Ground Beetles in Three Western Washington Prairies and Associated Oak Forests

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Abstract: Ground beetle (Coleoptera: Carabidae) diversity, distribution and activity density were investigated from April, 2005 to April, 2006 at three prairies in Thurston County, Washington: Glacial Heritage, Mima Mounds, and Scatter Creek. I collected ground beetles in pitfall traps from six prairie transects and two oak forest transects. I collected a total of 12,464 beetles representing 24 species. Species composition varied among the three different sites. Large numbers of an introduced species, *Calathus fuscipes* (Goeze), were found in the prairie habitats, comprising 1% to 82% of the carabids in each prairie. Activity-density peaked from August through October in the prairies and July through September in the forests. Some beetle activity occurred throughout the winter.

Introduction

The Puget Sound basin in the State of Washington was excavated by glaciers 18,000 years ago. The receding glaciers left large outwash plains of gravelly deposits. The drier and warmer climate following the glacial retreat resulted in treeless areas, colonized by unique prairie plants and interspersed with oak forests. Thousands of years later, indigenous people burned these prairies in part to encourage the growth of camas (*Camassia quamash*) which has an edible tuber (Storm, 2004). In 1850, about 250,000 acres of these prairies existed; today due to farming, grazing, road building, introduction of non-native species, and development, only three percent remain in a relatively intact condition. These prairie remnants tend to be the stony glacial outwash unsuitable to tillage. The plant composition in these prairies is rapidly changing due to colonization by foreign invasive plant species and Douglas fir (*Pseudotsuga menziesii*). The three prairies studied are aggressively managed for control of Douglas fir, Scotch broom (*Cytisus scoparius*), and tall oatgrass (*Arrhenatherum elatius*).

Knowledge of the invertebrate fauna of these prairies is limited mostly to the Lepidoptera. Baseline information on easily captured invertebrates such as ground beetles (Coleoptera: Carabidae) can provide managers with another tool to assess prairie health. Ground beetles are considered good indicators of environmental health for agricultural regions, forests, open lands, and urbanizing areas (Holland, 2002; Niemela 2000; Rainio 2003; Ribera 2001).

My primary objective was to better understand ground beetle species composition and abundance in the prairies throughout the year. A secondary objective was to record carabid species composition and abundance in the oak forests.

Materials and Methods

In order to assess the Carabid fauna of western Washington prairie remnants, I chose three protected sites. All sites were in southern Thurston County, beginning about 10 miles south of the southernmost inlet of Puget Sound, at the southernmost outwash area of the glaciation: Glacial Heritage Park, a limited public access park owned by Thurston County and managed by their county parks department and by the Nature Conservancy; Mima Mounds, owned and managed by the Washington Department of Natural Resources; and Scatter Creek, owned and managed by the Washington Department of Wildlife. Each owner/manager had somewhat different management goals but a major unifying theme was controlling the invasive plants.

Site	Owner/Manager	Management History	Management Goals
Glacial Heritage	Thurston County Parks /The Nature Conservancy	A cattle ranch beginning with European settlement. Portions were lightly grazed. Untilled. County purchased it in 1989	Improve the quality of the native prairie recognizing non-native control is difficult. Limited public use.
Mima Mounds	Washington Department of Natural Resources	State owned since 1905. Heavily grazed by cattle until 1967. Untilled. Managed for prairie ecosystem enhancement since 1967.	Maintain and enhance prairie ecosystem. Mimic fire succession by fire and mowing. Promote & allow research & education. Public access trail.
Scatter Creek	Washington Department of Wildlife	Settled in 1860. Used as a dairy but the cows rarely grazed the transect area. Untilled. Acquired by the State Department of Game in 1964.	Preserve existing native plant community. Restore and protect state endangered species and rare plants. Multiple use: Dog training, bird hunting. Public access trail

Each site is similar in that the soil consists of glacial outwash cobble. Because of this, the transect study locations were never tilled. They were all grazed by cattle. Each site varies in past use and current management techniques and goals.

From April 7, 2005 through March 16, 2006, transects of pitfall traps were employed at the three prairies. Two transects of pitfall traps were also employed in the two Garry oak (*Quercus garryana*) stands, one at Scatter Creek and one at Glacial Heritage.

This method of insect sampling was chosen for three reasons. First, it is an easy and inexpensive method. Second, it is effective at capturing active, ground dwelling arthropods. Third, pitfall traps allows for comparisons between different sites. The pitfall traps employed caught larger carabids while small carabids may have been able to detect the rim in time to avoid capture (Halsall & Wratten 1988). The smaller carabids dwelling in the soil may not be as active on the surface or cover as much ground so as to encounter the traps.

The rate of capture in pitfalls traps is related to the degree of activity and also the population density, weather, and vegetative cover. The rate of capture can also be influenced through depletion of the population by trapping when the traps are first employed. The method of sampling, pitfall trapping, is not a true picture of the abundance and distribution of ground beetles. It is merely a convenient method to find beetles that fall into the traps. Beetles that have long legs and roam larger distances, feeding behavior, flora density that limits beetle movement, and weather all have an influence on the species and capture rate in the pitfall traps. (Halsal 1988). Therefore, the results (see Table 1) have to be considered relative to beetle mobility, flora density, and other considerations.

Transect were selected from sites exhibiting 1) the least disturbance and most characteristic native flora and 2) environmental heterogeneity, including topography and plant communities. These were determined through discussion with the land managers, visual inspection in March of 2005, and reference maps. There were nine transects: eight with ten pitfall traps 60 feet apart and one with 15 pitfall traps 60 feet apart. The number of traps was scaled back from fifteen (the first transect employed) to ten due to limited time and resources. A handheld Global Positioning System (GPS) unit was used to pinpoint each transect (Attachment A).

Each pitfall trap consisted of two 12 ounce plastic cups, one nested within the other. These were buried in the ground up to and level with the rim of the internal cup. This design made removal of the internal cup easier, without disturbing the soil held in place by the bottom cup when acquiring samples. Each trap was partially filled with fifty percent propylene glycol and fifty percent water to prevent specimen decay. Ethylene glycol was not used because it is fatal to vertebrates which may be attracted to drink it. Two or three drops of liquid soap per trap were added to reduce surface tension. Eight by eight-inch pieces of plastic laminate were placed over each trap to prevent rainwater from entering. A twig was placed over the top of each cup and under the covering to provide space for the insects to enter the traps.

The sampling period began with the placement of the traps on April 7, 2005 and ended with the removal of the traps on March 16, 2005. Samples were taken roughly to every two weeks from April 24, 2005 to July 16, 2005. Limits on my time forced me to reduce the sampling frequency to approximately monthly from July 16, 2005 through March 16, 2006. Three transects were employed at each site from April 24, 2005 through October 19, 2005. Also due to time constraints, on October 19, 2005 two transects were removed from each site leaving only one prairie transect for each of the three sites for the remainder of the study until March 16, 2006.

Some predation of traps by coyotes and foxes occurred at all transects. No more than two cup-traps were dug up from any site during sampling trips except at Mima Mounds in September when nine of ten traps in transect 2 were excavated and eight of ten in transect 3. This data was still included with an explanation in the discussion section of this paper.

Beetles trapped were placed, in the field, into separate labeled containers for each trap. Each container was labeled for trap number and transect. Bycatch of mostly Silphidae (burying beetles), Staphylinidae (rove beetles), and in the fall, Gryllidae (crickets) were discarded in the field. In the lab, those carabids easily identified were separated by species into 95% ethyl alcohol. Those specimens that were more taxonomically challenging were later pinned and identified to species, using the keys found in Lindroth

(1961-1969) with occasional use of several other keys (see literature cited). A few specimens were identified by J. R. LaBonte.

There were a total of 22,935 trap days which consisted of 18,060 trap days in the prairies and 4,875 trap days in the oak forests.

<u>Results</u>

A. Transects and Activity-Density

The catch results for prairie and oak forest are reported in Table 1, in order of the number of total individuals per species trapped. Twenty four species of carabid beetles were caught in pitfall traps: 22 in the prairies and 14 in the oak forests. Breeding season is included, though imperfectly known, in Table 1 as a general indication of activity though there can be considerable overlap in the time of year that these beetles breed.

This said, *Pterostichus algidus* was encountered in all five sites (three prairie and two oak forests). This was the most consistently abundant species at most times of the year at most sites, prairies and the forests.

Species that were active in the prairies from January to mid-March, from greatest abundance to least: *Pterostichus algidus*, *Calathus fuscipes*, *Carabus nemoralis* and *Nippononebria virescens*.

TABLE 1

Number of specimens trapped at each of the five transects

Species name	Breeding season	Scatter Creek Prairie	Glacial Heritage prairie	Mima Mounds prairie	Scatter Creek oak	Glacial Heritage oak	Total
Pterostichus algidus (Leconte)	Fall	2963	182	848	696	1979	6668
**Calathus fuscipes (Goeze)*	Fall	331	2061	312	1	0	2705
Omus audouini	Spring	0	0	1487	0	6	1493
Carabus taedatus (Fabricius)	Spring	16	111	130	3	300	560
Poecilus lucublandus (Say)	Spring	2	0	440	0	0	442
**Carabus nemoralis (Müller)*	Spring	29	28	86	7	5	155
Harpalus cautus (Dejean)	Fall	4	83	45	0	0	132
Scaphinotus marginatus (Fischer)	Fall	0	0	0	0	108	108
Omus dejeani (Reiche)	Spring	0	0	39	0	0	39
Amara littoralis (Mannerheim)	Spring	0	22	2	0	2	26
Harpalus cordifer (Notman)	Fall	4	0	0	21	0	25
**Pterostichus melanarius(Illiger)*	Fall	5	0	2	11	4	22
Zacotus matthewsii (Leconte)	Fall	0	0	1	15	6	22
Harpalus laticeps (Leconte)	Spring	0	20	0	0	0	20
Amara latior (Kirby)	Fall	0	7	7	0	1	15
Amara conflata (Leconte)	?	1	0	1	9	2	13
Cychrus tuberculatus(Harris)	Fall	0	0	0	4	0	4
Harpalus somnulentus (Dejean)	mostly Fall	0	0	4	0	0	4
Calathus ruficollis (Dejean)	Spring	0	3	0	0	0	3
Amara idahoana(Casey)	?	0	1	0	1	0	2
Pterostichus crenicollis (Leconte)	Fall	2	0	0	0	0	2
Anisodactylus similis (Leconte)	Spring	0	1	1	0	0	2
Agonum piceolum (Leconte)	Spring	0	0	1	0	0	1
Nipponebria virescens(Horn)	Spring	0	1	0	0	0	1
Total individuals		**3357**	**2520**	**3406**	**768**	**2413**	**12464**
Number of Species		**10**	**12**	**16**	**10**	**10**	**24**

* = introduced

B. Phenology

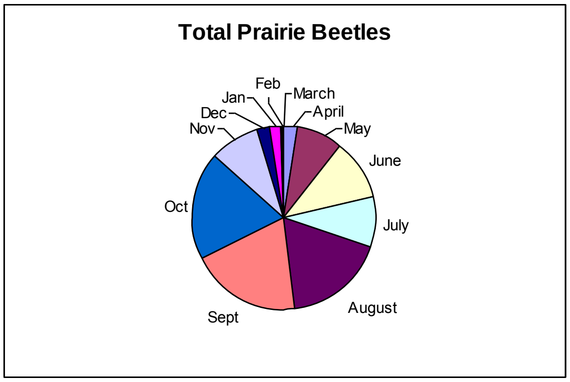

Figure 1: Total prairie beetles per month

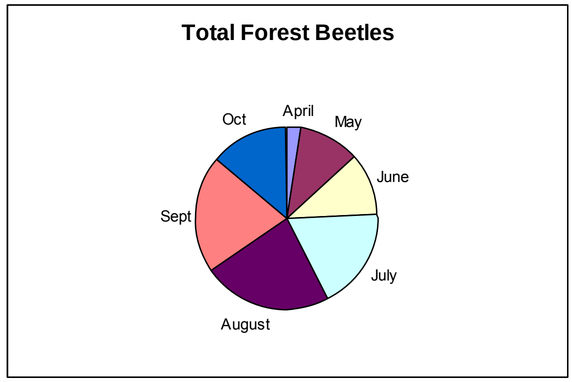

Figure 2: Total forest beetles per month

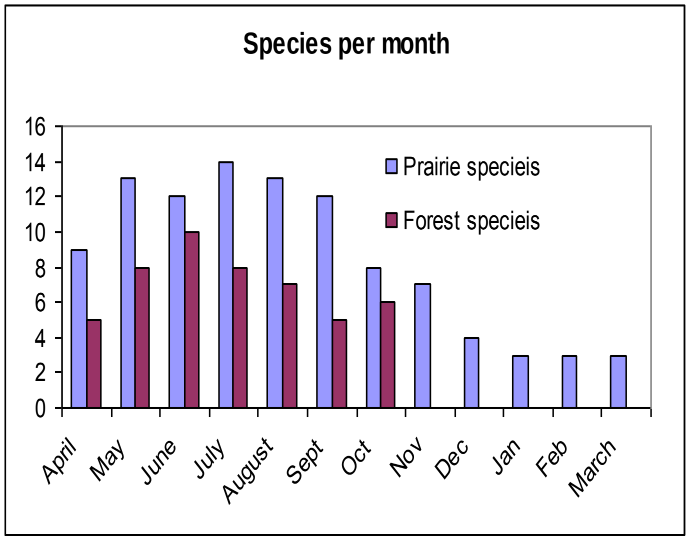

Figure 3: Prairie and forest species per month

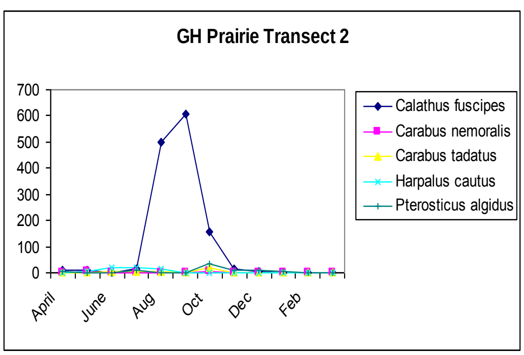

Figure 4: Glacial Heritage prairie. Individuals per species per month

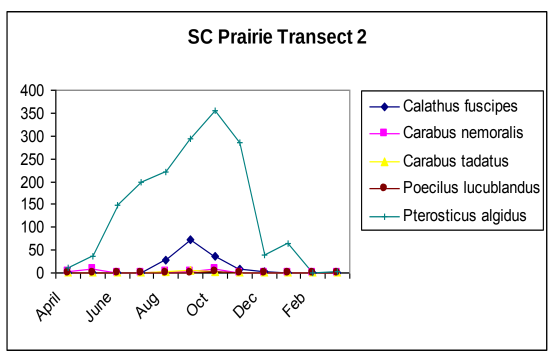

Figure 5: Scatter Creek prairie. Individuals per species per month

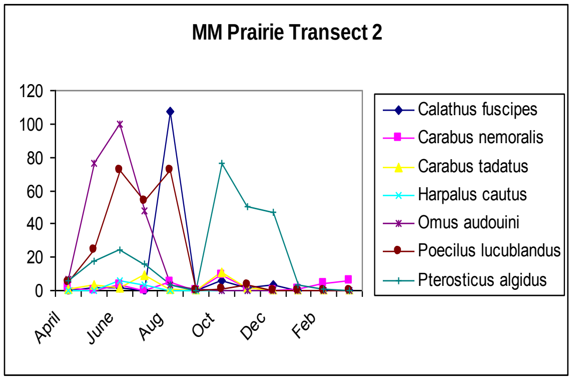

Figure 6: Mima Mounds prairie.
Individuals per species per month

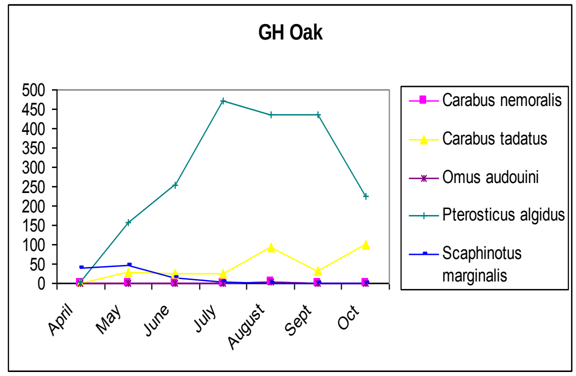

Figure 7: Glacial Heritage oak.
Individuals per species per month

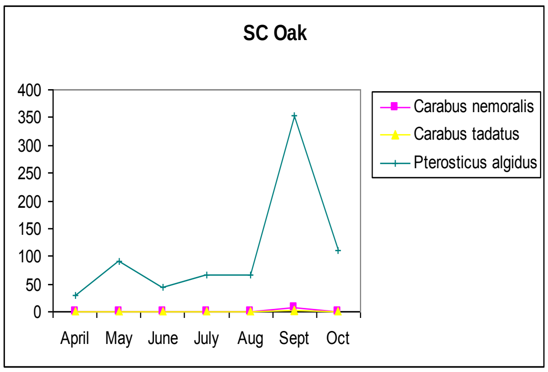

Figure 8: Scatter Creek oak.
Individuals per species per month

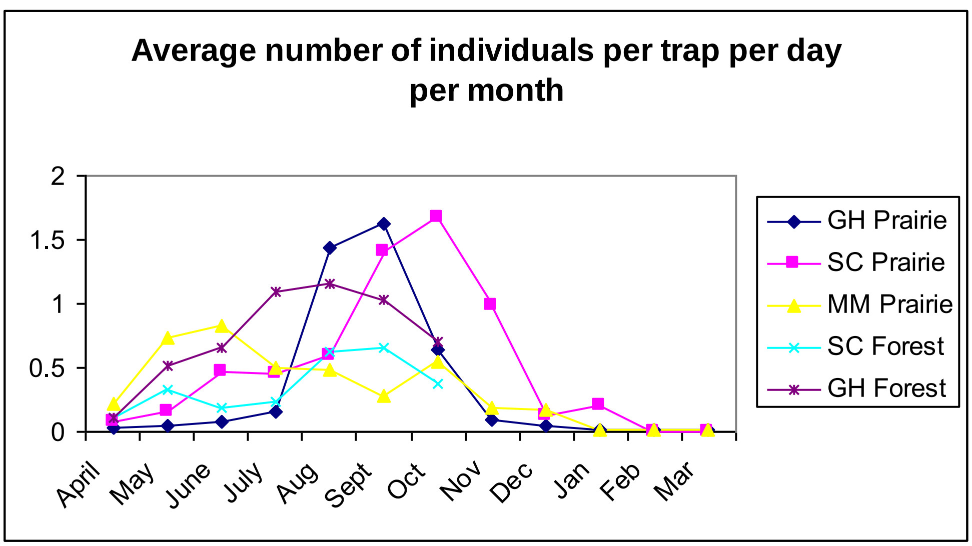

Figure 9: Average number of individuals per trap day per month

TABLE 2 Several species were collected via means other than pitfall traps. These were excluded from the data analysis. However, this information is provided in this report because it may be of interest to land managers, especially as two species are introduced.			
Species	**Site**	**Habitat**	**Date**
Cicindela purpurea hatchi (Lefffler)	Scatter Creek	Moist trail	4/24/2005
Lebia sp	Glacial Heritage	Moist cobble	5/06/2005
**Elaphropus parvulus* (Dejean)	Glacial Heritage	Moist cobble	5/06/2005
**Trechus obtusus* (Erichson)	Glacial Heritage	Moist cobble	5/06/2005

Discussion

The species of carabids encountered during this study were common and expected in the prairies and oak forests. No endangered or threatened or even uncommon species were encountered. Species diversity was greatest in the prairies. Introduced species were found in both types of habitat, though they were only a numerically significant component in the prairie sites.

Pterostichus algidus was encountered in all five sites (three prairie and two oak forests). This was the most consistently abundant species at most times of the year at most sites, prairies and the forests.

Species that were active in the prairies from January to mid-March, from greatest abundance to least: *Pterostichus algidus*, *Calathus fuscipes*, *Carabus nemoralis* and *Nippononebria virescens*.

Using species accumulation curves, it appears that if the pitfall trapping was continued, additional species would continue to be encountered. The last new species encountered was *Nipponebria virescens* in February, toward the end of the study. In addition, smaller species and those that live primarily on plants or in the ground are most certainly present and could be collected by other methods.

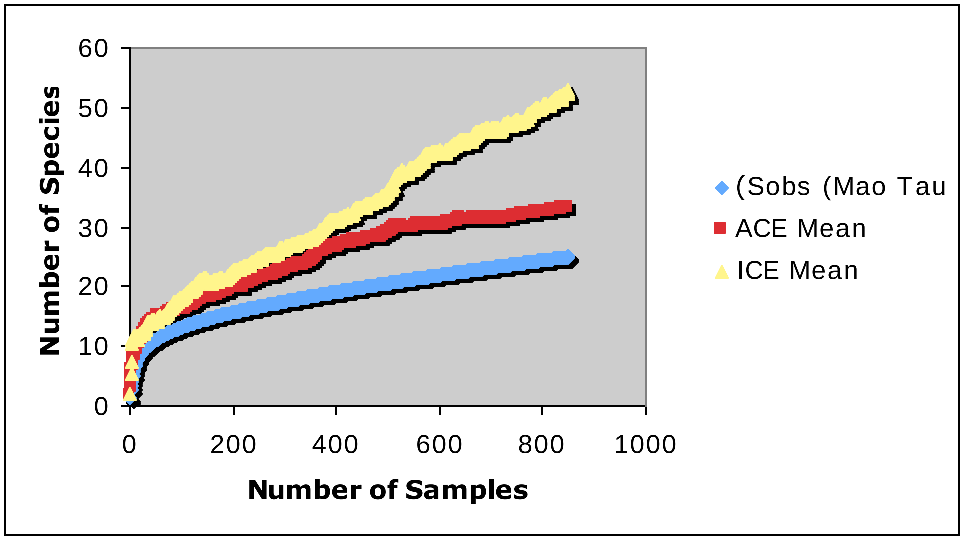

Figure 10. Species Accumulation Curve.

The Mima Mounds Prairie contained the highest diversity of species. This prairie also had the most species-diverse vegetation. The vegetation was neither as dense as Scatter Creek nor as sparse as the Glacial Heritage sites.

The graph (Figure 6) of the peak activity in the Mima Mounds prairie of the four most abundant beetles, *Pterostichus algidus*, *Omus audouini*, *Calathus fuscipes* and *Poecilus lucublandus* (see figure 6) provides some interesting comparisons. The activity of *C. fuscipes* and *Po.. lucublandus* peaked in late August while these species were almost completely absent in October. This, combined with the smaller peak of activity of *P. algidus* in June and the larger peak in October suggests the possibility of seasonal displacement among these species. However, heavy trap predation in September makes the data look as if the population of *Po. lucublandus*, *P. algidus* and *C. fuscipes* crashed, when it is more likely that *Pt. Algidus* populations experienced and slow rise and those *Pt. lucublandus* and *C. fuscipes* experienced a more gradual decline.

Calathus fuscipes, an introduced species, was first found in the Pacific Northwest in Vancouver, B.C. in 1928 (Hatch). The 1953 range of this beetle may still be expanding. For instance, while this species is widespread in western Washington, it is only known from a single site in Oregon (Westcott et al. 2006). Competition between it and *Pt. algidus*, *Po. lucublandus* and other carabid species may be occurring. This is only one of many possibilities however, since many other factors including available moisture, moisture preferences of the beetles; temperature patterns and preferences; food preferences and availability; predation by shrews, birds, bats, spiders, and other creatures; parasites and disease; competition with other invertebrates like ants; and life cycle timing all affect abundance at each time of year (Thiele, 1977). All of these four species of ground beetles are opportunistic feeders, eating such small macroinvertebrates as aphids, ants, and insect larvae. Three of the four species are also approximately the same size while *Omus audouini* is larger. The population of *O. audouini* peaks earlier in the summer. This beetle may feed on larger prey and respond differently than the other two smaller species to many environmental factors, especially moisture.

The Mima Mounds contained virtually the entire catch of the third most abundant beetle caught in all three prairies: *Omus audouini*. Most of these beetles were trapped in the northern transect near the public access area provided by Department of Natural Resources. The northern Mima Mound transect also provided all the catches of *O. dejeani*. Both of these species of Omus are known to dwell in both forests and prairies (Pearson, et al. 2006). This north transect is sited 500 yards from a mature second growth forest that might provide alternative habitat or overwintering habitat. Portions of this northern prairie were cleared of Douglas fir during prairie restoration efforts. The present flora of this area could still exhibit some of the character of forest undergrowth. Both species, but especially *O. dejeani* were found in greater abundance in the traps set in or near Kinnikinnick (*Arctostaphylos uva-ursi*). This plant was more abundant in the northern Mima Mound transect than in the two southern Mima Mound transects.

Poecilus lucublandus was found almost entirely (99.5%) in the Mima Mounds. Most of these beetles were caught in four traps located on the easternmost end of transect 2. The characteristics of the flora in this portion of the transect were indistinguishable from the characteristics of the plants in the other portions of both transects 2 and transect three. The mounds were similar in this part of transect 2 as was the compact nature of the cobble soil. Further investigation into the reason for the abundance of *P. lucublandus* in this area might reveal a larger population to the east although this would not explain why the population density did not continue further westward.

Calathus fuscipes had a short season of activity during August. Before and after August, this beetle was barely present in the catches at the Mima Mounds prairie. However, the steep decline in abundance for transect 2 in September as shown in Figure 6 is likely misleading due to the heavy trap predation that month. A slower decline in activity during September is more likely. Compared to catches at Glacial Heritage site which had a three-month season for *C. fuscipes*, the activity of the Mima Mounds population was significantly shorter. This could be a result of many environmental and biotic factors including competition at the Mima Mounds in October between P. algidus and *C. fuscipes.*

One forest species, *Zacotus matthewsii*, was found in the prairie at Mima Mounds, transect 1. It likely strayed from the nearby forest especially since only one specimen was caught. However, it is possible that, since prairie restoration efforts include the removal of Douglas fir in this area, that some of the forest fauna and flora characteristics remain conducive to this species.

The Glacial Heritage prairie contained fewer specimens through most of the year in comparison with the other prairie sites. The vegetation in these transects was sparser and the soils rockier and more compact. The site was the first to dry out. More diversity and abundance of the Harpalus and Amara genera occurred. These are beetles that are known to tolerate and inhabit fairly dry habitats (Lindroth. 1968). Traps here also caught the only *Calathus ruficollis*, *Nipponebria virescens*, and *Harpalus laticeps* and all but two of the *Amara littoralis*.

During August, September, and October, large numbers of *C. fuscipes* were trapped. This represented 76% of the *C. fuscipes trapped* in all three prairies. Several traps contained over one hundred specimens each. This spike in numbers coincided with the appearance and disappearance of a population of crickets though a direct relationship between the two insects is purely speculative. As figure 4 illustrates, *C. fuscipes* was by far, the dominant ground beetle represented in the catches at this site. This species represented 82% of the beetles caught. This beetle almost certainly does not face competition with other carabids at this site at this time of year. *Calathus fuscipes* adults may take advantage of at least one abundant food source present during the months of August, September and October and/or the larva does during its development in the preceding months. Further trapping over successive seasons could reveal whether the population of this introduced species has stabilized or is still adapting to a new niche.

The Scatter Creek prairie transects contained the highest and most dense vegetation. It included balsamroot (*Balsamorhiza sagittata*), not found on any of the other prairie study areas. Carabid species abundance and diversity here were significantly less than the other two study sites. The density of the vegetation may limit the available habitat and movement of ground-dwelling beetles. Recent management cycles such as mowing may have influenced the diversity of beetles encountered so in other years, during different periods of the management cycle, more or different species may have been caught.

Almost three thousand *Pterostichus algidus* were encountered. These beetles were the only ones trapped in May, but in low numbers. The numbers peaked in October and large numbers were still trapped in November. The only other carabid to be trapped in significant numbers was *C. fuscipes* in September, about one third as many as *P. algidus* at this time. The two species' peaked about the same time, in September. Many environmental and biotic factors may contribute to the dual peaks during this month including food availability, temperature and moisture, and life cycles. Both these species may be using the same or different food sources. Numbers of beetles trapped could reflect either a scarcity or abundance of food. Food scarcity contributing to higher catches seems plausible considering the beetles would have to search more for food, and travel further to find food; the more a beetle roams, the more chance it has of falling into a trap.

Oak forest Carabids activity peaked in September, 2005, before the prairies where activity peaked in October. Some of this is due to the abundance of *C. fuscipes* at Glacial Heritage prairie in October and steep declines in the abundance of *Pt. algidus* in the forests from September to October. Other factors which may have contributed to the earlier decline in activity were the types of other species using the prairies, the availability of different habitat niches and food availability throughout the seasons, the climate regime in 2005, including soil moisture. Both forests and prairies became successively drier from the start of the trapping in April, 2005 until the end of October when rains began. The forest litter contained more moisture than the prairies. Forest species are generally more moisture dependent than those encountered in the prairies (Thiele, 1977).

The lower species diversity in the oak forest at Scatter Creek follows the same pattern as was seen in the Scatter Creek prairie which contained fewer species in comparison with the other prairie sites. This forest was isolated from other forests by surrounding prairie. Past management of this oak forest is unknown; it could have been prairie earlier in the twentieth century, used for grazing dairy cows. The Glacial heritage site contained significant numbers of *Carabus taedatus* and, early in the season, *Scaphinotus marginatus*. The Glacial Heritage oak forest was also next to the Black River. Closer to the river, the oaks gave way to some coniferous evergreens (*Thuja plicata*, *Pseudotsuga menziesii*, and *Tsuga heterophylla*); cottonwoods (*Populus balsamifera*), and then to willows (*Salilx* spp.) and Oregon ash (*Fraxinus latifolia*). This more varied habitat likely contributed to a greater diversity of ground beetles at the site.

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Digital maps of native grasslands were provided by the Washington Department of Natural Resources

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Appendix A

Glacial Heritage	**Trap number**	**Lat/long**
Transect #1 Oak Forest	Trap #1	N46° 52,151' W123° 02.000'
	Trap #15	N46° 52.384' W123° 1.883'
Transect #2	Trap #1	N46° 52.239' W123° 02.997'
	Trap #10	
Transect #3	Trap #1	N46° 52.179' W123° 03.071'
	Trap #10	
Mima Mounds		
Transect #1	Trap #1	N46° 54.275' W123° 03.015'
	Trap #10	N46° 54.408' W123° 03.112'
Transect #2	Trap #1	N46° 53.323' W123° 03.061'
	Trap #10	N46° 53.389' W123° 02.873'
Transect #3	Trap #1	N46° 53.289' W123° 02.917'
	Trap #10	N46° 53.415' W123° 03.016'
Scatter Creek		
Transect #1 Oak Forest	Trap #1	N46° 49.570' W123° 01.192'
	Trap #10	N46° 49.604' W123° 01.043'
Transect #2	Trap #1	N46° 49.530' W123° 01.464'
	Trap #10	N46° 49.421' W123° 01.591'
Transect #3	Trap #1	N46° 49.557' W123° 01.554'
	Trap #10	N46° 49.411' W123° 01.497'