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Pitfall Trapping and Direct Counts of Darkling Beetles in Cheatgrass Communities[1]

Abstract

Autumn-emergent darkling beetles were observed by pitfall trapping and by direct counts periodically throughout the autumns of 1968 and 1969 in two cheatgrass communities located at different elevations in the Rattlesnake Hills of south-central Washington.

Two species, *Philolithus densicollis* and *Stenomorpha puncticollis,* comprised the beetle population at the low elevation community (305 m). *P. densicollis* was nearly absent from the high elevation community (518 m). Direct count and pitfall trap data showed more beetles present in the fall of 1968 than in 1969 and also more beetles on the low elevation community as compared to the high elevation community. At peak emergence we estimated that 20 kg per hectare ± 3 (standard error) of beetles were present on the low elevation community in 1968.

Introduction

The adult autumn-emergent Tenebrionid beetles, *Philolithus densicollis* (Horn) and *Stenomorpha puncticollis* (Le Conte), are seasonally conspicuous in the steppe vegetation of south-central Washington. Rickard and Haverfield (1965) readily captured them in pitfall traps.

This paper reports the results of pitfall trapping in conjunction with direct counts of beetles from plots located in cheatgrass, *Bromus tectorum*, communities on the United States Atomic Energy Commission's Hanford Reservation in Benton County, Washington. Although darkling beetles are a conspicuous part of the fauna of the steppe region, there have been few attempts to estimate their abundance or biomass.

Two fields abandoned for thirty years and persistently dominated by more or less even swards of the alien, annual grass, *Bromus tectorum*, were examined. One field is located at approximately 305 m above sea level and the other at 518 m. Native vegetation surrounding the fields consists of perennial grasses, especially *Agropyron spicatum,* and *Poa secunda.* Sagebrush, *Artemisia tridentata*, is superimposed over these grasses as small, widely spaced clumps (Daubenmire, 1970). The fields have been essentially undisturbed by livestock grazing since abandonment and have accumulated various amounts of standing dead litter and mulch.

Each of two fields had fifteen pitfalls arranged in three rows of five pitfalls each. Pitfalls were buried so that the open rim of a 4 x 10 inch can was at the same level as the surrounding soil surface. Pitfalls were set out in late summer, 1968, capped before the onset of winter snowfall, and reopened early in the fall of 1969. Pitfalls

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were visited at weekly intervals. Captured beetles were released near the pitfall in which they were caught. Density of adult beetles was determined by visually scanning 1-square-m quadrats systematically located at 5-m intervals along tape lines. The ends of the tape lines were marked with stakes to permit accurate relocation of plots. Three lines were visited at the low elevation field in 1968 and 1969. Only two lines were established at the high elevation field in 1968, but three lines were used in 1969. Eight to ten quadrats were scanned along each line by two observers. These beetles move so slowly that ingress and egress from the quadrats during the time spent in visual search was not a factor that needed consideration. Because prevailing air temperatures are important to beetle movements, visual searches were made between 11 A.M. and 1 P.M. To convert density values to biomass, numbers of beetles were collected elsewhere in the fields and individually weighed.

Observations on vegetation and soil were made on those factors considered likely to be important to the welfare of darkling beetles. Density counts of plants were obtained because a very dense stand of grass could impede mobility. Accumulated litter (mulch) was collected and weighed because thick mulch layers might interfere with egg deposition and have an effect on egg hatchability and/or larval survival through altered moisture and temperature regimes near the soil surface.

Soil samples were taken 1 decimeter deep from five holes in each field. These samples were air-dried and submitted for standard agricultural soil tests of pH, organic matter, calcium, potassium, phosphorus, and magnesium.

At the peak of the spring growing season in 1969 all plants were harvested from ten quadrats, each 1 x 1 ft in area (.093 m^2), located systematically along a line at 5-m intervals. Harvested plants were placed in paper bags and dried at 65°C for 48 hours. Mulch and standing dead litter were lifted by hand, then treated in the same way as the living shoots. After oven-drying, loose soil particles were sieved out of the collected litter. All vegetation categories are expressed as grams of dry matter per square foot of ground area.

Results and Discussion

A summary of total pitfall catches for 1968 and 1969 for the high and low elevation fields is shown in Table 1. These data show more beetles captured in 1968 than in 1969. Also, more beetles were captured on the low elevation field than on the high elevation field. On the low elevation field more than two thousand catches of *Philolithus* were recorded in 1968, but only 31 in 1969. *Philolithus* was captured only once on the high elevation field over a 2-yr period. The pitfall catch of *Stenomorpha* was greater on the low elevation field than on the high elevation field during both years of study, and the 1968 catch was greater than the 1969 catch (Table 1).

TABLE 1. Total pitfall catch of darkling beetles, September to November, 1968 and 1969, in cheatgrass communities at different altitudes.

Altitude	Year	*Philolithus*	*Stenomorpha*	Total
305 m	1968	2322	1832	4154
305 m	1969	31	691	722
518 m	1968	1	1003	1004
518 m	1969	0	634	634

Unfortunately, these pitfall trap data cannot be used to determine beetle abundance per unit area nor the subsequent calculation of beetle biomass. The primary reason for this is that pitfall catches reflect the mobility of beetles as well as the abundance, i.e., a mobile species is more likely to be caught than a more sedentary one.

The average number of beetles directly counted per square meter at near weekly intervals throughout the autumn of 1968 is shown in Table 2. Ninety-five percent

TABLE 2. Mean density of darkling beetles per square m in cheatgrass communities at two different altitudes at various times during the autumn of 1968.

Date	*Stenomorpha* Mean	*Stenomorpha* 95%CI	*Philolithus* Mean	*Philolithus* 95%CI	
		Altitude 305 m			
10/2	4.6	3.3- 6.4	1.9	1.0-3.1	
10/14	12.6	10.3-15.3*	6.1	4.5-8.1*	
10/21	5.8	4.2- 7.7*	1.8	1.0-2.9	Line 1
10/28	6.9	5.2- 8.9	2.2	1.3-3.6	(8 plots)
11/4	2.0	1.1- 3.2	0.5	0.1-1.3	
11/11	3.6	2.4- 5.2	0.9	0.4-1.8*	
10/2	6.3	4.8- 8.2	2.4	1.5-3.7	
10/14	7.6	5.9- 9.6*	2.9	1.9-4.2*	
10/21	3.7	2.5- 5.1	1.4	0.8-2.5	Line 2
10/28	6.0	4.5- 7.8	1.1	0.5-2.0	(9 plots)
11/4	2.6	1.6- 3.8*	1.0	0.5-1.9	
11/11	2.1	1.3- 3.3	0.4		
10/2	2.4	1.5- 3.7*	0.1	0.0-0.6	
10/14	3.1	2.1- 4.5	1.3	0.7-2.3	
10/21	0.9	0.4- 1.8	0.7	0.2-1.5	Line 3
10/28	3.6	2.4- 5.0	1.9	1.1-3.0	(9 plots)
11/4	2.4	1.5- 3.7	0.8	0.3-1.6	
11/11	1.1	0.5- 2.0	0.3	0.1-1.0	
		Altitude 518 m			
10/7	5.5	4.1- 7.2*			
10/14	1.5	0.9- 2.7*			
10/21	1.0	0.5- 1.8			Line 1
10/28	2.3	1.5- 3.5	(No *Philolithus*)		(10 plots)
11/4	1.7	1.0- 2.7			
11/11	0.3	0.1- 0.9			
10/7	1.6	0.8- 2.3			
10/14	4.1	2.9- 5.6			Line 2
10/21	2.8	1.9- 4.0	(No *Philolithus*)		(10 plots)
10/28	2.1	1.3- 3.2*			

*Chi-square goodness-of-fit or variance test of the Poisson distribution were statistically significant.

confidence intervals (CI) are computed under the assumption that the counts along a given row follow a Poisson distribution, i.e., are randomly distributed along the line. This assumption was tested using the chi-square goodness-of-fit test and/or the variance test of the homogeneity of the Poisson distribution (Snedecor and Cochran, 1967). Those days on which tests indicated that the counts did not follow the Poisson are indicated in the table. The CI's for these days are hence only rough approximations. As a means of further characterizing these data, the counts were pooled over the three lines on each day and expected counts obtained, assuming a negative binomial distribution (NBD) (Bliss and Fisher, 1953). These pooled data were found to be fit by the NBD for days, October 2, 14, and November 11, at the low elevation and for days, October 7, 14, 21, and 28, at the higher elevation. The pooled data for all other days were fitted better by the Poisson distribution.

The total living biomass of *Stenomorpha* and *Philolithus* on both fields was estimated by multiplying the highest density of beetles obtained on any one day by the average beetle weight. On the low elevation field, the greatest density of *Stenomorpha* occurred on October 14, 1968, when the three lines averaged 7.2 $\pm$ 1.2 (mean $\pm$ S.E.) beetles per m^2. The greatest density of *Philolithus,* 3.4 $\pm$ 0.6 beetles/m^2, also occurred on the same date. (Standard errors were computed under the assumption the counts follow the NBD.) The average weight of *Philolithus* in 1968 on the low altitude field was 118 mg with a standard error of 4.1 (n=151), as compared to 210 $\pm$ 4.1 mg (n=154) for *Stenomorpha.* Hence, the total living biomass of beetles in 1968 on the low elevation field was estimated at 20 $\pm$ 3 kg/ha at peak density.

TABLE 3. The percentage of *Philolithus* in total weekly pitfall catches compared with periodic quadrat counts in the cheatgrass community at 305 m altitude throughout the autumn of 1968.

Date of Pitfall Catches	% *Philolithus*	Date of Quadrat Counts	% *Philolithus*
9/30	70.2	10/2	24.7
10/7	69.1	10/14	30.6
10/14	59.8	10/21	27.5
10/21	60.5	10/28	24.2
10/28	56.9	11/4	24.7
11/4	40.0	11/18	19.4
11/11	20.9		
11/18	10.5		

As a guide to whether the average density of *Stenomorpha* was different at the two elevations, the data were pooled over all harvest days at each elevation, and a test of significance applied to the transformed counts log $(x + 1)$. This test was highly significant ($p < .01$) and suggested greater density at the lower elevation.

An estimate of the mean weight of *Stenomorpha* at the high elevation field was not obtained in 1968. However, such data were obtained in 1969 when *Stenomorpha* averaged 254 $\pm$ 4.4 mg (n=196). Using these data in conjunction with the mean density of *Stenomorpha* obtained during 1968 at the high elevation (3.6 $\pm$ 0.7 beetles), the estimate of *Stenomorpha* biomass is 9.1 $\pm$ 1.8 kg/ha. The mean weight of *Stenomorpha* on the low field during 1969 was 226 $\pm$ 4.9 mg (n=103). The difference (28 mg) in mean weight at the two elevations is statistically significant. These data suggest that the total beetle biomass in 1968 was greater on the lower than on the upper field.

Although density counts obtained by visually scanning square meter quadrats were not made as frequently in 1969 as in the previous year (3 days at each elevation), they indicated that beetles were not as numerous as they had been in 1968. This agrees with the pitfall data. The greatest density of beetles occurred on October 22 and averaged 1.0/m^2 in the low elevation field. Maximum density observed on the high elevation field was only 0.4/m^2 on October 23. We calculated approximately 2.6 kg/ha of beetle biomass present on the low field and approximately 1.0 kg/ha on the high field. Goodness-of-fit tests of the Poisson or NBD were not computed because too few beetles were present. For the same reason, reliable estimates of the variance of biomass could not be obtained.

Percentage composition of *Philolithus* is somewhat different, depending on whether pitfall or quadrat data are used (Table 3). About 70 percent of the pitfall catch is made up of *Philolithus* in late September, and this figure reduces to only 10 percent by mid-November. However, *Philolithus* comprises between 19 and 30 percent of the total quadrat count throughout the autumn. Under the assumption that direct counts yield a more accurate estimate of percentage composition than pitfall data, these data suggest that *Philolithus* is more mobile than *Stenomorpha,* especially in early autumn. The data also suggest that the mobility of *Stenomorpha* is less strongly affected by the onset of cold autumn temperatures.

Most of the life span of both species of beetles is spent below ground, as larvae (Brown, 1971). Thus, soil conditions associated with the high elevation field might make it unsuitable for propagation of *Philolithus.* Comparative data on some chemical properties of the soil from both fields are presented in Table 4. These data show no

TABLE 4. Soil properties in cheatgrass communities at two altitudes. The values for phosphorus, potassium, calcium, and magnesium are expressed as pounds per acre for a 6 inch layer of soil.

Soil Properties	Altitude 305 m	518 m
pH	**7.1 ± 0.06	6.7 ± 0.08
Nitrogen %	*0.096 ± 0.007	0.073 ± 0.004
Organic Matter %	**2.1 ± 0.03	1.6 ± 0.05
Phosphorus	31 ± 3.9	34 ± 1.4
Potassium	1404 ± 99	1082 ± 47
Calcium	**3180 ± 146	2600 ± 78
Magnesium	638 ± 32	682 ± 12

*Significantly different from the 518 m altitude at α=.05 level.
**Significant at α=.01 level.

pronounced differences in soil chemistry, although some differences in organic matter, nitrogen content, and pH are statistically significant.

Vegetation of both fields was dominated by cheatgrass, although there were strong differences in stem densities and amount of mulch. The high field had more mulch and a more dense stand of stems (Table 5). Hence, differences in vegetation may be responsible for the scarcity of *Philolithus* on the high elevation field, although no direct cause and effect relationships are known at this time. Rickard and Haverfield (1965) found *Philolithus* and *Stenomorpha* to be abundant in sagebrush vegetation that supported very little cheatgrass. Abundance of these beetles in cheatgrass swards is evidence that beetles find food there suitable for propagation.

The large-sized, conspicuous, tenebrionid beetles inhabiting the relatively sparse vegetation of desert and grassland regions of the western United States are more amenable to direct counting than other kinds of insects that are smaller, more wary, and highly mobile. Data obtained in this investigation show that darkling beetles can provide relatively high biomass values at least during certain years. The estimated peak beetle biomass of 20 kg/ha is about ten times greater than maximum values obtained for a jack rabbit population over a period of years in shrub-steppe vegetation of northern Utah (Gross, 1967).

TABLE 5. Average peak of live biomass and density of important plant taxa in cheatgrass communities at different elevations, 1969.

Plant Taxa	Altitude 305 m	Altitude 518 m
	(n=9)	(n=10)
Bromus tectorum	14.0 ± 1.76	15.1 ± 1.67
Sisymbrium altissimum	14.4 ± 1.87	0
Descurainea pinnata	1.3 ± 0.9	0
Erodium cicutarium	0.5 ± 0.4	0
Microseris lanciniata	0	.3 ± 0.2
Tragopogon dubius	0	4.6 ± 1.2
Miscellaneous forbs	0	.8 ± 0.2
Live biomass g/ft^2	30.1 ± 1.8	20.9 ± 1.4
Litter g/ft^2	21.0 ± 1.5	51.1 ± 9.1
	(n=8)	(n=10)
Bromus tectorum	147 ± 32.0	420 ± 59
Sisymbrium altissimum	91 ± 12.5	0
Descurainea pinnata	13 ± 8.9	0
Erodium cicutarium	6 ± 5.2	0
Microseris lanciniata	0	0.4 ± 0.3
Tragopogon dubius	0	2.8 ± 0.7
Number of plants/ft^2	257 ± 32	423 ± 53

± = Standard error of mean.

Darkling beetles are not generally regarded as an economic resource of rangelands, but they do play ecological roles. The larvae probably feed mostly on plant parts below ground. Probably, there is as much dry matter produced annually below ground from roots as above ground from shoots. Plant parts below ground are not exploited by most kinds of rangeland herbivores, i.e., livestock and rabbits. If beetles damage living roots, then they could have a detrimental effect on production above ground. If beetle larvae eat mostly dead plant material, then they could play a beneficial role in the release of plant nutrients from dead plant material to the soils.

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Literature Cited

Bliss, C. I., and R. A. Fisher. 1953. Fitting the negative binomial distribution to biological data. Biometrics 9:176-196.

Brown, K. W. 1971. Redefinition of the genera *Pelecyphorus* and *Philolithus* with a key to the genera of the tribe Asidini (Coleoptera: Tenebrionidae). The Coleopterists Bulletin 25(1):17-30.

Daubenmire, R. 1970. Steppe vegetation of Washington. Wash. Agric. Expt. Sta. Techn. Bull. 62. 131 p.

Gross, J. E. 1967. Demographic analysis of a northern Utah blacktailed jack rabbit population. Ph.D. Thesis. Utah State University, Logan, Utah. 127 p.

Rickard, W. H., and L. E. Haverfield. 1965. A pitfall trapping survey of darkling beetles in desert steppe vegetation. Ecology 46(6):873-878.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical Methods. Sixth Ed. Iowa State Univ. Press, Ames, Iowa. 593 p.

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