fir (*Psuedotsuga menziesii*) and Rocky Mountain Juniper (*Juniperus* *scopulorum*). Shrub species used for comparison were ribes (*Ribes cereum* and *Ribes inerme*), juniper (*Juniperus communis* and *Juniperus horizontalis*), bitterbrush (*Purshia tridentata*), sagebrush (*Artemesia tridentata*), rabbitbrush (*Ericameria parryi*), skunkbush (*Rhus trilobita*), chokecherry (*Prunus virginiana*), and snowberry (*Symphoricarpos* spps.). Data obtained from geographic information systems (GIS) and from microclimate measurements taken at each site were also tested for association with tick presence/absence. The GIS data included mean annual minimum and maximum temperatures, and mean annual precipitation (in.). Microclimate data included: soil temperature (°C), wind (m/s), air temperature (°C), and relative humidity (%).

Results

Chi-square analyses detected no significant associations between tick presence and vegetation composition, and did not support the expected correlation between tick presence and any certain tree or shrub species (Table 2). The presence of Sagebrush and Rabbitbrush were the closest to being correlated with the presence of ticks with p-values of 0.122 and 0.145, respectively. Lodgepole Pine and Douglas Fir were the next closest to being correlated with the presence of ticks with p-values of 0.206 and 0.256, respectively. There was no significant correlation between vegetation densities and tick presence for the canopy, shrub, or ground layers (Table 3). The amount of leaf litter was uninformative as well (Table 3). Neither mean annual minimum and maximum temperatures, nor mean annual precipitation were correlated with tick presence (Table 4). Microclimatic variables were not correlated with tick presence, however, average wind speed (m/s) was the closest to significance with a p-value of 0.326 (Table 4).

Discussion

This study failed to find any factor that significantly influences tick presence. The influence of Sagebrush and Rabbitbrush warrant further investigation as do Lodgepole Pine and Douglas Fir.

When sampling and data analyses were concluded, some unintentional biases were noted in the sites chosen. Sites were not evenly distributed in terms of percent canopy cover, shrub cover, and leaf litter, and were skewed towards the 0-25% range (Table 5, Fig. 2). In order to have accurately assessed the role of these factors in tick presence, each category ought to have been equally represented.

Mean annual climatic data that proved informative for Eisen *et al*. (2007), were not found informative in the current study. Similar to the bias in vegetation density, the climatic data assessed were not all equally represented and the range of the data is not sufficiently large to draw accurate conclusions (Fig. 3). On-site microclimate data were not considered in my hypothesis, but the results from these data show that throughout the sampling period temperature, humidity, wind, and soil temperature did not have an impact on tick presence and were not sources of bias. Ecoregion and land cover classifications from Montana GIS data show limited diversity amongst the sites. This may indicate further sampling bias and perhaps contributed to the lack of significant results. Classifications with ten or more sites were considered over-represented; those with fewer than five were considered under-represented. Over-represented land covers were Montane Sagebrush Steppe, Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland, and Rocky Mountain Ponderosa Pine Woodland and Savanna (Table 6a). Over-represented ecoregions (level 4) were Big Belt Forested Highlands, Eastern Divide Mountains, and Townsend Basin (Table 6b). Ecoregion classification level 3, a more general classification, shows that almost the entirety of sampling was from the Middle Rockies ecoregion (Fig. 4).

There is also the possibility that there was a more significant factor driving tick presence that was not accounted for in the analysis of these data. Results concurrent with this study from the same sampling locations show that slope aspect, specifically North versus South facing, significantly influenced tick presence (Jacobsen, unpublished). Vegetation and climate comparisons did not account for aspect and may have been confounded by interactions between these factors. Including data from aspects that rarely yield ticks could have weakened the results. Looking solely at sites that did yield ticks (still aspect independent) there was a difference in tick abundance at sites with sagebrush compared to those without (Fig. 5). The values are not significant at a 0.05 p-value, but these results suggest that a correlation may be present when more data are available.

The goal of this study was to attempt to find factors that are easy identifiers of tick presence, and be able to conclude in the field whether one is at greater exposure to ticks and tick-borne disease. By the conventional p-value of 0.05 there were no significant results from this study, but that does not definitively indicate that the factors assessed do not play roles in tick presence. With the interactions being analyzed, the limited sample size of this study is a concern. More data must be gathered to even out misrepresentations by increasing sampling range and sample size. Aspect will be accounted for in future analyses. Future studies will include GIS data for soil types which may be another factor impacting overwintering conditions.

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Table 1. Sample site coordinate data

Site #	Tick Presence*	Date	Longitude(W)	Latitude(N)	GPS Elevation (m)	Compass Aspect(°)	Compass Slope
13-001	0	5/21/13	112.12155	46.54539	1626	204	0-20
13-002	0	5/21/13	112.05956	46.57627	1366	112	0-20
13-003	0	5/27/13	112.09885	46.66891	1342	86	0-20
13-004	0	5/28/13	111.81214	46.71328	1141	112	0-20
13-005	0	5/28/13	111.78389	46.70813	1162	316	0-20
13-006	0	5/10/13	112.30476	46.56132	1914	292	0-20
13-007	0	5/10/13	112.30652	46.55635	1951	99	0-20
13-008	0	NA	111.88781	46.74892	1140	84	0-20
13-009	0	5/22/13	112.05194	46.58973	1320	82	0-20
13-010	0	5/24/13	111.76158	46.65103	1158	320	0-20
13-011	0	5/29/13	111.81039	46.70019	1146	36	0-20
13-013	0	6/03/13	113.00311	45.16150	1763	78	0-20
13-014	0	6/03/13	112.95779	45.23573	2068	206	0-20
13-015	0	6/03/13	112.46820	45.49285	1451	110	0-20
13-016	0	6/03/13	112.53830	45.44766	1496	174	0-20
13-017	0	6/04/13	112.42825	45.55265	1558	120	0-20
13-018	0	6/05/13	112.11993	46.51534	1796	96	0-20
13-019	0	60/5/13	112.13511	46.51166	1680	202	0-20
13-020	0	6/06/13	111.96310	46.25844	1784	158	0-20
13-021	0	5/21/13	112.12116	46.54636	1650	200	0-20
13-022	0	5/21/13	112.09446	46.56371	1441	200	20-40
13-023	0	5/21/13	112.09474	46.56329	1447	28	20-40
13-024	0	5/23/13	112.05357	46.59142	1342	80	20-40
13-025	0	5/23/13	112.05717	46.59224	1366	356	20-40
13-026	0	5/24/13	111.75712	46.65014	1199	30	0-20
13-027	0	5/24/13	111.75852	46.64947	1198	274	20-40
13-028	0	5/27/13	112.030226	46.60709	1192	30	0-20
13-029	0	5/28/13	111.74079	46.68644	1293	118	0-20
13-030	0	5/28/13	111.78587	46.67752	1177	276	0-20
13-031	0	5/29/13	111.78941	46.64279	1163	220	0-20
13-032	0	5/29/13	111.87067	46.64932	1166	236	0-20
13-033	0	6/03/13	112.99557	45.15937	1762	74	0-20
13-034	0	6/03/13	112.56521	45.43699	1487	74	0-20
13-035	0	6/04/13	112.33852	45.63367	1533	185	0-20
13-036	0	6/04/13	111.82123	45.82464	1332	230	0-20
13-037	0	6/04/13	111.85806	45.83778	1433	160	0-20
13-038	0	6/04/13	111.49359	45.93596	1233	33	0-20
13-039	0	6/05/13	112.11962	46.51458	1825	164	0-20
13-040	0	6/06/13	111.94099	46.30720	2531	196	0-20
13-041	0	6/06/13	111.95871	46.20963	1625	202	0-20
13-042	0	6/07/13	112.11942	46.55925	1665	116	0-20
13-043	0	6/07/13	112.10969	46.56792	1653	276	20-40
13-044	1	6/07/13	112.09983	46.57251	1616	124	0-20
13-045	1	6/07/13	111.95177	46.91685	1107	106	0-20
13-046	1	6/10/13	111.48945	46.71204	1527	208	0-20
13-047	1	6/10/13	111.53641	46.67072	1419	134	0-20
13-048	1	6/10/13	111.53928	46.66233	1401	160	0-20
13-049	1	6/10/13	111.71845	46.63330	1178	314	0-20
13-050	1	6/11/13	112.11363	46.67051	1325	260	0-20
13-051	1	6/11/13	112.19907	46.65767	1364	156	0-20
13-052	1	6/11/13	112.19935	46.65252	1379	312	0-20
13-053	1	6/11/13	112.20379	46.64993	1385	354	0-20
13-054	1	6/11/13	112.29030	46.64740	1598	290	0-20
13-055	1	6/11/13	112.29429	46.618196	1824	6	0-20
13-056	1	6/12/13	111.58373	46.67889	1549	192	0-20
13-057	1	6/12/13	111.58178	46.67616	1546	160	0-20
13-058	1	6/12/13	111.58647	46.66576	1491	154	0-20
13-059	1	6/12/13	111.65434	46.61122	1164	328	0-20
13-060	1	6/14/13	112.96535	47.11797	1444	190	0-20
13-061	1	6/14/13	112.96428	47.12651	1479	122	0-20
13-062	1	6/14/13	112.91746	47.02850	1390	262	0-20
13-063	1	6/14/13	111.541627	46.657597	1395	330	0-20
13-064	1	6/14/13	111.704767	46.611676	1168	132	0-20
13-067	1	6/18/13	112.48719	47.09800	1660	140	0-20
13-068	1	6/18/13	112.53465	46.97649	1457	220	0-20

Table 1 Continued.

Site #	Tick Presence*	Date	Longitude(W)	Latitude(N)	GPS Elevation (m)	Compass Aspect(°)	Compass Slope
13-069	1	6/18/13	112.87411	46.91748	1381	322	0-20
13-070	1	6/18/13	112.39052	46.98505	1596	288	0-20
13-071	1	6/19/13	112.02502	46.49437	1489	110	0-20
13-072	1	6/19/13	112.17112	46.45488	1935	12	0-20
13-073	1	6/21/13	112.05389	46.56878	1367	318	0-20
13-074	1	6/21/13	112.06029	46.56341	1374	334	0-20
13-075	1	6/25/13	112.53479	47.26565	1488	183	0-20
13-076	1	6/27/13	112.79130	47.04881	2230	236	0-20
13-077	1	NA	111.56406	46.72860	1989	264	0-20
13-078	1	NA	111.58513	46.73407	1969	266	0-20
13-079	1	NA	111.59080	46.75471	162	232	0-20
13-080	1	NA	111.975899	46.697906	1118	45	0-20

*0 signifies site where no ticks were recovered, 1 signifies tick presence

Table 2. P-Values from chi-square analyses comparing frequencies of species presence with frequencies of tick presence.

Species	p-Value
Tree	
Lodgepole Pine	0.206
Ponderosa Pine	0.998
Douglas Fir	0.256
Juniper	0.818
Shrub	
Ribes	0.464
Skunkbush	0.762
Chokecherry	0.998
Rabbitbrush	0.145
Snowberry	0.459
Maple	0.762
Juniper	0.795
Sagebrush	0.122

Table 3. p-Values from chi-square analyses comparing tick presence with vegetation density.

Factor	p-Value
% Canopy Cover	0.339
% Shrub Cover	0.830
% Ground Cover	0.384
% Leaf Litter	0.335

Table 4. t-Test results from microclimate and GIS data testing for association with tick occurrence.

Factor	t Statistic	p-Value
Air Temp. (°C)ǂ	0.57	0.571
Humidity (%)ǂ	0.85	0.397
Wind (m/s)ǂ	0.99	0.326
Soil (°C)ǂ	0.68	0.495
Tmin*	1.12	0.272
Tmax*	0.586	0.559
Precipitation (in.)*	0.806	0.423

ǂMicroclimate data collected in field
*Mean annual temp. and precipitation (GIS data)

Table 5. Number of sites with and without ticks in each density grouping for canopy, shrub, and ground layers/leaf litter.

Factor	0-25%	26-50%	51-75%	76-100%
Canopy				
ticks present	23	9	2	1
ticks absent	21	14	4	3
Shrub				
ticks present	12	11	9	3
ticks absent	13	16	10	3
Ground				
ticks present	6	13	8	8
ticks absent	11	10	14	7
Leaf Litter				
ticks present	22	7	4	2
ticks absent	27	4	6	5

Table 6. Number of sites sampled in A) Land Cover Classifications, and B) Ecoregion Classifications.

A)

Land Cover	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
Ticks Present	1	4	1	5	2	2	8	0	3	0	4	1	1
Ticks Absent	1	3	1	6	5	5	10	1	1	1	6	0	0
Sum	2	7	2	11	7	7	18	1	4	1	10	1	1

A	Aspen Forest & Woodland
B	Big Sagebrush Steppe
C	Developed, Low Intensity
D	Montane Sagebrush Steppe
E	Northern R.M.* Lower Montane Riparian Woodland & Shrubland
F	R.M. Lodgepole Pine Forest
G	R.M. Lower Montane, Foothill, and Valley Grassland
H	R.M. Lower Montane-Foothill Riparian Woodland & Shrubland
I	R.M. Montane Douglas-Fir Forest & Woodland
J	R.M. Montane-Foothill Deciduous Shrubland
K	R.M. Ponderosa Pine Woodland & Savanna
L	R.M. Subalpine Dry-Mesic Spruce-Fir Forest & Woodland
M	R.M. Subalpine-Montane Mesic Meadow

*Rocky Mountain

B)

Ecoregion	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Ticks Present	8	3	2	8	1	0	0	3	1	6	0
Ticks Absent	5	2	1	11	2	1	1	4	0	10	3
Sum	13	5	3	19	3	1	1	7	1	16	3

A	Big Belt Forested Highlands
B	Dry Gneissic-Schistose-Volcanic Hills
C	Dry Intermontane Sagebrush Valleys
D	Eastern Divide Mountains
E	Elkhorn Mountains-Boulder Batholith
F	Foothill Grassland
G	Foothill Potholes
H	Rattlesnake-Blackfoot South-Swan Northern Garnet-Saphire Mountains
I	Southern Carbonate Front
J	Townsend Basin
K	Townsend-Horseshoe-London Sedimentary Hills

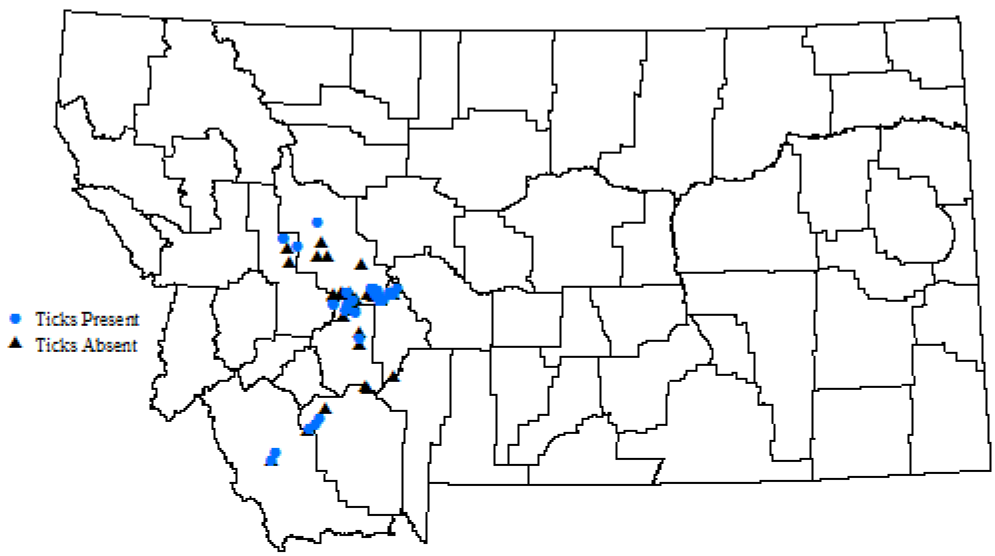

Figure 1. Site map showing distribution of sample sites.

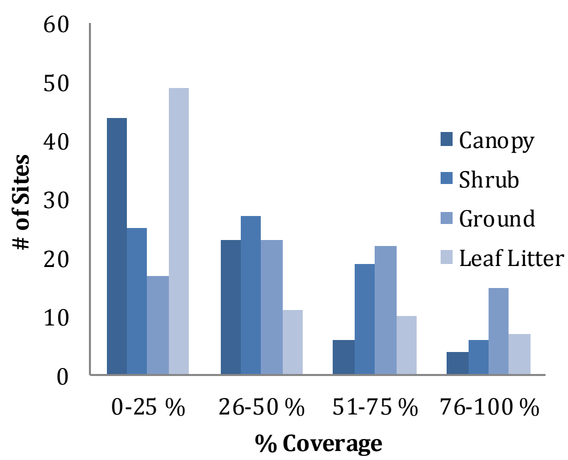

Figure 2. Total number of sites sampled in each density grouping for habitat composition variables.

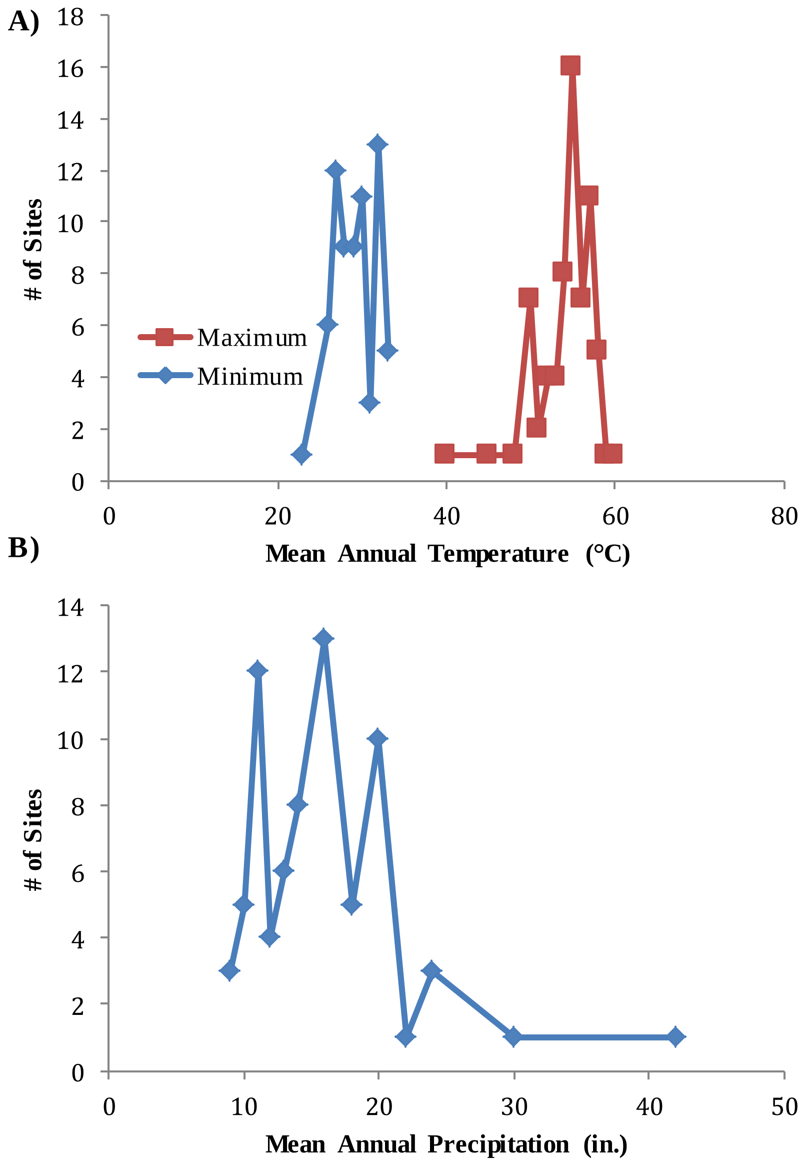

Figure 3. A) Number of sites sampled for mean annual minimum and maximum temperatures. B) Distribution of sites sampled in regard to mean annual

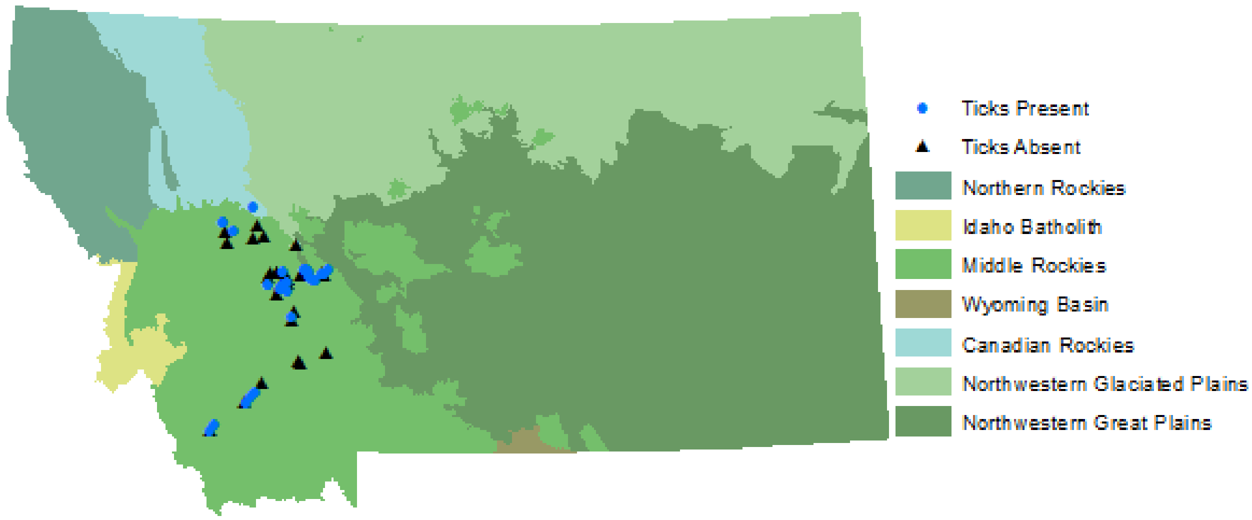

Figure 4.GIS map of Ecoregions at the level 3 classification.

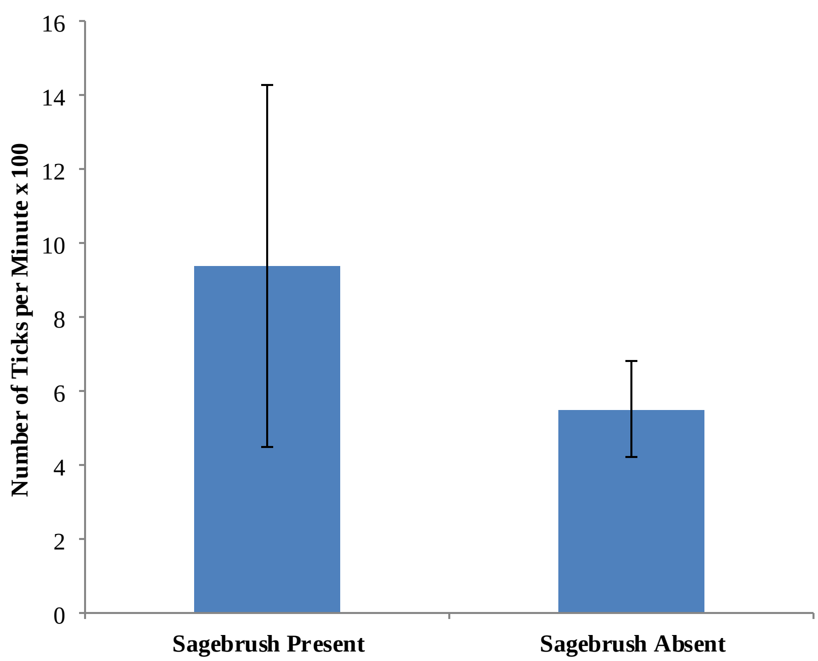

Figure 5. Tick Density at sites in relation to Sagebrush presence or absence.