Long Term Monitoring and Habitat Assessment of Henderson's Needlegrass Populations

Final Report
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Introduction

This project was designed to establish permanent plots in which to monitor population dynamics of a rare plant species, *Achnatherum hendersonii*. There is growing concern that Henderson's needlegrass populations are declining as a result of habitat deterioration and the rapid spread of non-native invasive annual grasses, ventenata (*Ventenata dubia*) and medusahead (*Taeniatherum caput-medusae*). Baseline data on population demography and habitat condition was collected for 10 populations of *Achnatherum hendersoni* on the Ochoco National Forest. In addition, a Bayesian risk assessment model is being developed by the Western Wildland Environmental Threat Assessment Center (WWETAC) and staff at Western Washington University to predict the risk of extirpation of Henderson's needlegrass populations using a variety of factors including the potential for competitive exclusion by non-native invasive annual grasses, habitat condition, and past and current management activities. This project produced baseline population data and habitat condition for the rare Henderson's needlegrass from which to monitor changes in the future as well as to produce a risk assessment model that will help predict which factors are most likely causing population declines.

Background

Henderson's needlegrass is a regional endemic with populations in both Washington and Oregon. There are 49 known populations in Oregon, 48 of which occur on federal land, with 33 sites occurring on the Ochoco National Forest, and 15 sites documented on the Prineville BLM district. Selected populations were revisited in 2006 and 15 of the 17 sites showed decreases in population size since the last census in the early 1990's. Five of these 15 populations went from no less than 150 individuals to zero in approximately ten years.

The first recommended conservation action item listed in the Conservation Assessment (Dewey 2013a) is to monitor selected Henderson's and Wallowa needlegrass sites to assess population trends and condition of habitat. Before this project was implemented in the summer of 2012, no population of Henderson's needlegrass in Oregon was being formally monitored, and many of the Henderson's needlegrass populations hadn't been visited in over a decade.

Based on information from the Conservation Assessments for both Henderson's and Wallowa needlegrass (Dewey 2013a; Dewey 2013b), the single greatest threat to the persistence of these species throughout their range is competition from non-native invasive plant species, such as ventenata and medusahead. Agency botanists have expressed great concern at the rate and extent of spread of these invasive species in scabland habitats, with medusahead present at two *Achnatherum* sites and ventenata found in several others. Other threats include grazing, timber and fuels management activities, and off-road vehicle use. This project provides the critical framework to generate standardized, long-term data on population trends, habitat conditions, and potential threats to species ranked "first priority" by ISSSSP.

Methods

Ten Henderson's needlegrass populations were selected and permanent 50m x 50m macro-plots were installed at each site. Transects were marked with rebar every 5 meters, running North to South for a total of ten 50-m transects for each macro-plot. PVC micro-plots ($1m^2$) were placed along these transects at meter intervals if any *Achnatherum hendersonii* was present and that location was permanently marked with a six inch painted nail. The number of meter square sub-plots was determined by the distribution of *Achnatherum hendersonii* in the macro-plot. Data collected in these m^2 micro-plots included: the number of genets of *Achnatherum hendersonii,* classified as a seedling (one to two leaf blades), a juvenile (anything more than two leaf blades and less than 2 cm in clump diameter and lacking reproductive structures), or an adult if larger than 2 cm in clump diameter. The diameter of each adult clump was recorded, along with the number of tillers and culms. The substrate in which seedlings were established was also recorded as either biocrust or bare soil. Additional parameters measured in each micro-plot included; % bare ground, % vegetative cover, number of non-native invasive plants, and % biocrust both on soil and on rock.

Habitat characteristics were recorded in separate micro-plots (20cm x 50cm), and sampled at meter 15 and 30 along each of the 10 transects (n=20). Data recorded in these plots included: % vegetative cover by life form (grass, forb, shrub, tree), gravel size (in), % bare ground, % bio crust, # of cow pies, and scat piles. Other data collected for each site included: elevation, aspect, percent slope and soil characteristics.

Soil was further characterized at each site and samples were analyzed at the soil lab at OSU. Soil pits were excavated to bedrock with a shovel, digging bar, and rock hammer. Standard USFS 2500-1 soil description forms were filled out for each pedon by Jim David, soil scientist on the Ochoco National Forest. Soil samples were collected for lab analysis from the surface A horizon and the lower Bt horizons. These samples were sent to the Central Analytical Laboratory at Oregon State University. Parameters tested include: pH, Bray Phosphorus, Potassium, Calcium, Magnesium, Boron, Copper, Manganese, Zinc, Iron, and Loss on Ignition of organic matter.

A risk assessment model is currently being constructed by WWETAC and Western Washington University with the plot data, distribution of non-native invasive weeds, soils, road distribution, type of disturbance and intensity, global climate change models and management activities to predict the rate of spread and the risk of extirpation of populations of *Achnatherum hendersonii*.

Results

Lithology

There were two distinct scabland types based on lithology. Six populations of *Achnatherum hendersonii* occurred on Picture Gorge Basalt scablands and four populations occurred on rhyolitic tuff scablands. Soils developed on tuffs are shallower and much lower in fertility than the basalt derived soils (see table 1). Soil pH differed between the two site types with the Basalt scablands averaging pH 6.42 and the tuff scablands averaging pH 6.21. Elevation also varied between sites, with the basalt scablands occurring on average at 4,729 feet above sea level and the rhyolitic tuff sites averaging 4,375 feet.

Habitat Characteristics

Habitat characteristics varied by site and are summarized in table 2. The plant association classification was the same for eight of the ten scabland sites, *Artemesia rigida*/ *Poa secunda* (SD9111) Scabland Shrub. The other two sites, 7 and 8, were classified as *Poa secunda/Elymus elymoides* (GB9111) Scabland Grass. Vegetation in all sites was sparse averaging 18% total plant cover. The most common plant species found on all sites include: *Poa secunda, Danthonia unispicata, Lewisia rediviva, Allium acuminatum, Trifolium macrocephalum, Sedum stenopetalum, Zigadenus venenosus, Lomatium hendersonii* and *Elymus elymoides.*

Scabland conditions ranged from being in relatively good condition for sites 5 and 6 to a much degraded condition in site 10. For example, sites 5 and 6 had no roads or ATV trails across them, no occurrence of *Ventenata dubia* on the surrounding scabland, very low occurrence of other non-native grasses, very few cow pies, and the highest percent cover of biocrust. Site 10 has a road built across the scab with one of the highest occurrences of *Ventenata dubia* in the permanent plots and the lowest percent cover of biocrust of all the sites.

Only three of the 10 sites did not have *Ventenata dubia* present in the permanent plot. Medusahead was found in plots at site 7, and was also present at site 8, but not found in any sub-plots. *Bromus squarrosus* was another common non-native invasive grass present in all but two sites.

Population demography

The total number of microplots (n) varied by site as did the total number of genets and the size class distribution of *Achnatherum hendersonii* (see table 3). Presence of ventenata varied from 0 at site 1, 5 and 6 to an average of 63 individuals at site 9. Absence of ventenata did not appear to correlate with lower total numbers of Henderson's needlegrass genets relative to the other 7 sites. However, sites 9 and 10 had the highest infestation of ventenata with an average of 30.5 and 27.8 stems per plot respectively, with the lowest seedling density of Henderson's needlegrass averaging 9 and 5 per plot respectively.

Variables thought to be important for seedling establishment for *Achnatherum hendersonii*, such as biocrust, varied from less than one percent cover on average for site 8 to 16.9% cover for site 5. Total number of *Achnatherum hendersonii* seedlings ranged from 5 in site 10 to 304 in site 3. Seedlings appeared to have slightly higher establishment in the biocrust (n=861) then on bare soil (n=723) all sites pooled. The juvenile class had the lowest density of all size classes for all sites with less than half the total number (n=656), than for seedlings (n=1584), or adults (n=1594).

Discussion

The most significant trend from this data appears to be the relatively low number of Henderson's needlegrass genets in the juvenile size class. The juvenile size class is less than half of the total seedling and adult size classes. Low juvenile numbers suggest that although seedlings are establishing (except for in site 10), they are not persisting into the next size class, so as older genets die off, fewer and fewer are being replaced. This trend may be responsible for the decline in the overall populations. There are several possible explanations for this trend. One may be that seedlings germinate on any substrate, but only the seedlings that establish on or near biocrust survive and grow to be reproductive adults. Biocrust formed by mosses and lichens, provide moisture longer in the season as well as contribute nitrogen to this nutrient-poor,

drought stressed environment. If biocrust cover has been reduced in these fragile habitats from historic levels that could explain the low numbers of juvenile size classes and the current population declines. Potential reductions in biocrust cover could be a result of cattle trampling, road construction and scraping for rock, OHV use and recreational activities all of which are evident on these sites. Monitoring changes in biocrust cover and establishment trends from seedling to juvenile size classes will help elucidate the role of biocrust in Henderson's needlegrass establishment. Another potential explanation is the invasion of non-native invasive annual grasses onto the scablands. These invasive winter annual grasses, *Ventenata dubia* in particular, have colonized these scablands potentially competing for limited resources of soil moisture and nutrients. Ventenata germinates in the fall, grows through the winter and reproduces early in the spring taking advantage of higher soil moisture content and nutrient availability before *Achnatherum hendersonii* begins its growth and reproductive cycle. There could also be competition for establishment between ventenata and Henderson's needlegrass because much of the scabland surface is rocky, seedlings must establish in the spaces between the gravels and rock, and fresh soil disturbance created by frost heaving and solar fluxion (Binney and Bradfield 2000). Since ventenata produces seed in the early spring it may occupy those interstitial establishment spaces before Henderson's needlegrass which sets seed in the fall. Climate change may also play a role in the decline of Henderson's needlegrass. As winter temperatures rise there could be less snow pack and frost heaving which Henderson's needlegrass is well adapted to (Maze 1981), favoring establishment and growth of winter annuals such as ventenata and medusahead. In addition warmer winters, longer dryer summers are also predicted in climate change models (Mote and Salathe Jr. 2010), which would result in even stronger drought stress during the growing season for Henderson's needlegrass and favoring winter annuals that are dormant in the summer.

The risk assessment model will help predict the viability of rare needlegrass populations as they are potentially affected by the invasion of non-native invasive winter annual grasses such as ventenata and medusa head, ATV or other motorized use, soil conditions, disturbance from livestock, management activities, and climate change.

This study established baseline data from which to compare demography and population dynamics in the years to come. Sub-plots should be resampled every 3-5 years to determine if *Achnatherum hendersonii* is suffering major population declines that may warrant its listing as a candidate species for protection.

References

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Table 1. Scabland soil characteristics averaged by lithology

Geology	Horizon Average	pH	Bray-P ppm	K ppm	Ca ppm	Mg ppm	B ppm	Cu ppm	Mn ppm	Zn ppm	Fe ppm	LOI %	Soil depth cm	Elev feet
Basalt	A	6.38	13.5	175	1653	368	0.63	5.1	17.8	3.7	30.3	7.12	14.8	4,729
	B	6.47	7.0	69	1660	407	0.35	3.5	7.4	0.13	11.0	2.7		
Tuffs	A	6.2	6.8	117	866	167	0.2	1.2	9.6	0.35	12.4	2.41	12.5	4,375
	B	6.23	6.25	138	1057	206	0.25	0.83	5.5	0.09	9.1	1.91		

Table 2. Habitat characteristics averaged for each site n=20; except cow pies=total/site 50X50m^2

Site	Rock Size (in)	Rock Cover %	Bare Soil %	bare ground %	Ventenata stems	Other Non-Native	% cover biocrust	total % plant cover	Road/ disturbance	cow pies total # in plot
1	1.9	54.7	9.0	63.7	0.0	5.7	12.8	9.6	Scraped road	29.0
2	2.7	79.3	7.7	87.0	0.1	7.7	10.8	11.1	Scraped road	18.0
3	2.9	60.7	7.5	68.2	5.4	4.0	9.5	21.1	none	13.0
4	1.8	65.5	4.3	69.8	1.9	3.7	8.7	13.4	Illegal road	6.0
5	1.1	40.0	7.2	47.2	0.0	1.1	35.1	21.5	none	4.0
6	6.1	62.7	6.2	68.9	0.0	3.7	26.5	20.3	none	1.0
7	0.5	75.0	4.3	79.3	6.6	0.0	12.0	11.0	none	23.0
8	0.6	85.5	2.8	88.3	12.9	0.4	4.3	12.1	road	22.0
9	0.7	43.3	6.1	49.4	30.6	2.2	31.0	42.8	none	20.0
10	4.3	66.6	6.5	73.1	27.8	0.0	2.3	21.5	road	26.0

Table 3. Population demography of Achnatherum hendersonii

Site	Seedlings Crust	Seedlings Rock	total seedlings	Juven-iles	Adults	Adult Dia (cm)	Adult Seed-heads	Adult Culms	total indv ACHE	% Cover	Ventenata dubia	Non-native brome	Medusa head	n= #plots
1	43	175	218	77	85	4.1	3.0	12.3	380.0	0.2	0.0	32.0		63.0
2	73	61	134	92	165	4.1	3.5	21.7	391.0	0.2	0.0	26.9		91.0
3	250	54	304	17	127	5.3	3.0	20.4	448.0	25.6	19.6	30.9		88.0
4	48	89	137	64	59	3.4	0.8	12.5	260.0	20.7	18.7	38.0		67.0
5	151	102	253	26	65	4.3	0.7	13.3	344.0	23.7	0.0	14.6		54.0
6	191	97	288	36	82	6.8	1.6	28.9	406.0	25.4	0.0	12.6		51.0
7	95	99	194	50	377	6.5	2.7	26.3	621.0	18.6	58.8	0.2	8.3	203.0
8	9	32	41	127	274	4.7	1.8	25.4	442.0	15.9	38.0	0.3		130.0
9	1	9	10	31	143	3.6	2.3	18.9	184.0	30.3	63.5	2.0		54.0
10	0	5	5	45	217	3.6	2.9	22.3	267.0	16.3	42.1	0.4		86.0

Figure 1. *Achnatherum hendersonii* and *A. wallowensis* locations on Ochoco National Forest and nearby.

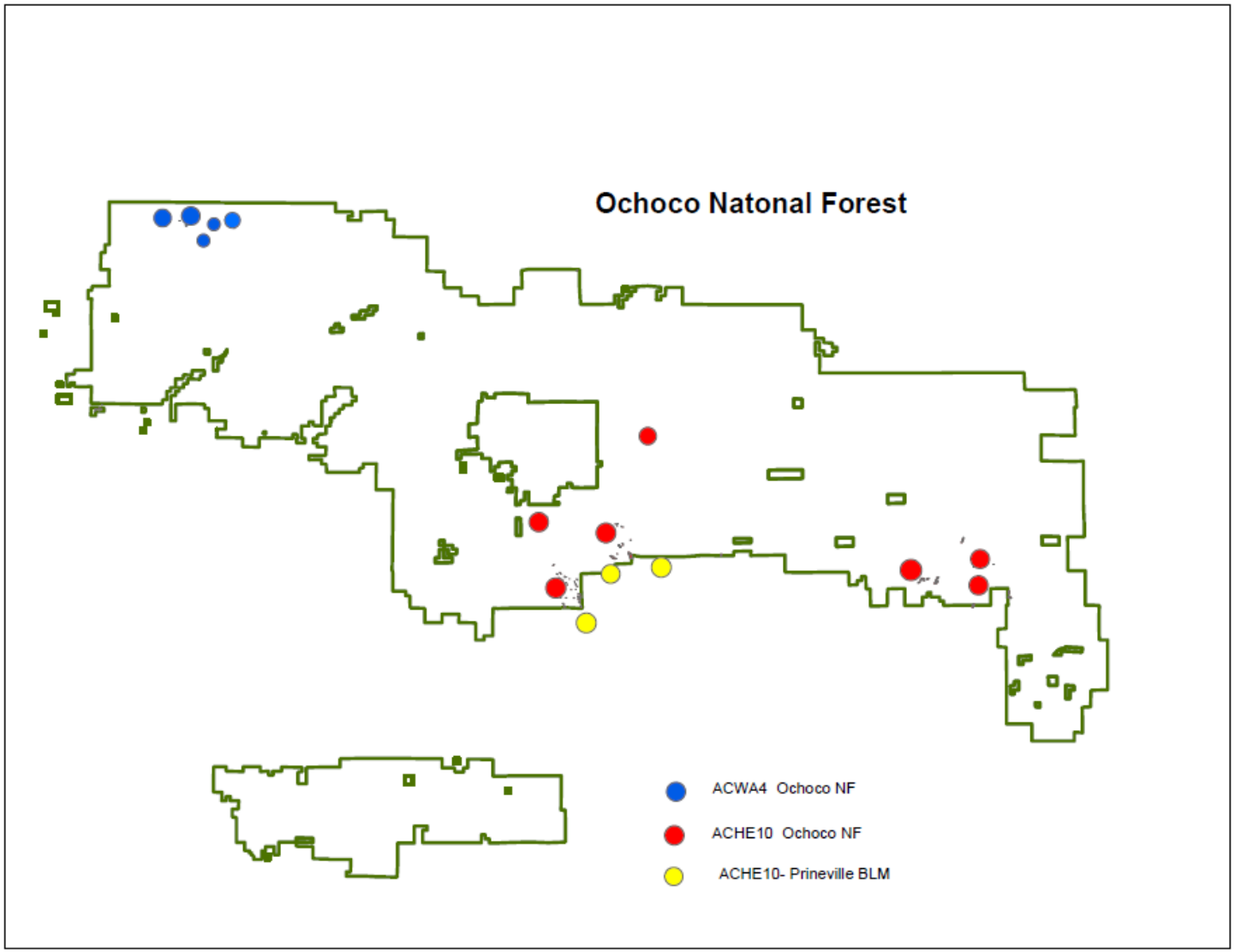


Figure 2. Monitoring *Achnatherum hendersonii* in scabland habitat.

Figure 3. Photo plot example.

Figure 4. Soil analysis in rare needlegrass habitat.

Figure 5. *Ventenata dubia* colonizing scablands.

Appenidix A

HENDERSON's RICEGRASS *(ACHNATHERUM HENDERSONII*) (species code ACHE10)

SOIL & SITE RELATIONSHIPS

Jim David, Forest Soil Scientist, Ochoco National Forest & Crooked River National Grasslands

PURPOSE: TO FURTHER SOILS KNOWLEDGE REGARDING THE ECOLOGY OF *ACHNATHERUM* SPECIES ON THE OCHOCO NATIONAL FOREST.

Henderson's ricegrass occurs on scablands on the old Big Summit District and the Paulina District roughly from Big Summit Prairie to the North Fork of the John Day River. It is most commonly found on stiff sage (*Artemisia rigida*) scablands (Plant Assoc Code SD9111) and on Sandberg bluegrass (*Poa secunda*) scablands. The geology of these sites is largely Picture Gorge Basalts and rhyolitic tuffs. The soils vary between these lithologies as a result of differential weathering characteristics and chemistry. Soil moisture varies from saturated in the late fall, winter and early spring to droughty in late spring, summer and early fall (xeric moisture regime). Soil temperature ranges from frozen in the late fall, winter and early spring to warm in the late spring, summer and early fall. (frigid temperature regime)

This study was designed to look at various Henderson's ricegrass populations across its range on the Ochoco National Forest. Specific soils data was collected to help understand the role of substrate in herbivory and plant persistence in these sensitive populations.

Methods:

Ten populations of Henderson's ricegrass were selected to be studied. Plots (50m X 50m) were set up on these sites. Population studies were conducted which include phenology and age. One soil pit per plot was excavated to characterize each site. Plant cover by species was estimated along with surface rock type and the presence or absence of cryptogamic crusting.

Six of the populations occurred on Picture Gorge basalt scablands and four occurred on rhyolitic tuff scablands.

Lithology	Elevation	Soil Depth	Soil Classification	Closest Soil Series Concept
Basalt	Average= 4,729 Range= 4,386 to 5,106	Ave= 14.8 cm Range= 11 to 18 cm	Lithic Argixerolls; loamy-skeletal, mixed, superactive, frigid	Canest Series
Rhyolitic Tuffs	Average= 4,375 Range= 4,200 to 4,500	Ave= 12.5 cm Range= 10 to 19 cm	Lithic Argixerolls; loamy-skeletal, mixed, superactive, frigid	Tweener Series

Soil pits were excavated to bedrock with a shovel, digging bar and rock hammer. Standard USFS 2500-1 Soil Description Forms were filled out for each pedon which included existing vegetation by percent crown cover by species. Pictures were taken of each pedon.

Samples were collected for lab analysis from the surface A horizon and the lower Bt horizons. These samples were sent to the Central Analytical Laboratory at Oregon State University Department of Crop Soil Science. Parameters sampled were lab pH, Bray Phosphorous, Potassium, Calcium, Magnesium, Boron, Copper, Manganese, Zinc, Iron and Loss on Ignition of Organic Matter. Known deficiencies in native soils in this area include sulphur, boron and zinc.

Below (on 11 x 17 inch format for printing) are the individual soil pedon data for the 10 ACHE10 sites followed by the soil chemistry results for each pedon.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
4240-1	A	0 to 4	7.5YR 4/4	7.5YR 2.5/3	CBV-ASHY SL 12% CLAY	2f-m Platy	SH(Slightly Hard)	SO/PO	GR: 30; CB: 50	2F-M	3F-M Ves	6.2	
	Bt1	4 to 11	7.5YR 4/4	7.5YR 2.5/3	CBX-ASHY SL 20% CLAY	2f-m Platy-> 2f SBK	SH(Slightly Hard)	SS/SP	GR: 20: CB: 40	2F-M	2F Irr	6	

Bed rock name: Dice Andesitic Basalt; Elevation: 4,683 Ft; Potential Vegetation ARRI, POSE; %Crown Cover Shrubs: ARRI 15, % Crown Cover Forbs: Lomatium 8, allium 5, epilobium 8; % Crown Cover Grasses: POSE 25, BRSQ 8, Vulpia 5. Notes: Scab appears scraped for road rock - No ACHE growing where scraped. Lots of scraped rock gone- bare surface. Ventenata in roadside ditches. Total cow pies in plotted area 29 and 2 elk.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
4230-1			Biocrust layer Rock Pavement Erosion										
	A	0 to 5	10YR 4/3	10YR 3/3	CBX-ASHY SL 14% CLAY	2n-F Platy	SH & Fr	SO/PO	GR:35; CB:60; ST:1	3vf-f 2m	3vf-f Ves	6.4	CW
	Bt1	5 to 10	10YR 4/4	10YR 3/4	CBX-ASHY SL 20% CLAY	2f- SBK Platy	SH & Fr	SS/SP	GR:20; CB:50	3vf-f 2m	2vf-f Irr	6.2	CW
	Bt2	10 to 17	10YR 4/4	10YR 3/3	CBX SCL 24% CLAY	3vf- SBK	SH & Fr	SS/SP	GR:20; CB:50	2vf-f	2vf-f Irr	6	CW

Parent Material: Ash/Loess over residual; Bed rock name: Basalt; Elevation: 5,081 Ft; Landform: Plateau; Slope: a.2-5%, b.Shape:CV, c.Length: 500+ft, d.Aspect: SW; Surface Stone & Rock: a. GR 35%, b. CB: 60%, c. ST: 1%; Potential natural Vegetation: ARRI/POSE/ACOC/DAUN %Crown Cover Trees: Juniper 1-3, %Crown Cover Shrub: ARRI 15-20, %Crown Cover Grasses: POSE 25, ACOC 5; Notes: Heavy grazing at bottom of scab. No noticeable roads or disturbance on scab plateau by humans. Lots of rodent/badger activity in plot see photo. Total cow pies 4 and 2 elk.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
4230-2	O		0 to 1 cm moss crust layer with fine litter										
	A1	1 to 4	10YR 4/3	10YR 3/3	CBX-ASHY SL 15% CLAY	2fm Platy	SH & Fr	SO/PO	GR:10; CB:70; ST:10	3vf-m	3vf-f Ves	6.4	
	Bt1	4 to 10	7.5YR 4/4	7.5YR 2.5/3	CBX-ASHY SL 18% CLAY	2f-m Platy	SH & Fr	SS/SP	GR:20; CB:60	2f-m	3f-m Ves	6.2	
	Bt2	10 to 18	7.5YR 4/4	7.5YR 2.5/3	CBX SCL 26% CLAY	2f-m SBK	SH & Fr	SS/P	GR:20; CB:60	2vf-f	2vf-m Irr	6	

Parent Material: Ash/Loess over residual; Bed rock name: Basalt; Elevation: 5,106 Ft; Landform: Plateau; Slope: a.5-8%, b.Shape:CV, c.Length: 500+ft, d.Aspect: SW; Surface Stone & Rock: a. GR 10%, b. CB: 70%, c. ST: 10%; Potential natural Vegetation: ARRI/POS/ALAC/DAUN %Crown Cover Shrubs: 15, %Crown Cover Forbs: Lomatium 8, LIAC 5, Zygademis 2, %Crown Cover Grasses: POSE 25, DAUN 10, BRSQ 15. Notes: Much larger rock 10-12 inches. Sloping/Rodent activity. No obvious roads/ATVs well developed biocrust. Thicker soil development in O horizon. Total Cow pies 1 and 4 elk.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
150-1		0 to 2		Rock Mulch Channery					CH: 95; FL:2; CH(Channery) FL(Flagstone)				AS
	A1	2 to 6	10YR 5/3	10YR 3/3	CNV-ASHY CO-SL 14% CLAY	2n-Med Platy	SH	FR	CH:35; FL:0	2vf-FM	3vf-co Ves	5.6	AS
	Bt	6 to 10	10YR 5/4	10YR 3/4	CNV-ASHY FINE SL 20% CLAY	1 Med Platy	SH	FR	CH:34; FL:2	1vf-Med	2vf-f Irr	5.8	AW
	R	10+											

Bed rock name: Welded Tuffs; Elevation: 4,400 Ft; Landform: Plateau-Top Scabland; Slope: a. 0-5%, b.Shape: Convex, c. 150ft, d. South; Potential Vegetation: VEDU, POSE, PONE, ACHE, SIHY; %Crown Cover Grasses: POSE 15, VEDU 10, PONE 5, SIHY 2, ACHE 10.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
4240-Loc A				Rock Pavement 80% GR 10% CB									
	A	0 to 6			CRX-ASHY SL 14% CLAY	2n-m Platy	SH-sfi	SO/SP	GR:80; CB:10	2vf-F	3vf-m Ves	6	AS
	Bt1	6 to 10			CB-ASHY L 21% CLAY	2m Platy	SH-sfi	SS/SP	GR:25; CB:10	3vf-F 1m-co	2vf-m Ves	6	AW
	Bt2	10 to 15			CBX-SCL 35% CLAY	2f-m ABK	H-fi	S/P	GR:25; CB:40	1vf-f	2vf-f Irr	6	AW
	R	15+			FRACTURED DICE BASALT								

Parent Material: Ashy loess over Basalt. Bedrock Name: Picture Gorge Basalt. Elevation: 4386Ft. Landform Plateau Top. Slope: a.%: 2-5, b. Shape: CV, c. Length: 1-200ft, d. aspect: All. Surface Stone and Rock: a.GR: 80, b. CB:10. Potential Natural Vegetation: ARRI, POSE. %Crown Cover Shrubs: ARRI 10, %Crown Cover Forbs: Allium 1, %Crown Cover Grasses: POSE 25, SIHY 7%. Notes: Total Cow pies 3 in the 25x25m.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
4240-3				Rock Pavement 15%GR 70%CB									
	A1	0 to 6	7.5YR 5/4	7.5YR 3/3	CBX-ASHY SL 14% CLAY	2n-m Platy	SH	SFI	GR:15; CB:70	3vf-f- M	3f-m Ves	6	A
	Bt1	6 to 9	7.5YR 5/4	7.5YR 3/3	CBX-ASHY SCL 22% CLAY	2f-m Platy	SH		GR:15; CB:60	3vf-m vf-m	3vf-f Irr	6.2	CW
	Bt2	9 to 15	7.5YR 4/4	7.5YR 3/3	CBX-SCL 32% CLAY	2f-m SBK	SH	SS-P	GR:15; CB:70	2f-m Common	1vf-f Irr	6	CW

Bedrock Name: Picture Gorge Basalt. Elevation: 4,500 ft. Surface Stone and Rock: a.GR: 15, b.CB: 70. Potential Natural Vegetation: ARRI, POSE. %Crown Cover Shrubs: ARRI 12%, %Crown Cover Forbs: LOGR 3%, ASFI 3%, STLA 2%, ZYVE 3%, % Crown Cover Grasses: POSE 25-30%, DAUN 3-5%, VEDU 25%, VUOC 10%. Notes: NO ATV's or apparent roads, Total cow pies in plot 13. Not accessible by road.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
4240-2				Rock Pavement embedded 15%GR 80%CB									
	A1	0 to 5	7.5YR 4/4	7.5YR 3/4	CBX-ASHY SL 14% CLAY	2n-m Platy	SH	SO/PS	GR:15; CB:80	3vf-f	3vf-m Ves	5.8	AW
	Bt1	5 to 9	7.5YR 4/4	7.5YR 3/4	CBX-ASHY SCL 22% CLAY	2f-m SBK	SH	SS/SP	GR:10; CB:70	3vf-f 1m	2vf-f Irr	6	CW
	Bt2	9 to 13	7.5YR 4/4	7.5YR 3/4	CBX CL 33% CLAY	1f SBK	SH	SS/P	GR:15; CB:80	2vf-f	2vf-f	6	AW

Bedrock Name: Picture Gorge Basalt. Elevation: 4618 Ft. Landform: Plateau top-scabland. Slope: a. 0-2%, b. Shape: CV c. Length: 200Ft, d. Aspect: 0 Potential Natural Vegetation: ARRI, POSE Surface Stone and Rock: a.GR: 15% b.CB: 80% %Crown Cover Shrubs: ARRI 5, %Crown Cover Forbs: Lomatium 15, %Crown Cover Grasses: POSE 25, DAUN 10. Notes: Scab has old logging road along the edge has been scraped/mounds created from scraping. Road through the plot. Total cow pies 18 and 1 elk. Cows in area.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
5820-1		Welded Tuffs Channery 2mm-6in diameter=80% Flaggy 6-15"=8%							CH: CHANNERY FL: FLAGSTONE				
	A	0 to 5	10YR 5/3	10YR 3/3	CNX-ASHY SL 12% CLAY	2n-m Platy	SH	SO/PO	CH:80; FL:8; ST:2	2vf	3vf- Ves-Mod	5.8	AW
	Bt	5 to 10	10YR 6/3	10YR 3/3	CNX-ASHY SL 18% CLAY	2n-m Platy	SH	SO/PO	CH:70; FL:5	1vf	3vf- Ves-Mod	5.6	AW
	R	10+											

Bedrock Name: Welded Tuffs. Elevation: 4,200 feet Landform: Plateau top scabland. Slope: a. 0-5%, b.shape: slightly rounded, c. Length 600Ft, d.Aspect: S. Surface Stone and Rock: a. CH: 80% b.FL:8% c.ST: 2%. Potential Natural Vegetation: ARRI, POSE, PONE, BASE,VEDU. %Crown Cover Shrubs: ARRI 10, %Crown Cover Forbs: BASE 1, %Crown Cover Grasses: POSE 1, PONE 5, VEDU 20, DAUN 1, ACHE 1. Notes: Total Cow Pies 20, Elk 9, Deer 1, Antelope 1.

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
5820-2		0 to 4		Welded Tuffs Rock Mulch Channery						1vf-f			AS
	A1	4 to 10	10YR 5/3	10YR 3/3	CNV-ASHY CO-SL 14%CLAY	2t-co Platy	SH	FR	CH:95; FL:5	2vf-f	3vf-co Bas	5.8	AS
	Bt1	10 to 15	10YR 5/4	10YR 3/4	CNV SCL 25 %CLAY	2fm-SBK	S	FR	CH:40; FL:5	2vf-f	3vf-f Irr	6	AW
	Bt2	15 to 19	10YR 5/4	10YR 3/4	CNV SCL 33 %CLAY	2fm-SBK	S	FR	CH:60; FL:5	1vf-f	2fm-SBK	5.6	AW
	R	19+											

Bedrock Name: Welded Tuffs. Landform: Plateau- top scabland. Slope: a. 0-5%, b.Shape: Convex, c.Length: 900Ft, d.Aspect: S. Surface Stone and Rock: a. CH: 95, b. FL:5. Potential Natural Vegetation: VEDU, BASE, DAUN, POSE< ACHE. %Crown Cover: ARRI 7, %Crown Cover: BASE 5, %Crown Cover POSE 10, PONE 2, VEDU 25, DAUN 1, ACHE 1. Notes: Road built straight through the plot. Now has vedu growing on it. Total Cow pies 26, Elk 2 Deer 2, Antelope 1 .

Site Number	Horizon	Depth(cm)	Color: Dry	Color: Moist	Texture	Structure	Consistence: Dry	Consistence: Moist	% Rock Fragments	Roots	Pores	Field pH	Boundary
150-2		0 to 2		Rock Mulch Tuff Channery					CH:80; FL:10; ST: 5				AS
	A	2 to 6	10YR 5/3	10YR 3/3	CNV-ASHY SL 14%CLAY	2n-m Platy	SH-FR	SO/PS	CH:40; FL:10	2vf-f	3vf-co Ves	5.8	AS
	B	6 to 11	10YR 5/4	10YR 3/4	CNV-ASHY SL 20%CLAY	2f-m SBK	SH-FR	SO/PS	CH:40; FL:10	2vf-f	2vf-f Irr	5.6	AW
	R	11+		Welded tuffs-Bedrock									

Parent Material: Ash/Locss over residual. Bedrock Name: Welded Tuffs. Elevation: 4,400 ft. Landform: Plateau. Slope: a. 2-10%, b. Shape: CV, c. Length 150Ft, d.Aspect SW. Surface Stone and Rock: a. CH: 80, b. FL:10, c.ST 5. Potential Natural Vegetation: POSE, ACHE, VEDU, BRSQ, %Crown Cover Trees: JUOC 1, %Crown Cover Forbs: ERFI 2, %Crown Cover Grasses: POSE 10, ACHE 10, VEDU 5, SIHY 1, DAUN 1. Notes: No cow pies counted at this plot.

Submitted:
130083

Sample Number	Lab Number	pH	Bray-P ppm	K ppm	Ca ppm	Mg ppm	B ppm	Cu ppm	Mn ppm	Zn ppm	Fe ppm	LOI %
[4240-1] 1	130083.01	6.57	13	89	1316	312	0.3	1.6	6.3	< 0.1	9.4	1.43
[4240-1] 2	130083.02	6.46	7	55	1761	427	0.2	1.4	6.7	< 0.1	6.6	1.65
[4240-2] 3	130083.03	6.45	9	91	1039	267	0.3	3.8	11.5	0.2	13.5	2.19
[4240-2] 4	130083.04	6.37	7	72	1697	398	0.3	3.8	7.3	< 0.1	10.3	2.37
[4240-3] 5	130083.05	6.34	9	89	1371	299	0.3	3.2	7.8	0.3	11.6	3.10
[4230-3] 6	130083.06	6.40	7	59	1839	417	0.2	3.2	7.5	< 0.1	7.7	2.67
[4240-Loc A] 7	130083.07	6.45	13	180	1709	430	0.5	6.1	19.3	1.6	17.5	4.96
[4240-Loc A] 8	130083.08	6.51	7	75	1460	405	0.2	5.0	8.0	< 0.1	12.2	2.35
[4230-1] 9	130083.09	6.26	16	270	2261	454	1.6	10.8	24.5	10.2	78.9	18.61
[4230-1] 10	130083.10	6.51	6	63	1870	445	0.2	3.4	6.4	< 0.1	11.0	2.93
[4230-2] 11	130083.11	6.18	21	335	2220	443	0.8	5.1	37.1	9.9	50.9	12.41
[4230-2] 12	130083.12	6.57	8	92	1333	351	0.3	4.2	8.7	0.4	18.3	3.99
[150-1] 13	130083.13	6.33	5	147	947	186	0.3	2.2	10.1	< 0.1	17.9	2.48
[150-1] 14	130083.14	6.35	6	191	1266	264	0.3	0.7	5.7	< 0.1	10.0	2.25
[150-2] 15	130083.15	6.25	6	111	985	193	0.3	0.9	12.6	0.6	13.3	2.56
[150-2] 16	130083.16	6.14	6	99	1011	205	0.3	1.0	8.1	< 0.1	11.1	1.61
[5820-1] 17	130083.17	6.26	8	113	641	123	0.2	0.7	5.9	0.3	5.9	1.96
[5820-1] 18	130083.18	6.39	7	149	798	147	0.2	0.6	3.5	0.1	6.5	1.75
[5820-2] 19	130083.19	5.91	8	98	892	164	0.3	0.9	9.9	0.4	12.3	2.62
[5820-2] 20	130083.20	6.02	6	112	1153	207	0.2	1.0	4.8	0.1	8.6	2.02

Average Soil Chemical Values by Substrate: Picture Gorge Basalt and Rhyolitic Tuffs

Geology	Horizon Average	pH	Bray-P ppm	K ppm	Ca ppm	Mg ppm	B ppm	Cu ppm	Mn ppm	Zn ppm	Fe ppm	LOI %
Basalt	A	6.38	13.5	175	1653	368	0.63	5.1	17.8	3.7	30.3	7.12
	B	6.47	7.0	69	1660	407	0.35	3.5	7.4	0.13	11.0	2.7
Tuffs	A	6.2	6.8	117	866	167	0.2	1.2	9.6	0.35	12.4	2.41
	B	6.23	6.25	138	1057	206	0.25	0.83	5.5	0.09	9.1	1.91

Discussion: Overall there are quite significant differences in soil chemistry between the basalt and tuffs. The soils developed on tuffs are much lower in fertility almost across the board. Soil pH is several tenths higher, but both staying in the slightly acid range, which is to be expected from acid volcanic rocks such as basalts and tuffs. Bray Phosphorous is higher in the basaltic A horizon. Potassium is higher in the basalt A horizons also. Calcium is approximately twice the concentration in the basaltic A horizon than the tuff A horizon. Magnesium is approximately twice the concentration in the basaltic A horizons. Boron is three times the concentration in the basalt surface. Copper is 5 times as high in the basaltic A. Manganese is twice as high in the basalt surface versus the tuffs. Zinc is 10 times higher in the basaltic surface. Iron is approximately 2.5 times higher on the basalt surface. Loss on ignition of organic matter is approximately three times higher in the basaltic A horizon. Other factors to check include the difference in ACHE10 density, height and vigor.

Average Surface Soil [A Horizon(s)] characteristics by Substrate: Picture Gorge Basalt and Rhyolitic Tuffs

Geology	A Horizon Average	Gravels 2 to 75mm (2 mm to 3 in)	Cobbles 75 to 25 mm (3 to 10 in)	Stones 250 to 600 mm (10 to 24 inches)	Channers 2 to 150 mm -flat (2mm to 6 inches – flat)	Flagstones 150 to 380 mm- flat (6 to 15 inches- flat)	Stones 380 to 600 mm- flat (15 to 24 inches – flat)	Gravel Mulch (loose surface gravel as a distinct layer) in centimeters	Surface Texture (fines)	Crytogamic Crust thickness in mm or cm
Basalt		14.8	56.7	1.8					CBX-Sandy Loam	0 to 1cm
Tuffs					62.5	6.3	0.5	2 cm (0-4cm)	CNX-Sandy Loam to COSL	0??

Discussion: The above scabland soils are very rocky in the surface horizon, which influences plant establishment, current wind erosion potential, water erosion potential, frost heaving severity, post-holing and plugging by ungulates(both wild and domestic), plant detachability (entire plants being pulled up) during wet season grazing and trafficability by ungulates and vehicles. The individual parameters are discussed below.

Plant Establishment: Henderson's ricegrass establishment, being on an extremely rock surface in general, is often limited to exposed soil fines between rock fragments. These areas of surface fines may occur as small gaps between larger rocks, areas of lighter gravelly fines or as rodent burrow spoils. The nature of ricegrass seeds may be an additional factor.

Current Wind Erosion Potential: The soils on these scablands have been eroded down to more resistant rocky surfaces over time. The Mazama ash from Crater Lake (former Mt Mazama, with an average deposition of 1.5 feet approximately 7000 years ago during the much drier Altithermal Period) has largely been eroded away by wind and water erosion. The current A horizons contain evidence of this residual ash, which gives them an ashy sandy loam surface texture in the fine soil portion.

Current Water Erosion Potential: Scabland soils function like tin roofs during snow melt and during summer thunderstorms. Runoff from these sites can be quite rapid and will move surface fines downslope especially if concentrated along roads, skid trails, landings and cattle trails, which serve as curtain drains and can concentrate water flow on to downstream deeper soils often causing rills and gullies in downslope areas. The large amounts of surface rock helps to slow this surface flow by creating roughness and providing surface protection.

Frost Heaving Severity: One of the variables emphasized by Elizabeth Binney and Gary Bradfield in support of ACHE10 competitive advantage over Sandbergs bluegrass (*Poa secunda*) was its ability to withstand frost heaving by having deeper roots and a root cortex that is separated from the stele *(Maze 1981*; *Binney, Elizabeth P. and Bradfield, Gary E. 2000. An initial comparison of growth rates in the rare grass Achnatherum hendersonii and its common associate Poa secunda. Ecological Research 15,181-185*) Soils in this Ochoco National Forest study are ashy sandy loam grading to clay loam in the Bt horizon(s). From the literature, soils containing between 40 and 60 percent silt are most susceptible to frost heaving. Higher daily temperatures occur on southwest and west facing slopes in the northern hemisphere. If the temperature is near freezing, this attribute of slope aspect increases the number of freeze thaw cycles. In addition, the insulating effect of snow would be less on these slopes. Snow cover would be more readily removed or reduced at the beginning of winter or at the end of spring. Unlike east or southeast-facing slopes, west and southwest-facing slopes receive direct sunlight in the afternoon when diurnal temperatures are highest. This results in a greater number of freeze thaw cycles on these slopes and on flat areas *(DeGraff, Jerome V. 1976. Relict Patterned Ground, Bear River Range, North Central Utah. Utah Geology, Vol. 3, No. 2, p. 111 to 116).*

Post Holing and Plugging: These are surface features caused by ungulate hooves on wet or saturated soils. Post holes appear as hoof-sized holes with plugs as the intact interspaces that have been isolated by plugging. The amount, size and shape of surface rock often determines the depth of hoof penetration into these seasonally wet soils. Studies show that hoof pressure (kg/cm^2) is reasonably constant over the full range of body sizes from 5 to 2,275 kg (dik-dik to female elephant) and scales to body mass with an exponent of zero (*Cumming, David H. M. and Cumming, Graeme S. 2003. Ungulate community structure and ecological processes: body size, hoof area and trampling in African savannas. Oecologia 134:560-568).* Typical range cattle vary from 400 to 530 kg (884 to 1,171 pounds) with the higher weights

generating 250 kPa (36.3 psi) of vertical stress while walking on level ground with 2 hooves in contact at one time while walking *(Trimble, Stanley W. and Mendel, Alexandra C. 1995. The cow as a geomorphic agent --- A critical review. Geomorphology 13 (1995) 233-253).* Dry season grazing where range readiness criteria are applied before the cattle turn-on date helps prevent damage to scablands. Elk, deer and antelope do graze all year round with potential for hoof impacts in wet conditions.

Seasonality of Grazing: Grazing impacts can vary with rock fragments and soil moisture. Dry season grazing on these skeletal Lithic Argixerolls is not very impacting. Monitoring done across the SW Blue Mountains has shown that dry season cattle grazing has not changed lichen lines on rock fragments, plant cover or species composition in over 50 years of scabland monitoring by Fred Hall, retired Region 6 plant ecologist (Fred Hall; pers. Communication and observation over several decades of helping Fred measure his plots).

Plant Detachability: Henderson's ricegrass appears to be more susceptible to early season plant detachment on channery rhyolite surfaces with gravel mulch depths of 2 to 4 cm. Pulled out plants were observed on plots.

Trafficability: Scablands which contain larger rock sizes such as rounded basalt cobble and stone sized fragments are less susceptible to ungulate grazing due to livestock preference for less rocky grazing opportunities. Potential off road traffic is naturally discouraged due to potential for tire and undercarriage damage. Vehicle speeds are also reduced on the rockier scablands.

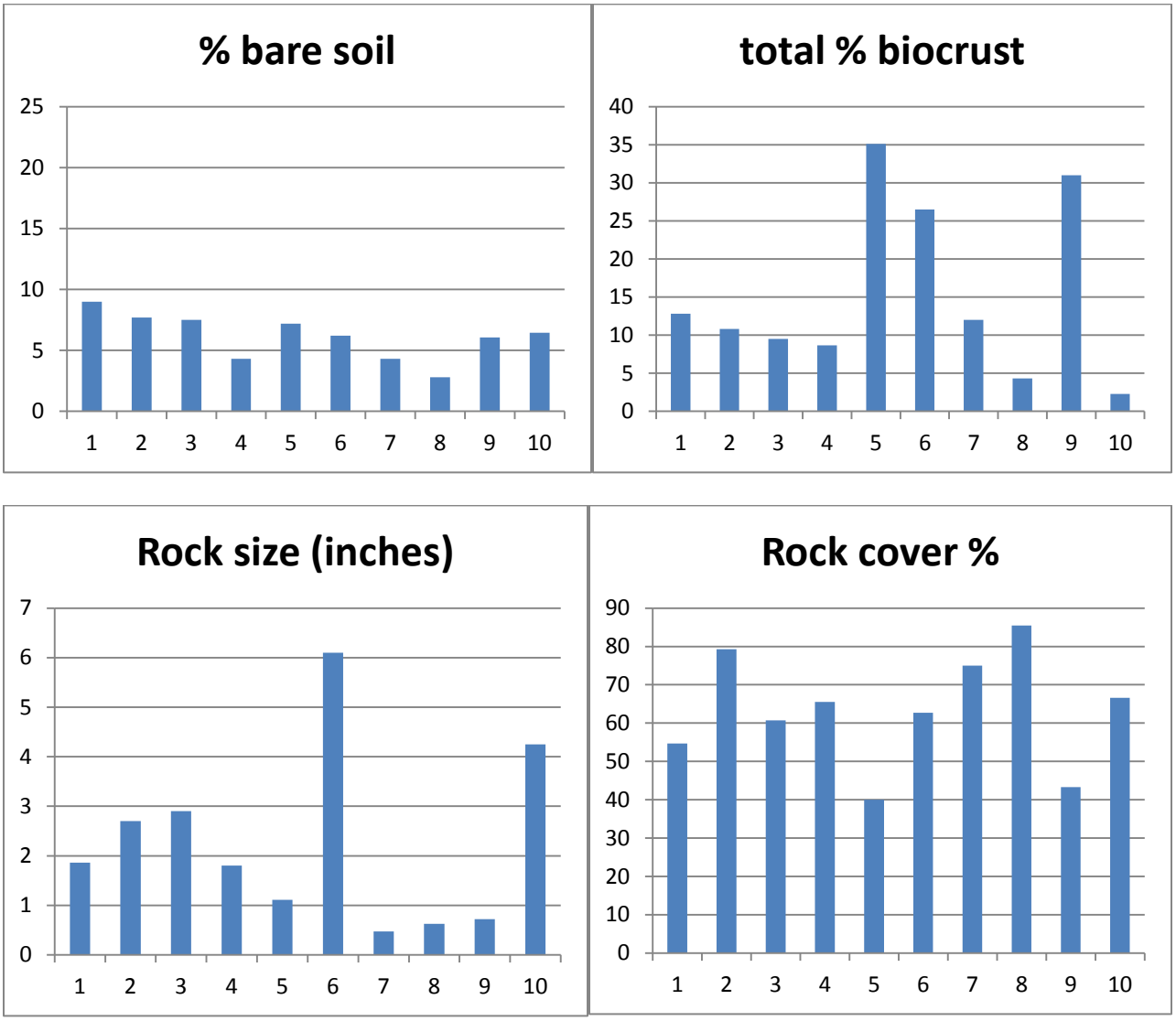
Cryptogamic Crusts: Due to the stony nature of the soils in the ***Artemisia rigida l Poa secunda*** associations, the crust is less developed with lower species diversity. Here, the crust is unimportant with regard to reduction of soil erosion and hydrologic relations. The unattached lichens and mosses likely serve as a mulch in areas where plant litter is scarce. Nitrogen-fixing species such as ***Coflemu tenax*** and ***Peltera rufescens*** can contribute nitrogen to this nutrient-poor environment. All species, both terricolous and vagrant, contribute to organic matter and species diversity. Daubenmire (1970) stated that *A. rigida* is readily consumed by livestock where grass forage is unavailable, and that ***Bromus tectorum*** increases as a result of disturbance. Protection of good examples of these unique plant communities from grazing would therefore be important from a diversity standpoint, as increased litter from ***Bromus tectorum*** could exclude crust organisms as well as vagrant species (*Kaltenecker, Julie and Wicklow-Howard, Marcia. 1994. Microbiotic Soil Crusts in Sagebrush Habitats of Southern Idaho. Prepared for Eastside Ecosystem Management Project, (ICBEMP)).* See above comments under erosion and trafficability. One of the few plots with observable dry period cryptogamic crusting was plot 4230-2 where moss was observed between rock fragments.

Weed Species Encroachment: The scabland areas throughout the southwest Blue Mountains have had encroachment from invasive annual grasses since the mid to late 1800s following the huge numbers of sheep, cattle and horses. Annuals such as cheatgrass (*Bromus tectorum*), corn brome (*Bromus squarrosum*), rattlesnake brome (*Bromus briziformis*) and ventenata grass (*Ventenata dubia*) were introduced during the initial wave of invasion. Ventenata grass was not initially recognized as it was often confused with the native grass *Deschampsia danthanoides*. (Fred Hall, pers. comm.). Cattle grazing has been changed to largely dry season grazing since the 1950s.

Surface Albedo: surface albedo (reflectivity) is relatively low for basalt scabslands with rock color in the black to very dark grayish range. The rhyolitic tuff scablands have higher reflectivity with rock color in the light gray to brownish yellow range. This could affect surface soil temperatures.

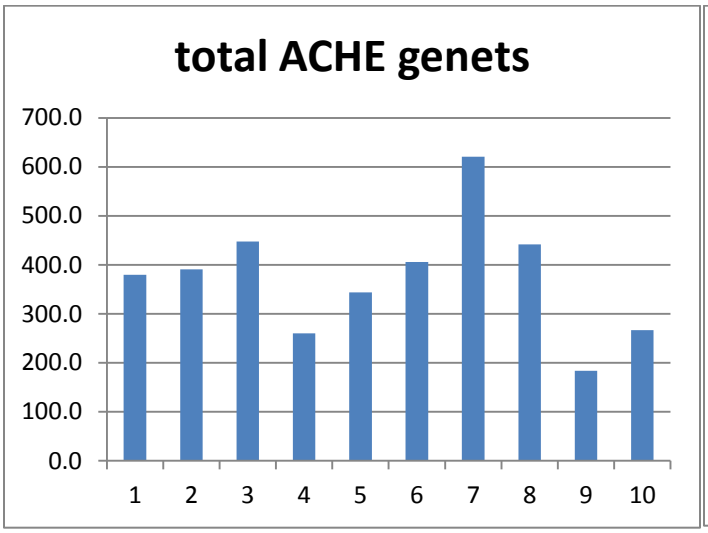
Appendix B

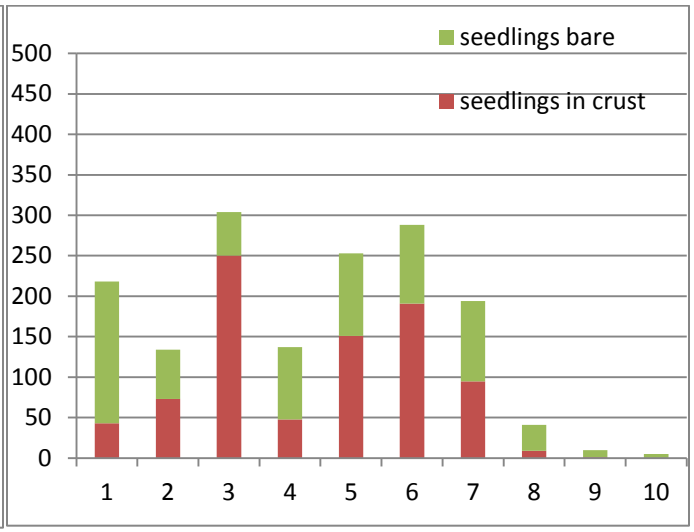
Scabland habitat condition (measured in 20 cm x 50 cm plots) averages n=20 for each site

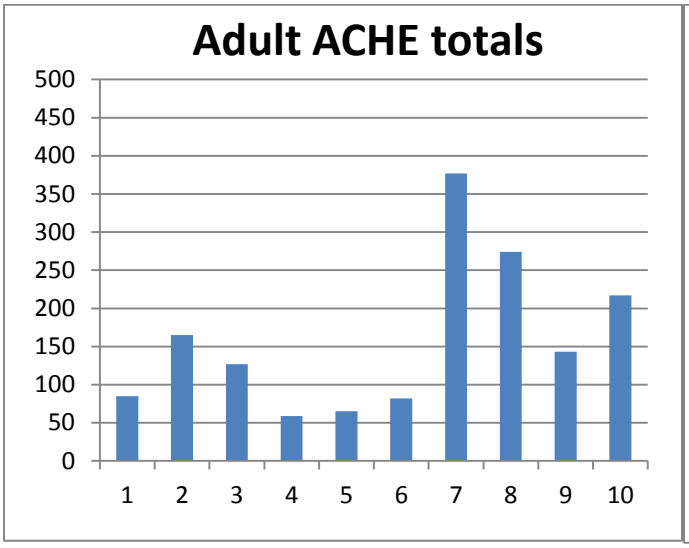


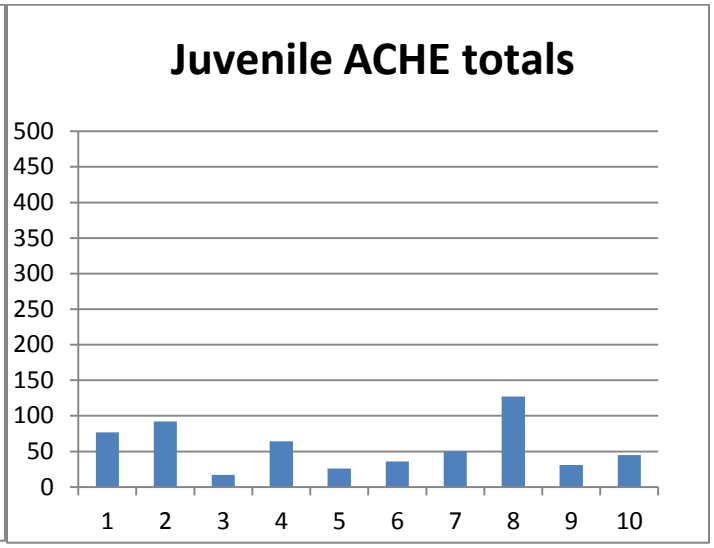
Site number

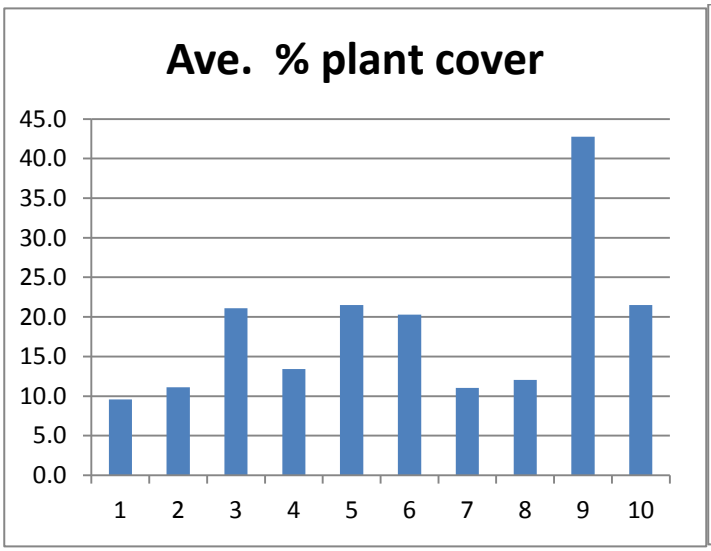
Population demography (in M^2 plots) totals for each site

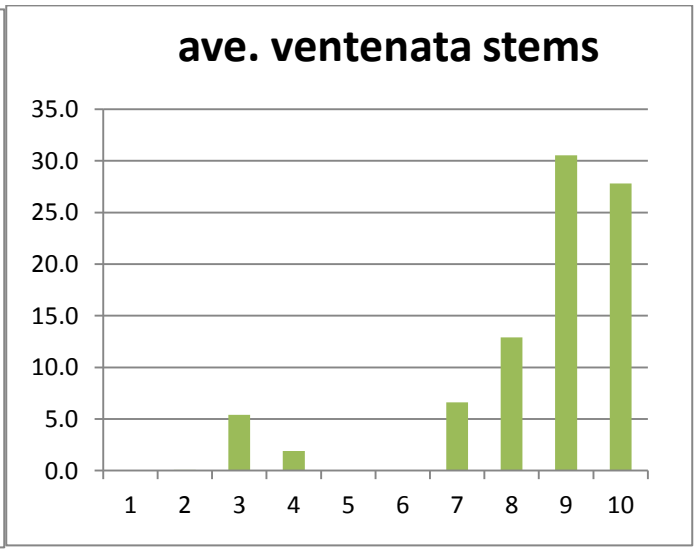












Site Number