ABSTRACT: The human-biting adult stage of the Rocky Mountain wood tick (Dermacentor andersoni) can cause tick paralysis in humans and domestic animals and is the primary tick vector in the intermountain west of the pathogens causing Colorado tick fever, Rocky Mountain spotted fever, and tularemia. We conducted drag sampling studies in Poudre Canyon and Rocky Mountain National Park of Larimer County, CO, to determine microhabitat use patterns by host-seeking D. andersoni adults and find environmental factors signaling elevated risk of tick exposure. Big sagebrush (Artemisia tridentata) was found to serve as a general indicator of areas with elevated risk of exposure to host-seeking D. andersoni adults; this likely results from a shared climate tolerance of big sagebrush and D. andersoni. Grass was the favored substrate for host-seeking ticks. Drag sampling of open grass or grass bordering rock or shrub produced abundances of D. andersoni adults significantly higher than sampling of brush. Sampling sites in Rocky Mountain National Park, relative to Poudre Canyon, were characterized by more intense usage by elk (Cervus elaphus) but decreased brush coverage, smaller brush size, and lower abundances of host-seeking D. andersoni adults. There has been a tremendous increase in the population of elk in Rocky Mountain National Park over the last decades and we speculate that this has resulted in an ecological cascade where overgrazing of vegetation by elk is followed by suppression of rodent populations, decreased tick abundance, and, ultimately, reduced risk of human exposure to D. andersoni and its associated pathogens. Journal of Vector Ecology 33 (1): 117-128. 2008.

Keyword Index: Dermacentor andersoni, elk, microhabitat, risk indicators, Rocky Mountain National Park.

INTRODUCTION

The human-biting adult stage of the Rocky Mountain wood tick, Dermacentor andersoni, is the primary vector in the Rocky Mountain region of the causative agents of tularemia, Rocky Mountain spotted fever, and Colorado tick fever (Jellison 1974, Hopla 1974, Burgdorfer 1977, Emmons 1988, Bowen 1989, Hayes 2005, Macaluso and Azad 2005, Marfin and Campbell 2005). Bites by this tick can also cause tick paralysis in humans (Jellison and Gregson 1950, Dworkin et al. 1999, Pape et al. 2006). The ecology of this important vector has, however, largely been ignored in recent decades and risk factors for human exposure to host-seeking adults are not adequately understood. This is in part because many older studies used overnight CO$_2$-trapping as the method for estimating abundances of host-seeking D. andersoni adults (Clark et al. 1970, CDC 1975, 1976, Carey et al. 1980, McLean et al. 1981, Eads and Smith 1983), and it is not clear how the results of these studies relate to human risk of tick exposure. As a case in point, CO$_2$-trapping has been reported (Garcia 1965) to yield up to 25-fold higher numbers of D. andersoni adults than drag sampling, which mimics the movement of a person through the landscape and thus yields a more realistic measure of human risk of tick exposure. We have therefore revisited the issue of human risk of exposure to host-seeking D. andersoni adults in a series of studies based on drag sampling and exploring tick seasonality (Eisen 2007), climate-based modeling of tick abundance (Eisen et al. 2007), and habitat and microhabitat associations of host-seeking ticks (present study). These studies have focused on the ecologically and climatically highly diverse Larimer County, CO, which extends from the western edge of the Central Plains into the eastern edge of the Rocky Mountains and includes the entire climate range allowing for establishment of D. andersoni populations (Eisen et al. 2007). The aims of the present study were to: 1) test the hypothesis that big sagebrush (Artemisia tridentata) can serve as an indicator of areas with elevated risk of exposure to D. andersoni adults; 2) determine which microhabitats represent the highest risk of exposure to host-seeking adults in their favored south-facing grass-brush-conifer habit; and 3) explore associations between deer/elk abundance, vegetation cover, microclimate, and tick abundance.

MATERIALS AND METHODS

Study area and general sampling and data analysis scheme

Studies were conducted in Poudre Canyon (PC) and Rocky Mountain National Park (RMNP) in Larimer
County, CO, during 2006-2007 (Table 1; Figure 1). Ticks were collected by drag sampling during the mid-April to early June peak activity period for *D. andersoni* adults in Larimer County (CDC 1975, 1976, Eads and Smith 1983, Eisen 2007). Collected ticks were stored in 95% ethanol prior to identification to species using published keys (Gregson 1956, Brinton et al. 1965, Furman and Loomis 1984). All tick sampling sites were located on south-west-facing, rocky hillsides dominated by grasses, brush, and scattered ponderosa pine (*Pinus ponderosa*), common juniper (*Juniperus communis*), and aspen (*Populus tremuloides*). This is a key habitat type for *D. andersoni* and Colorado tick fever virus in Larimer County (CDC 1975, 1976, Carey et al. 1980, Bowen et al. 1981, McLean et al. 1981, McLean et al. 1989, Eisen et al. 2007). Dominant brush types included bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata*), and wax currant (*Ribes cereum*).

Sampling site locations were determined with a Trimble Geo XT (Trimble Corp., Sunnyvale, CA) GPS receiver. Site-specific long-term (1961-1990) climate conditions were derived from Geographic Information System-based data (2x2 km spatial resolution; Climate Source LLC, Corvallis, OR) and elevation data from the U.S. Geological Survey 30- m digital national elevation data-set. All statistical analyses were carried out using the JMP statistical package (Sall et al. 2005) and results were considered significant when *P* < 0.05.

**Big sagebrush as an indicator of areas with elevated risk of exposure to host-seeking adults**

The rationale for targeting big sagebrush as a potential indicator of areas with elevated risk of exposure to *D. andersoni* adults was an observation by L.E. during preliminary sampling in 2005 that ticks commonly were collected in mid-range to high elevation montane areas with big sagebrush present but rarely in low montane areas where this brush species is absent. The big sagebrush-related study component was carried out from 30 April – 18 May 2007 in five south-west-facing PC sites (Rustic, Pingree Hill Rd, Poudre Chapel, Profile Rock, Washout Gulch) and five south-west-facing RMNP sites (Eagle Cliff Mtn, Windy Gulch, Hollowell Park, Fall River, Deer Mtn). Drag sampling of six microhabitat categories (big sagebrush, bitterbrush, juniper, grass bordering rock, grass bordering brush, open grass more than 0.5 m from either brush or rock) was conducted, during 0800-1600 hours, on three occasions per site using a 0.5 x 0.5 m white cloth. The rationale for using a smaller drag cloth in this study component was to be able to sample individual brush specimens without also coming into contact with adjacent grass. Sampling included 50 drags of 10 s per microhabitat category (25 for juniper), site, and sampling occasion. A drag unit time of 10 s, rather than the 15 s used in 2006, was used because 10 s was found to be a suitable length of time to cover individual brush specimens. Sampling efforts resulted in a total of 125 min of active dragging per microhabitat type (62.5 min for juniper) in each of PC and RMNP over the study period. However, there were a few exceptions to this rule because juniper or big sagebrush was lacking or scarce in three of the five RMNP sites.

The drag was examined for ticks every 10 s to minimize the number of ticks detaching from the drag during its movement. Ticks recovered from clothing were not included in this study component because we could not be sure which microhabitat type they originated from. In the analysis of this study component, multiple sampling occasions from the same site were included and treated as independent observations; this can be justified because sampling was not carried out along fixed transect lines but rather by drag time with individual 10 s drag areas varying between sampling occasions.

**Microhabitat-specific risk of exposure to host-seeking adults**

The study component exploring microhabitat-specific risk of exposure to *D. andersoni* adults was carried out from 30 April – 18 May 2007 in five south-west-facing PC sites (Rustic, Pingree Hill Rd, Poudre Chapel, Profile Rock, Washout Gulch) and five south-west-facing RMNP sites (Eagle Cliff Mtn, Windy Gulch, Hollowell Park, Fall River, Deer Mtn). Drag sampling of six microhabitat categories (big sagebrush, bitterbrush, juniper, grass bordering rock, grass bordering brush, open grass more than 0.5 m from either brush or rock) was conducted, during 0800-1600 hours, on three occasions per site using a 0.5 x 0.5 m white cloth. The rationale for using a smaller drag cloth in this study component was to be able to sample individual brush specimens without also coming into contact with adjacent grass. Sampling included 50 drags of 10 s per microhabitat category (25 for juniper), site, and sampling occasion. A drag unit time of 10 s, rather than the 15 s used in 2006, was used because 10 s was found to be a suitable length of time to cover individual brush specimens. Sampling efforts resulted in a total of 125 min of active dragging per microhabitat type (62.5 min for juniper) in each of PC and RMNP over the study period. However, there were a few exceptions to this rule because juniper or big sagebrush was lacking or scarce in three of the five RMNP sites.

The drag was examined for ticks every 10 s to minimize the number of ticks detaching from the drag during its movement. Ticks recovered from clothing were not included in this study component because we could not be sure which microhabitat type they originated from. In the analysis of this study component, multiple sampling occasions from the same site were included and treated as independent observations; this can be justified because sampling was not carried out along fixed transect lines but rather by drag time with individual 10 s drag areas varying between sampling occasions.

**Associations between deer/elk usage, vegetation cover, microclimate, and abundance of host-seeking adult ticks**

This study component focused on four PC sites (Rustic, Pingree Hill Rd, Poudre Chapel, Profile Rock) and five RMNP sites (Eagle Cliff Mtn, Windy Gulch, Hollowell Park, Fall River, Deer Mtn) sampled for ticks in both 2006 and 2007 (Figure 1). Elk (*Cervus elaphus*) were perceived to more commonly utilize the RMNP sites based on repeated elk observations during tick sampling in 2005-2006 and the well-documented presence of a large elk population in RMNP (Singer et al. 1998, Lubow et al. 2002). During tick sampling in 2006, we also observed that individual brush specimens of the same species appeared to be smaller in RMNP relative to PC. Analyses for abundance of *D. andersoni* in 2006 or 2007 (see descriptions of sampling schemes above) were
based on data for the sampling occasion yielding the highest tick number in each site and year.

Tick abundance data were complemented by data collected in 2006 for density of elk and *Odocoileus* spp. deer pellet groups, brush coverage, and brush size, and data collected in 2007 for microclimatic conditions. At each site, elk and deer pellet groups were counted on a single occasion in 10-m increments along a 300 m transect representative of where tick drag sampling had been conducted. Counts included all pellet groups spotted within ~2 m of the transect line. Elk and deer pellets are distinguished from each other by a clear difference in size (Halfpenny 2001). This could possibly have resulted in an underestimation of elk abundance by counting small pellets produced by elk calves as deer pellets. Brush coverage was estimated at 1-m intervals along the same 300 m transect; brush was classified as absent or present for each 1 m point. In addition, we measured the height and width of representative specimens of the two most commonly occurring species of brush: bitterbrush and big sagebrush.

Microclimate conditions from March - August 2007 were examined using HOBO H8 Pro series loggers (Onset Computer Corporation, Pocasset, MA). The rationale for including data for July-August when host-seeking activity of *D. andersoni* adults has practically ceased (Eisen 2007) is that larval and nymphal ticks are active during these months (CDC 1975, 1976, Sonenshine et al. 1976). Each site held two loggers placed at the base of specimens of bitterbrush and taking temperature and relative humidity (RH) measurements at 30-min intervals. One of the loggers was fixed to a bitterbrush specimen of average size for the specific site and the other one to a bitterbrush specimen of average size for the other tick collection area (i.e., PC for RMNP sites and RMNP for PC sites). Comparisons of microclimate data between PC and RMNP, or between loggers attached to brush of different sizes at either PC or RMNP, were based on average data from all pertinent loggers for a given comparison.

**RESULTS**

**Tick species and life stages collected**

The tick species and life stages collected by drag sampling in Poudre Canyon (PC) and Rocky Mountain National Park (RMNP) in 2006 and 2007 are shown in Table 2. Excluding a single cluster of *D. albipictus* larvae from a PC site, *D. andersoni* adults accounted for 99.7% of collected ticks in PC and 97.7% in RMNP. The few remaining ticks were a single *D. andersoni* nymph from a PC site and low numbers of *D. albipictus* adults from PC (n = 2) and RMNP (n = 8).

**Big sagebrush as an indicator of areas with elevated risk of exposure to host-seeking adults**

Data from 2006 demonstrated that presence of big sagebrush can serve as an indicator of areas with elevated risk of exposure to host-seeking *D. andersoni* adults in Poudre Canyon (Figure 2). Peak abundance of host-seeking adults was 30-fold higher for 11 south/west-facing sites with abundant sagebrush (elevation range, 2,160-2,500 m; average of 0.31 ticks per 15-s drag) than for six south/west-facing sites lacking sagebrush (elevation range, 1,700-2,090 m; average of 0.01 ticks per 15-s drag) (Wilcoxon ranked sums test: $\chi^2 = 129.20$, df = 1, $P < 0.001$).

**Microhabitat-specific risk of exposure to host-seeking adults**

Host-seeking *D. andersoni* adults were collected more commonly from grassy substrates (open grass, grass bordering rock, grass bordering brush) than from brush (big sagebrush, bitterbrush) or juniper both in PC (Figure 3) and RMNP (Figure 4). For example, open grass yielded 13- to 17-fold higher tick abundances than bitterbrush-big sagebrush. In PC, tick abundance in open grass was higher than in either grass bordering rock or grass bordering brush (Figure 3). In RMNP, open grass and grass bordering rock yielded similar tick numbers, whereas tick abundance was lower in grass bordering brush (Figure 4). Microhabitat use patterns were similar between PC and RMNP (Figures 3-4) as well as for female and male ticks (data not shown).

**Associations between deer/elk abundance, vegetation cover, microclimate, and abundance of host-seeking adults**

Host-seeking *D. andersoni* adults were two- to four-fold more abundant in south/west-facing grass-brush-conifer habitats in PC versus RMNP in 2006 ($\chi^2 = 71.55$, df = 1, $P < 0.001$) and 2007 ($\chi^2 = 6.17$, df = 1, $P = 0.01$) (Table 3). This was surprising because the RMNP sites were utilized far more heavily by elk (which is a potential key host for *D. andersoni* adults) than the PC sites; elk pellet counts were 20-fold higher in RMNP (3.9 pellet groups per 10 m observation unit; Table 3) than in PC (0.2 pellet groups per 10 m observation unit) ($\chi^2 = 181.19$, df = 1, $P < 0.001$). In contrast, density of deer pellet groups was similar between RMNP and Poudre Canyon (0.2 pellet groups per 10 m observation unit in both cases; $P = 0.97$).

High usage of tick sampling sites in RMNP by elk may be associated with negative impacts on the vegetation. Sampling sites in RMNP, relative to PC, had a lower percentage of brush coverage (18% versus 34%; Fisher’s 2-tailed exact test, $P < 0.001$; Table 3) and both bitterbrush and sagebrush were smaller in RMNP than in PC (Table 3). Sagebrush averaged 74 cm height and 142 cm width in PC as compared to 43 cm height and 120 cm width in RMNP (ANOVA: Height, log-transformed: $F_{1,223} = 145.24$, $P < 0.001$; Width, log-transformed: $F_{1,223} = 8.88$, $P = 0.003$). Similarly, bitterbrush averaged 82 cm height and 176 cm width in PC versus 61 cm height and 155 cm width in RMNP (Height, log-transformed: $F_{1,223} = 72.95$, $P < 0.001$; Width, log-transformed: $F_{1,223} = 9.62$, $P = 0.002$).

Long-term average mesoclimate data for the PC and RMNP sites (based on 2x2 km pixel size GIS-derived data from 1961-1990) indicated that daily maximum spring temperatures are similar but that RMNP receives more rainfall (Table 1). Microclimate conditions during March-
Table 1. Environmental characteristics for selected sites in Poudre Canyon and Rocky Mountain National Park.

<table>
<thead>
<tr>
<th>Site</th>
<th>Exposure</th>
<th>Slope</th>
<th>Dominant brush type</th>
<th>Elevation (m)</th>
<th>Annual growing degree days</th>
<th>Daily maximum temp., April-May (°C)</th>
<th>Precipitation, April-May (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poudre Canyon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rustic (RUS)</td>
<td>SE</td>
<td>Moderate</td>
<td>B, BS, W</td>
<td>2,200</td>
<td>848</td>
<td>11.5</td>
<td>83</td>
</tr>
<tr>
<td>Pingree Hill Rd (PHR)</td>
<td>S</td>
<td>Moderate</td>
<td>B, BS, W</td>
<td>2,360</td>
<td>820</td>
<td>11.2</td>
<td>78</td>
</tr>
<tr>
<td>Poudre Chapel (POC)</td>
<td>S</td>
<td>Mild</td>
<td>B, BS, W</td>
<td>2,240</td>
<td>643</td>
<td>10.5</td>
<td>85</td>
</tr>
<tr>
<td>Profile Rock (PRR)</td>
<td>S</td>
<td>Mild</td>
<td>B, BS</td>
<td>2,260</td>
<td>643</td>
<td>10.5</td>
<td>85</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
<td></td>
<td>2,200-2,360</td>
<td>643-848</td>
<td>10.5-11.5</td>
<td>78-85</td>
</tr>
<tr>
<td>Rocky Mountain National Park</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eagle Cliff Mtn (ECM)</td>
<td>S</td>
<td>Moderate</td>
<td>B, W</td>
<td>2,450</td>
<td>952</td>
<td>12.1</td>
<td>118</td>
</tr>
<tr>
<td>Windy Gulch (WIG)</td>
<td>S</td>
<td>Mild</td>
<td>B, W</td>
<td>2,510</td>
<td>778</td>
<td>10.9</td>
<td>128</td>
</tr>
<tr>
<td>Hollowell Park (HOP)</td>
<td>SE</td>
<td>Moderate</td>
<td>B, BS</td>
<td>2,580</td>
<td>760</td>
<td>10.7</td>
<td>125</td>
</tr>
<tr>
<td>Fall River (FAR)</td>
<td>S</td>
<td>Moderate</td>
<td>B, W</td>
<td>2,580</td>
<td>806</td>
<td>11.5</td>
<td>133</td>
</tr>
<tr>
<td>Deer Mtn (DEM)</td>
<td>SW</td>
<td>Steep</td>
<td>B, BS</td>
<td>2,620</td>
<td>929</td>
<td>11.8</td>
<td>124</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
<td></td>
<td>2,450-2,620</td>
<td>760-952</td>
<td>10.7-12.1</td>
<td>118-133</td>
</tr>
</tbody>
</table>

All sites are located on south/west-facing, rocky hillsides with mixed grass-brush-ponderosa pine/juniper vegetation.

a B, bitterbrush (*Purshia tridentata*); BS, big sagebrush (*Artemisia tridentata*); W, wax currant (*Ribes cereum*).
b Extracted from Geographic Information System-based data from 1961-1990 (2x2 km spatial resolution) based on site locations determined with a GPS receiver. Annual growing degree days were calculated using a 10° C base.
Figure 1. Location of tick sampling sites in Poudre Canyon (circles) and Rocky Mountain National Park (squares), Larimer County. The four Poudre Canyon sites included in the study component determining associations between deer/elk usage, vegetation cover, microclimate, and abundance of host-seeking adults are shown in black. The distribution of montane ponderosa pine habitat in the county is shown in gray. The inset map shows the location of Larimer County within Colorado.

Figure 2. Comparison of abundance of host-seeking *D. andersoni* adults in Poudre Canyon sites where big sagebrush (*Artemisia tridentata*) was abundant vs lacking.

Figure 3. Comparison of abundance of host-seeking *D. andersoni* adults by microhabitat type in Poudre Canyon. Tick abundance differed significantly (*P* < 0.05) between microhabitat types denoted by different letters.
Table 2. Tick species and life stages collected by drag sampling in Poudre Canyon and Rocky Mountain National Park in 2006 and 2007.

<table>
<thead>
<tr>
<th>Year</th>
<th>[Dermacentor andersoni]</th>
<th>[Dermacentor albipictus]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nymphs</td>
<td>Females</td>
</tr>
<tr>
<td>Poudre Canyon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>0</td>
<td>353</td>
</tr>
<tr>
<td>2007</td>
<td>1</td>
<td>225</td>
</tr>
<tr>
<td>Rocky Mountain National Park</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>0</td>
<td>89</td>
</tr>
<tr>
<td>2007</td>
<td>0</td>
<td>102</td>
</tr>
</tbody>
</table>

*Eighteen sites sampled on three occasions.

*Five sites sampled on three occasions.

*Collected on a single 10-s drag.

August 2007 under brush cover at RMNP, relative to PC, were found to be characterized by higher relative humidity (as expected from the long-term mesoclimatic data) but also by lower temperature (Table 4; Figures 5-6). This held true for average daily relative humidity (paired t-test: $t = 2.00$, df = 182, $P = 0.046$), average minimum daily relative humidity ($t = 6.16$, df = 182, $P < 0.001$), average daily temperature ($t = -15.37$, df = 182, $P < 0.001$), and average daily maximum temperature ($t = -19.00$, df = 182, $P < 0.001$). By July-August, daily maximum temperatures were $4-5^\circ C$ lower and average relative humidity values were $5-6\%$ higher in RMNP than in PC ($t \geq 11.54$, df = 61, $P < 0.001$ in both cases).

In both PC and RMNP, data loggers placed under larger-sized brush specimens recorded lower average daily maximum temperature and higher average minimum daily relative humidity from March-August than those located under smaller brush specimens (Table 4; $t \geq 6.03$, df = 182, $P < 0.001$ in all four cases). The potential for larger average brush size in PC, relative to RMNP, resulting in cooler and moister microclimate conditions more suitable for ticks was, however, offset by the generally cooler and moister mesoclimatic temperature in RMNP; temperatures were consistently lower and July-August relative humidity was higher under smaller brush in RMNP than under larger brush in PC (Table 4).

DISCUSSION

Our study confirms that D. andersoni adults present the only real threat as human-biting ticks in the Colorado Front Range (CDC 1975, 1976, McLean et al. 1981, Eads and Smith 1983, Eisen 2007, Eisen et al. 2007). Other mammal-infesting tick species occurring in this area specialize on either rodents or other small mammals (e.g., Haemaphysalis leporispalustris, Ixodes spinipalpis, I. kingi, I. sculptus) or large herbivores (the winter tick D. albipictus) (CDC 1975, 1976, Gage et al. 1997, Salkeld et al. 2006). D. albipictus is a one-host tick typically infesting large ungulates such as deer, elk, and moose (Bishopp and Trembley 1945, Gregson 1956, Wilkinson 1970, Furman and Loomis 1984, Sonenshine 1993, Samuel 2004), and the few adult specimens collected by drag sampling in this study most likely had been dislodged from elk or deer and were attempting to re-acquire a host. Occasional collections of D. albipictus adults from vegetation or by CO$_2$-trapping have been reported previously (CDC 1975, Furman and Loomis 1984).

This study complements previous ones focusing on seasonality of host-seeking D. andersoni adults (Eads and Smith 1983, Eisen 2007) and broad spatial tick abundance patterns (Eisen et al. 2007) with information on fine-scale spatial risk patterns and indicators of elevated risk. Big sagebrush, which is easily recognized by a lay person in the field, was shown to serve as an indicator for presence of areas with elevated abundances of D. andersoni adults in Larimer County (Figure 2). Similar associations between D. andersoni and sage or other brush (Saskatoon serviceberry [Amelanchier alnifolia], rose [Rosa spp.], common snowberry [Symphoricarpos albus], and chokeberry [Prunus virginiana]) were previously reported from Canada (Holland 1940, Wilkinson and Loomis 1984). The weak association observed by us between big sagebrush and host-seeking D. andersoni adults at the microhabitat spatial scale (Figures 3-4) suggests that the reason for big sagebrush signaling presence of areas with elevated tick abundances is a shared climate tolerance with D. andersoni rather than presence of big sagebrush per se being crucial to the tick or its hosts. Nevertheless, the public can reduce risk of acquiring tick bites in the Colorado Front Range by either avoiding areas where big sagebrush is present or by conducting frequent tick checks when moving through such areas.

Our study also generated new knowledge of microhabitat use patterns of host-seeking D. andersoni adults. The vast majority of ticks were collected from grassy microhabitats with only sporadic collections from brush. Previous information on microhabitat use patterns of D. andersoni adults has been qualitative (Holland 1940, Brown...
### Table 3. Deer and elk usage, brush characteristics, and abundance of host-seeking *Dermacentor andersoni* adults in Poudre Canyon and Rocky Mountain National Park.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mean (S.D.) pellet group density&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Brush coverage (%)</th>
<th>Mean (S.D.) brush size (cm)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Peak mean (S.D.) no. of adults per drag unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deer</td>
<td>Elk</td>
<td>Bitterbrush</td>
<td>Big sagebrush</td>
</tr>
<tr>
<td></td>
<td>Height</td>
<td>Width</td>
<td>Height</td>
<td>Width</td>
</tr>
<tr>
<td>Poudre Canyon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUS</td>
<td>0.4 (0.6)</td>
<td>0.1 (0.3)</td>
<td>35</td>
<td>70 (12)</td>
</tr>
<tr>
<td>PHR</td>
<td>0.3 (0.4)</td>
<td>0.4 (0.9)</td>
<td>34</td>
<td>85 (25)</td>
</tr>
<tr>
<td>POC</td>
<td>0.1 (0.3)</td>
<td>0.1 (0.3)</td>
<td>30</td>
<td>84 (21)</td>
</tr>
<tr>
<td>PRR</td>
<td>0.1 (0.3)</td>
<td>0 (0)</td>
<td>36</td>
<td>90 (21)</td>
</tr>
<tr>
<td>Mean</td>
<td>0.2 (0.4)</td>
<td>0.2 (0.5)</td>
<td>34&lt;sup&gt;d&lt;/sup&gt;</td>
<td>82 (21)&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rocky Mountain National Park</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECM</td>
<td>0.2 (0.5)</td>
<td>4.4 (2.2)</td>
<td>22</td>
<td>73 (14)</td>
</tr>
<tr>
<td>WIG</td>
<td>0.1 (0.2)</td>
<td>3.8 (2.1)</td>
<td>16</td>
<td>68 (18)</td>
</tr>
<tr>
<td>HOP</td>
<td>0.4 (0.6)</td>
<td>2.9 (1.9)</td>
<td>22</td>
<td>53 (9)</td>
</tr>
<tr>
<td>FAR</td>
<td>0.2 (0.4)</td>
<td>3.7 (2.7)</td>
<td>16</td>
<td>61 (17)</td>
</tr>
<tr>
<td>DEM</td>
<td>0.3 (0.6)</td>
<td>4.7 (1.7)</td>
<td>16</td>
<td>52 (8)</td>
</tr>
<tr>
<td>Mean</td>
<td>0.2 (0.5)</td>
<td>3.9 (2.2)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>18</td>
<td>61 (16)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Pellet group density per 10 m observation unit.

<sup>b</sup> Based on 25 observations per site for bitterbrush, 25 observations per site for sagebrush in Poudre Canyon, and 40 (DEM, HOP) or 5 (WIG) observations per site for sagebrush in Rocky Mountain National Park.

<sup>c</sup> Based on data for the sampling occasion yielding the highest tick number in each site and year. Data for 2006 and 2007 should not be compared because of differences in drag unit time (15 s in 2006 and 10 s in 2007) and drag cloth size (1x1.25 m in 2006 and 0.5x0.5 m in 2007). Data from 2007 were based on microhabitat types present in all Poudre Canyon and Rocky Mountain National Park sites sampled (bitterbrush, grass bordering rock, grass bordering brush, open grass).

<sup>d</sup> Value for Poudre Canyon significantly ($P < 0.05$) higher than for Rocky Mountain National Park.

<sup>e</sup> Value for Rocky Mountain National Park significantly ($P < 0.001$) higher than for Poudre Canyon.
Table 4. Microclimate conditions in tick sampling sites in Poudre Canyon (PC) and Rocky Mountain National Park (RM), March-August 2007, based on data from HOBO loggers placed at the bases of bitterbrush of average size for the specific site (PC - PC sized brush or RM - RM sized brush) or average size for the sites in the other area (PC - RM sized brush or RM - PC sized brush).

<table>
<thead>
<tr>
<th>Month</th>
<th>PC-PC sized brush</th>
<th>PC-RM sized brush</th>
<th>RM-PC sized brush</th>
<th>RM-RM sized brush</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average daily mean</td>
<td>Average daily maximum</td>
<td>Average daily mean</td>
<td>Average daily minimum</td>
</tr>
<tr>
<td>March</td>
<td>4.4</td>
<td>4.5</td>
<td>4.2</td>
<td>4.6</td>
</tr>
<tr>
<td>April</td>
<td>4.8</td>
<td>4.5</td>
<td>4.6</td>
<td>4.5</td>
</tr>
<tr>
<td>May</td>
<td>10.2</td>
<td>9.0</td>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>June</td>
<td>16.0</td>
<td>15.0</td>
<td>15.0</td>
<td>15.0</td>
</tr>
<tr>
<td>July</td>
<td>20.0</td>
<td>17.8</td>
<td>18.1</td>
<td>17.3</td>
</tr>
<tr>
<td>Aug.</td>
<td>18.6</td>
<td>16.8</td>
<td>16.8</td>
<td>17.3</td>
</tr>
</tbody>
</table>

*Based on data collected at 30-min intervals from four Poudre Canyon sites and five Rocky Mountain National Park sites.
Figure 4. Comparison of abundance of host-seeking *D. andersoni* adults by microhabitat type in Rocky Mountain National Park. Tick abundance differed significantly (*P* < 0.05) between microhabitat types denoted by different letters.

Figure 5. Comparison of daily maximum temperature under brush cover in Poudre Canyon (average for eight data loggers in four sites) and Rocky Mountain National Park (average for ten data loggers in four sites) from March-August, 2007.

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**Vol. 33, no. 1**

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immature tick stages (due to diminished vegetation cover) was followed by decreased tick abundance and, ultimately, reduced risk of human exposure to *D. andersoni* and its associated pathogens.

RMNP was a hot-spot for human exposure to *D. andersoni* and Colorado tick fever (CTF) virus during the 1970s. Camp site visitors reported 4.2 tick exposures with 1.8 bites per 100 camp-days in 1975 and there was a well documented outbreak of CTF among RMNP visitors at this time (CDC 1975, 1976). It is tempting to speculate that a tremendous population increase of elk in RMNP during the 1980s and 1990s (Singer et al. 1998, Lubow et al. 2002) and subsequent overgrazing of vegetation (Zeigenfuss et al. 2002, Schoenecker et al. 2004, Kaye et al. 2005) ultimately has had a negative impact on abundance of *D. andersoni* and resulted in decreased risk of human exposure to CTF virus and other pathogens transmitted by this tick. Current plans to cull the elk population in RMNP (http://www.nps.gov/romo/parkmgmt/elkvegetation.htm) will provide an intriguing opportunity to determine if a decrease in the population size of elk will be followed by recovery of vegetation, increased abundances of rodents and *D. andersoni* ticks, and a resurgence of tick paralysis and tick-borne diseases among visitors to RMNP.

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**REFERENCES CITED**


Ixodes scapularis


