Wildlife on Conservation Reserve Program lands and native shrubsteppe in Washington

Progress Report: 2004

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Cover Photo: Conservation Reserve Program field planted to big sagebrush and a mix of native and non-native grasses and forbs, Douglas County, Washington. Native shrubsteppe can be seen in the background.

Suggested citation

Vander Haegen, W. M., M. A. Schroeder, S. S. Germaine, S. D. West, and R. A. Gitzen . 2005. Wildlife on Conservation Reserve Program lands and native shrubsteppe in Washington: Progress Report for 2004. Washington Department of Fish and Wildlife, Olympia. 51pp.

Abstract

The Conservation Reserve Program (CRP) is currently the only large-scale effort to restore habitat that may be used by grassland and shrubsteppe wildlife in the Columbia River Basin. Administered by the US Department of Agriculture, this voluntary program pays farmers to take agricultural lands out of production to achieve conservation objectives including reducing soil erosion and providing wildlife habitat. In Washington, over 1 million acres (405,000 ha) of converted farmland has been planted to non-native grasses and to native grasses, forbs and shrubs under the CRP. In 2003 we began a study to evaluate the potential role of CRP in the long-term conservation of obligate grassland and shrubsteppe wildlife in the Columbia River Basin. We established 48 study sites in CRP fields of varying age and landscape contexts and in extant shrubsteppe communities. In 2004, we repeated surveys of birds, herptiles, and small mammals and we examined reproductive parameters of selected bird species. In addition, we characterized the vegetation on all sites and we added two new components to the study: a survey of the mosses and lichens that make up the biological soil crusts and pellet surveys to document use by lagomorphs, deer, and prairie grouse. Plans for 2005 include continued bird and small mammal surveys, pellet sampling, and sampling of the remaining sites for biological soil crusts.

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Introduction

Shrubsteppe historically was the dominant habitat in eastern Washington (Daubenmire 1970). Daubenmire described shrubsteppe as vegetative communities consisting of one or more layers of perennial grass with a conspicuous but discontinuous overstory layer of shrubs. Although the dominant shrub is usually big sagebrush (*Artemisia tridentata*), other shrubs may also be common including threetip sagebrush (*A. tripartita*), rabbitbrush (*Chrysothamnus nauseosus*), bitterbrush (*Purshia tridentata*), greasewood (*Sarcobatus vermiculatus*), and spiny hopsage (*Grayia spinosa*). Shrubsteppe is considered a 'priority habitat' within the state of Washington (WDFW 2001) that warrants special management considerations due to threats from human-associated causes.

Today, less than 40% of Washington's historic shrubsteppe remains, and much of it is degraded, fragmented, and/or isolated from other similar habitats (Jacobson and Snyder 2000, Vander Haegen et al. 2000). The distribution, density, and diversity of shrubsteppe wildlife has been adversely affected by habitat conversion for crop production (Buss and Dziedzic 1955, Swenson *et al*. 1987, Vander Haegen *et al*. 2000) and hydropower (Howerton 1986), a differentially high loss of deep-soil communities (Dobler *et al*. 1996), fragmentation through habitat conversion, roads, power lines, and fences (Vander Haegen *et al*. 2001), and alteration of the vegetation through over-grazing, invasion by exotic plants, and changes in fire frequency (Yensen *et al*. 1992, Pashley *et al*. 2000, Vander Haegen *et al*. 2001). Various mapping efforts have provided information on the extent of remaining shrubsteppe in eastern Washington (Dobler et al. 1996, Jacobson and Snyder 2000), but detailed data exist only for a few tracts of mostly public lands.

Loss and degradation of once extensive shrubsteppe communities has greatly reduced the habitat available to a wide range of shrubsteppe-associated wildlife including several birds restricted to this community type (Quigley and Arbelbide 1997, Saab and Rich 1997, Vander Haegen et al. 2000). Sage sparrows, Brewer's sparrows, sage thrashers, and sage grouse are considered shrubsteppe obligates and numerous other species are associated primarily with shrubsteppe at a regional scale. In a recent analysis of birds at risk within the interior Columbia River Basin, most species identified having a high management concern were shrubsteppe species. Moreover, according to the Breeding Bird Survey, half these species have experienced long-term declines in their populations (Saab and Rich 1997). In Washington, greater sage-grouse, sharp-tailed grouse, and ferruginous hawk are listed as state threatened, and sage sparrow, sage thrasher, loggerhead shrike, and golden eagle are listed as state candidates (scientific names for wildlife species mentioned in the text are listed in the Appendix).

Previous work on shrubsteppe passerines in Washington has examined the relationship between various site-specific parameters and species occurrence and abundance (Rotenberry and Wiens 1980, Dobler et al. 1996, Vander Haegen et al. 2000). Sage sparrows are associated with less annual grass in the herbaceous layer, and grasshopper sparrows with more perennial grass. Brewer's sparrows and sage thrashers are less abundant in shrubsteppe habitats of relatively poor quality (Vander Haegen et al. 2000). Habitat-specific population parameters, including productivity, dispersal, and adult and juvenile survival are unknown for most of these species. Fragmentation and degradation of shrubsteppe adversely affect some species, although relatively few have been studied. Sage sparrows are less abundant (Vander Haegen et al. 2000) and Brewer's sparrows and sage thrashers are less productive (Vander Haegen et al. 2002, WDFW, unpubl. data) in fragmented landscapes. Rates of parasitism by brown-headed cowbirds (*Molothrus ater*) were found to be low for several shrubsteppe obligate passerines in Washington and were greater in fragmented than in continuous sites for Brewer's Sparrows (Vander Haegen and Walker 1999; WDFW unpubl. data).

Few studies of small mammals (shrews and rodents) have been conducted in the shrubsteppe habitats of eastern Washington except for studies at the Hanford Reservation, the Arid Lands Ecology Reserve, and the Yakima Training Center (West *et al*. 1999). Gitzen *et al*. (2001) recently completed one of the larger investigations of small mammals in the shrubsteppe at the Hanford Reservation; Great Basin pocket mice, deer mice, western harvest mice, grasshopper mice, and sagebrush voles were the primary species captured. Given that conditions at previously studied sites do not represent ecological conditions present in much of the remainder of eastern Washington, extrapolation of species habitat occurrence and abundance patterns from these areas may be unwarranted. For some shrubsteppe mammals in Washington, almost no data on current population status and trends and habitat requirements are available, and for some species, even the statewide distribution is poorly known (Johnson and Cassidy 1997). This basic information is needed to prioritize management actions.

No studies have specifically addressed the habitat associations of reptiles and amphibians in Washington's shrubsteppe. Even the distribution of most species is poorly known. At a coarse scale, many species are associated with shrubsteppe (Vander Haegen et al. 2001). Of these, the sharptail snake and striped whipsnake are state candidates for threatened status, the night snake is a state monitor species in Washington, the sagebrush lizard is a federal species of concern, and the northern leopard frog is endangered in Washington State. Declines associated with habitat loss are suspected, but the status of most amphibians and reptiles is unknown.

The Conservation Reserve Program (CRP) is currently the only large-scale effort to restore habitat that may be used by grassland and shrubsteppe wildlife in the Columbia River Basin. Administered by the US Department of Agriculture (USDA), this voluntary program pays farmers to take agricultural lands out of production to achieve conservation objectives including reducing soil erosion and providing wildlife habitat. In Washington, over 1 million acres (405,000 ha) of converted farmland has been planted to non-native grasses and to native grasses, forbs and shrubs under the CRP (Fig. 1). The program allows farmers to enroll lands for periods of 10-15 years, with periodic opportunities for entering land into the program. While not an ideal solution to the problem of declining native habitat, CRP has enormous potential to provide habitat for many grassland and shrubsteppe species. The current acreage of CRP land in eastern Washington is equal to almost 15% of the state's total agricultural lands. Despite the potential of CRP land as wildlife habitat, no studies have examined use of these lands by grassland and shrubsteppe obligate wildlife in the Columbia River Basin.

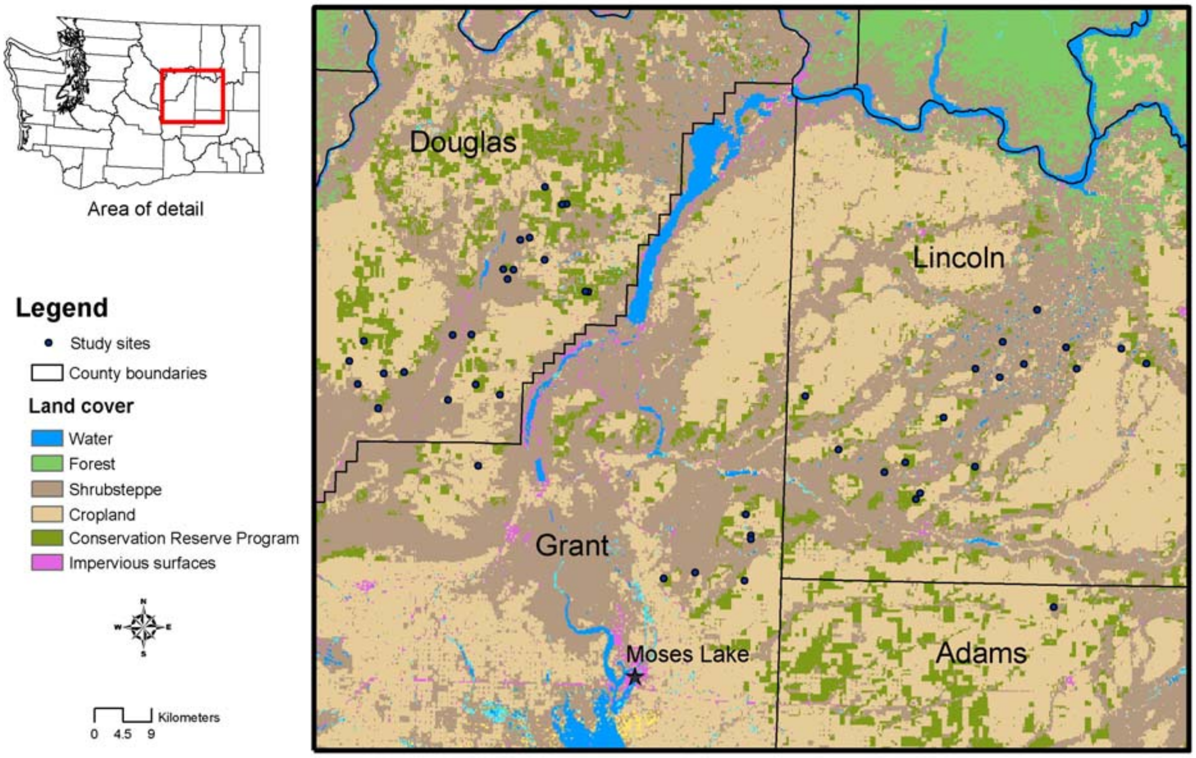

Figure 1. Location of study sites in eastern Washington. Land cover derived from Landsat imagery and aerial photographs in 1996.

Studies in the mid-west have documented a variety of grassland birds using CRP fields (Patterson and Best 1996, Eggebo 2001). In Washington, Grasshopper sparrows, Columbian sharp-tailed grouse, and the greater sage-grouse are known to use CRP fields (WDFW unpublished data) and there is the potential for use by other grassland birds such as short-eared owls, burrowing owls, horned larks, and western meadowlarks. Although CRP fields have historically been planted to a variety of non-native grasses, more recently an increasing number of fields have been planted to native grasses, forbs, and native arid-land shrubs. Moreover, native shrubs (particularly big sage) frequently seed-in from adjacent shrubsteppe, making some fields of potential use to shrub-nesting species such as sage sparrows, Brewer’s sparrows, and loggerhead shrikes.

The general goal of this research is to evaluate the potential role of CRP in the long-term conservation of obligate grassland and shrubsteppe wildlife in the Columbia River Basin. The specific objectives are to 1) compare wildlife populations in CRP lands with those in nearby native shrubsteppe, 2) compare wildlife populations in CRP lands of different ages and in different landscape contexts, 3) derive species-habitat relationships for poorly understood bird, mammal, and reptile species that depend on shrubsteppe, and 4) provide information that will support management of CRP in Washington to benefit shrubsteppe associated wildlife.

Study design

We will compare wildlife communities in CRP fields and those in native shrubsteppe. There are 6 "treatments": 3 vegetation communities, each represented in landscapes dominated by agriculture and in landscapes dominated by shrubsteppe (Table 1). Study sites are clustered into 8 study areas or "clusters". Each cluster has six study sites; one of each "treatment" type. Shrubsteppe communities are dominated by native vegetation, with an overstory of big sagebrush and an understory of bunchgrasses and forbs. "New" CRP communities are former agricultural lands planted in the last sign-up (1998-2000) to a mix of non-native and native species including big sagebrush. Old CRP communities are former agricultural fields planted to non-native bunchgrasses in previous sign-ups (1986-1988). Each study site has a single survey plot of 25ha. Each plot contains 4 100-m fixed-radius point counts (Ralph et al. 1993) spaced 300m apart (100m buffer between each circle perimeter) (Fig 2). This 25ha study plot is the focus of all survey work.

Table 1. Study site configurations used in shrubsteppe restoration study.

Vegetation community	Landscape
Shrubsteppe	Shrubsteppe dominated
Shrubsteppe	Agricultural dominated
New CRP (planted 1998-2000)	Shrubsteppe dominated
New CRP (planted 1998-2000)	Agricultural dominated
Old CRP (planted 1986-1988)	Shrubsteppe dominated
Old CRP (planted 1986-1988)	Agricultural dominated

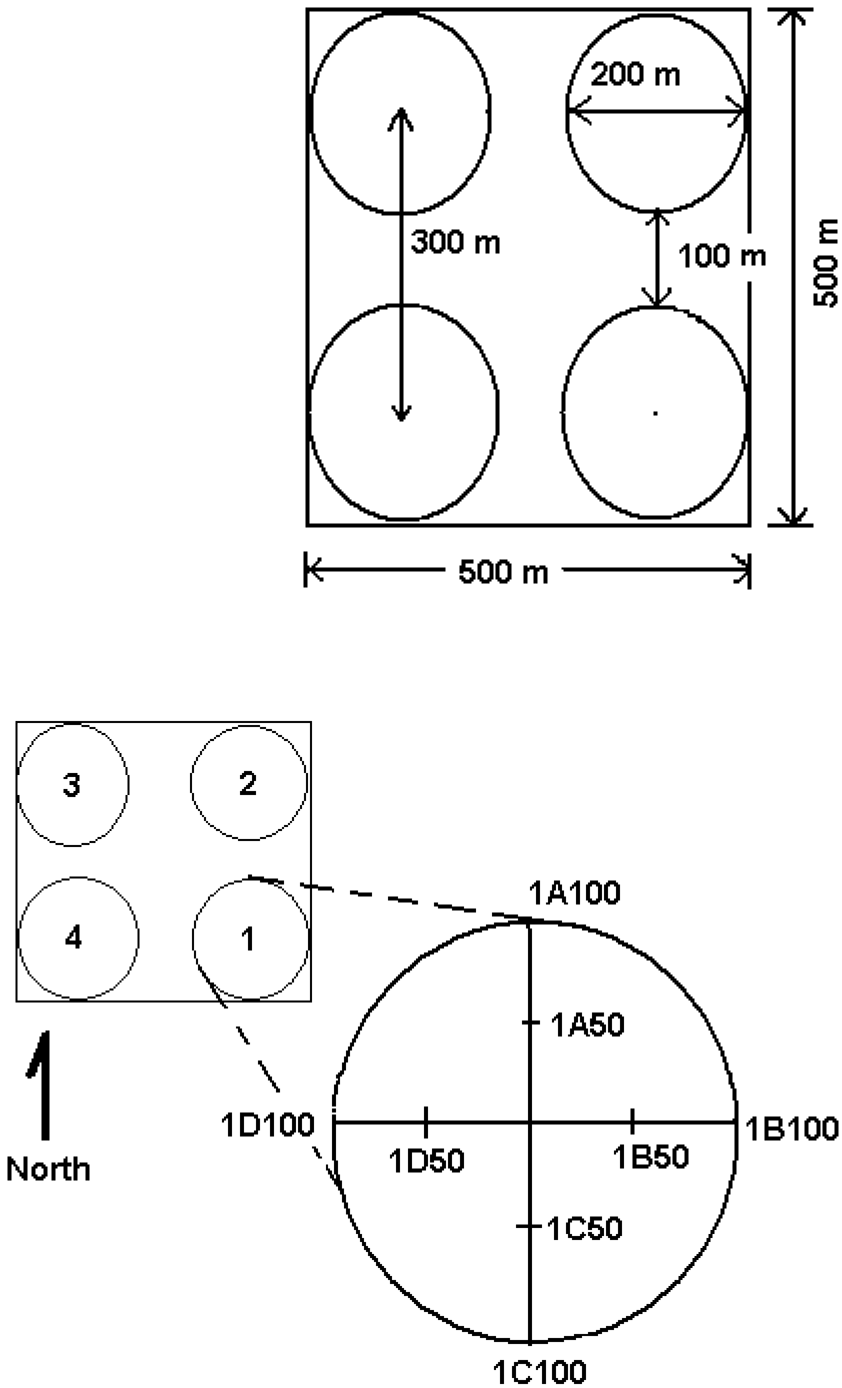

Fig. 2. *Top*. Sample design for study sites illustrating the configuration of the four 100-m fixed-radius point counts within the 25 ha square plot. Each of 4 center points were marked with a permanent fiberglass stake (1m electric fence post). A metal washer at the base of each stake is stamped with the point number. *Bottom.* Colored flagging was placed on shrubs (or bamboo stakes) at 50m and at 100m from the point in each of the 4 cardinal directions to aid in determining distance during point counts. Points on each "arm" are labeled as shown with the number of the point, followed by the letter of the "arm", and the distance from the center point.

Each of the 48 study sites is identified by a four-letter code (Table 2). The first two letters are the first letters of each word of the study area name. The third letter can be "N" for new CRP, "O" for old CRP, or "S" for shrubsteppe. The fourth letter describes the landscape surrounding each plot and can be "C" for cropland or "S" for shrubsteppe (e.g., "SFSS" is Sagebrush Flats study area, Shrubsteppe site in a Shrubsteppe landscape).

Table 2. Four-letter codes for each of 48 study sites. Shrubsteppe (SS) and Conservation Reserve Program (CRP) "vegetation types" in each of 2 landscapes (Shrubsteppe dominated and cropland dominated).

Study Area (cluster)	SS in shrubsteppe	SS in cropland	New CRP in shrubsteppe	New CRP in cropland	Old CRP in shrubsteppe	Old CRP in cropland
Chester Butte	CBSS	CBSC	CBNS	CBNC	CBOS	CBOC
Black Rock	BRSS	BRSC	BRNS	BRNC	BROS	BROC
Jameson Lake	JLSS	JLSC	JLNS	JLNC	JLOS	JLOC
Pine Canyon	PCSS	PCSC	PCNS	PCNC	PCOS	PCOC
Pacific Lake	PLSS	PLSC	PLNS	PLNC	PLOS	PLOC
Coyote Canyon	CCSS	CCSC	CCNS	CCNC	CCOS	CCOC
Swanson Lake	SLSS	SLSC	SLNS	SLNC	SLOS	SLOC
Tracy Rock	TRSS	TRSC	TRNS	TRNC	TROS	TROC

Passerine Birds

Objectives

Our objectives were to measure the occurrence and abundance of avian species using each of the 6 treatments and to document reproductive success at 2 levels: success rates of individual nests, and seasonal fecundity of individual focal birds.

Methods

Abundance— We surveyed birds on all study plots using fixed-radius point-counts (Ralph et al. 1993). Counts at each point were 5 minutes in duration during which all birds seen or heard were noted, along with their sex (if known), distance from the point (within 50m, >50 but <100m, or beyond 100m), and behavior (singing, calling, silent, or flying over the site). Surveys were conducted once each in May and June and within prescribed weather parameters (i. e., no rain and low wind). Layout of point-count plots is illustrated in figure 2.

Productivity—We measured reproductive parameters on all study sites in shrubsteppe landscapes (OS, NS, SS). We located nests by following behavioral cues (e.g., adults carrying nest material or food) and by searching likely areas of the 25-ha study plots. Once found, nests were marked with a single piece of colored flagging placed ≥8m distant and status (number of eggs/young) was noted. We visited nests every 3-4 days until fledging or failure.

We used a modification of the Vickery technique (Vickery et al. 1992) to assess the seasonal productivity of selected species (Brewer's Sparrow and Savannah Sparrow). We used mist nets and song play-back to capture and color-band the male of each focal species that was singing nearest to each point-count center. If a point had no male singing nearby, we attempted to capture and mark a second male at another point. Focal (color-banded) males were visited twice each week in order to obtain clues to their reproductive status. We attempted to follow each male for a minimum of 30 min during each visit, looking for evidence of pairing, nesting, and successful fledging of one or more nests. On visits where the male could not be relocated we spent 30 min searching his activity area for nests or for signs of a female feeding young. Focal male studies were restricted to sites in shrubsteppe landscapes due to logistical constraints.

Results

Abundance—We counted 4792 individual birds on 384 point-counts in 2004. Of those, 2440 were counted within the 100m-radius circle (Table 3). Savannah Sparrows were the most abundant species occurring in CRP fields, whereas Brewer's Sparrows were the most abundant species in shrubsteppe sites.

All site types had a high number of individual birds counted, ranging from 342 in SS sites to 487 in NC sites. Shrubsteppe sites had a more diverse bird community, including several shrubsteppe-associated species that were not recorded in CRP sites (Lark Sparrow, Loggerhead Shrike, Black-billed Magpie). Eighteen species were counted >1 time on surveys in shrubsteppe sites and from 6-8 were counted >1 time on CRP sites (Table 3).

Nest Success—We located and tracked the fates of 567 nests on the study sites (Table 4). Nests of the 2 focal species (Brewer's Sparrow and Savannah Sparrow) made up 59% of the total sample of nests found. The most common nests found in SS and OS plots were those of Brewer's Sparrows; Savannah Sparrow nests were found most often in NS plots. Of interest, nests of the 3 shrubsteppe obligates (Sage Sparrow, Brewer's Sparrows, and Sage Thrashers) were found in some CRP fields when shrubs were present.

Mayfield nest success rates for the 3 species with the largest number of nests are reported in Table 5. Rates of daily nest survival were similar between years (2003 and 2004) for all 3 species so we combined data across years. For all 3 species, rates of nest success in CRP sites were equal to or greater than those in shrubsteppe sites.

Seasonal Reproductive Success—We banded a total of 167 Brewer's Sparrows and Savannah Sparrows on 24 sites in shrubsteppe landscapes in 2004. We obtained sufficient information on 62 Brewer's Sparrows and 66 Savannah Sparrows to estimate seasonal reproductive success. Sample sizes from 2003 were low so we combined data across years for the analysis. The proportion of color-banded males obtaining mates ranged from 82 to 89% and was similar between site types for both species (Fig 3). More Brewer's Sparrow pairs went on to successfully fledge young on OS sites compared to SS sites; however, we observed multiple brooding only on SS sites. Savannah Sparrow pairs were more successful in fledging at least one brood in OS sites compared with NS sites and this trend also was true for pairs raising multiple broods.

Table 3. Birds counted on point-count surveys (within 100m) in 2004, summed across plots by site class.

Species code	NC	NS	OC	OS	SC	SS	Total
Savannah Sparrow	259	130	148	100	25	27	689
Brewer's Sparrow	29	27	15	70	140	96	377
Horned Lark	59	72	75	70	42	30	348
Grasshopper Sparrow	88	73	87	56	11	6	321
Vesper Sparrow	26	41	38	60	83	67	315
Western Meadowlark	16	30	11	30	47	62	196
Sage Thrasher				16	36	14	66
Brown-headed Cowbird					24	9	33
Sage Sparrow				6	2	17	25
Lark Sparrow					1	9	10
Short-eared Owl	6		2		1		9
Ring-necked Pheasant		1	1		4	1	7
Red-winged Blackbird					7		7
Brewer's Blackbird	2				4		6
Gray Partridge		1			4		5
Loggerhead Shrike					2	2	4
Mourning Dove					2	2	4
Northern Harrier	1				2		3
Song Sparrow					3		3
Common Raven			1		1		2
Barn Swallow	1						1
Black-billed Magpie					1		1
Common Nighthawk					1		1
Gray Flycatcher			1				1
Killdeer					1		1
Rock Wren					1		1
Tree Swallow				1			1
Yellow-headed Blackbird		1					1
Total	487	376	380	409	446	342	2440

Table 4. Nests found and tracked in 2004, summed across plots by site class. Nest-searching and related demographic work was focused on study sites in shrubsteppe landscapes (site types SS, OS, and NS), resulting in a greater number of nests found in these site types.

Species	NC	NS	OC	OS	SC	SS	Total
Brewer's Sparrow	3	17	1	96	3	91	211
Savannah Sparrow	2	43		61		15	121
Vesper Sparrow	1	13		17	4	38	73
Horned Lark	1	6	2	28	1	9	47
Sage Thrasher		2	1	8	6	14	31
Western Meadowlark		1		8		14	23
Grasshopper Sparrow	2	7		6			15
Sage Sparrow				3		9	12
Mourning Dove						6	6
Loggerhead Shrike						5	5
Short-eared Owl	2			2			4
Lark Sparrow						3	3
Common Nighthawk						2	2
Northern Shoveler			1	1			2
Rock Wren						2	2
Say's Phoebe				1		1	2
Gadwall		1					1
Gray Partridge		1					1
Northern Harrier				1			1
Ring-necked Pheasant					1		1
Sage Grouse		1					1
Swainson's Hawk					1		1
Tree Swallow						1	1
Total	11	92	5	232	16	211	567

Table 5. Daily survival rate and nest success rate (Mayfield) for birds nesting in shrubsteppe and CRP lands in Washington, 2003-2004.

Species	Site type	N	Daily survival rate	Success rate
Brewer's Sparrow	SS	133	0.966	0.43
	OS	128	0.979	0.59
	NS	24	0.986	0.72
Savannah Sparrow	OS	76	0.977	0.53
	NS	59	0.956	0.30
	SS	29	0.906	0.07
Vesper Sparrow	OS	36	0.974	0.51
	NS	21	0.982	0.62
	SS	56	0.975	0.52

Summary

Similar to our findings from 2003, point count results from 2004 show a bird community dominated by grassland species in CRP sites. This pattern was not unexpected and reflects the structure of the vegetation and its similarity to native steppe communities. Three shrubsteppe-obligate passerines (Sage Sparrow, Sage Thrasher, and Brewer's Sparrow) also occurred in CRP stands, with Brewer's Sparrows occurring in considerable numbers. Highest numbers of all 3 species within CRP were recorded in OS sites, likely reflecting the increased occurrence and height of big sagebrush in these old CRP stands. All 3 of these species typically nest on or beneath sagebrush shrubs. Nesting data confirmed that these shrubsteppe-obligates were breeding successfully on these CRP sites, with numbers of Brewer's Sparrow nests found in OS sites equaling that found in shrubsteppe controls (SS) and rates of nest success equal to or greater than those in shrubsteppe. Data from the focal males indicate that Brewer's Sparrows and Savannah Sparrows were successful in pairing in the different site types examined but that those pairs were more successful in raising young in OS sites. Data collection will be repeated in 2005 to see if these patterns hold.

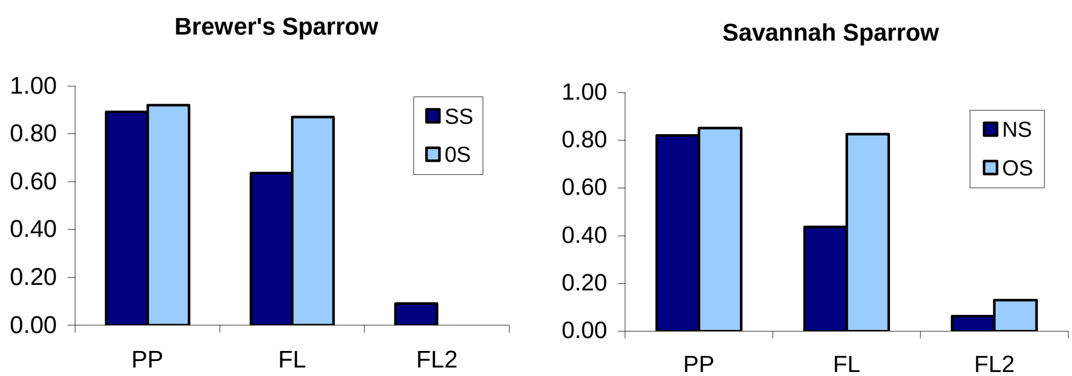

Figure 3. Proportion of Brewer's Sparrow and Savannah Sparrow males that paired (PP), and proportion of pairs that fledged young (FL) and fledged second broods (FL2) on study sites in shrubsteppe and CRP lands in eastern Washington, 2003-2004.

Reptiles and Amphibians

Objectives

Our primary objective was to compare reptile and amphibian distributions among the 6 site types. Response variables included species-specific frequency of occurrence (using raw counts and/or catch per unit effort estimates; cpu), species richness (no. species), and abundance pooled across all species and within groups, such as grassland snakes and amphibians.

Methods

During 2004 we again employed two formal survey methods to document reptile and amphibian distributions among site types, and expanded both the sampling intensity and number of sites surveyed. We also included incidental observation information from herptile, bird, or mammal field crewmembers to enhance species lists for each site type.

We conducted area-constrained visual searches at all 48 sites during 14 May – 19 August, 2004. Each site was surveyed by two trained observers, with recurring surveys at each site rotated among morning, afternoon, and evening periods in order to sample across the widest possible range of ambient temperature conditions. Each survey lasted approximately 2 person-hours, varying slightly depending on degree of vegetative complexity at each plot. To remain consistent with 2003, we again considered plot SLSC a part of the Pacific Lake replicate and surveyed plot PLSC with the Swanson Lake replicate. Surveys were again constrained within the 400 m x 400 m (16 ha) area defined by flags marking 50 m distance beyond bird survey station centers (Fig. 1).

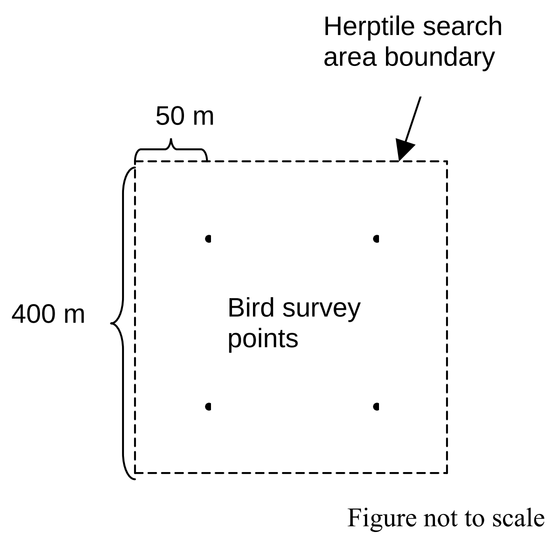

Figure 1. Boundary of time and area-constrained survey plots superimposed over bird survey points, shrubsteppe CRP study, 2003 and 2004.

During each survey, we high-graded plots by searching first in areas containing basking, den, and foraging (etc.) habitat features for species potentially present, then searching through progressively less optimal areas. In plots containing little vegetative or structural diversity, two observers covered the entire plot by walking a systematic zig-zag pattern while spaced a short distance apart.

We completed installation of drift fence-funnel trap arrays at all 48 sites, and conducted funnel trap sampling during 23 April – 19 August. Arrays were again located at plot center, as determined by averaging UTM coordinates of the bird point count origins. Drift fence arrays were 3-armed, with radial arms spaced 120^0 apart. Each arm was 10 m long and approx. 45 cm in height, constructed of 1.5 mm (approx). mesh nylon window screen, buried to 10 – 15 cm depth along the entire bottom edge, and held upright with wooden stakes. Funnel traps were constructed of the same material, and were located 0.5 m from array center and at the distal end of each fence arm (Fig. 2). Central traps were double-funneled, while distal traps had funnels only at the inner end. When open, funnels contained soil and stones, and were shaded with landscaping cloth held in place by rocks. Funnel entrances were plugged when traps were not in use.

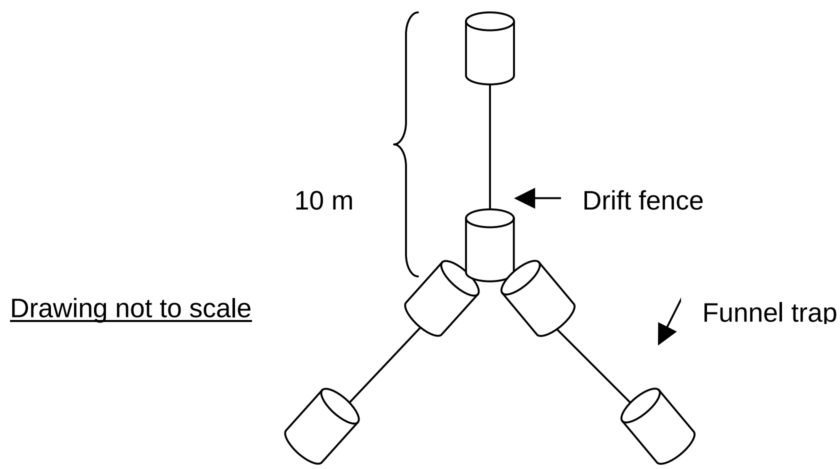

Figure 2. Drift-fence and funnel-trap array design.

Capture, marking, data recording of animals—All herptiles captured (except venomous snakes) received a unique toe or caudal scale clip, were weighed and measured (snout-vent length; svl), and released near the point of capture. Shed snake skins found in plots were keyed to species when possible, and incorporated into species list data. Unidentifiable skins and tracks of snakes or lizards crossing dirt roads within plots were recorded as unidentified snake or lizard, and included in cpu estimates.

Variable generation—Pooling incidental observation and formal survey data resulted in more thorough species lists at sites than by using formal survey information alone. In addition to enabling comparison of species distributions among site types, species lists were useful in evaluating relative efficiency of each survey method in detecting species known to be present.

Species occurrence data were summarized in two ways; raw counts were pooled within site types, and cpu counts were generated by dividing number of observations by relative amount of effort expended in each site type. In addition, number of species and total number of all herptiles observed were summed.

Analysis—Observed distribution of each species among treatments will be evaluated against the H_o of randomness using Poisson regression analysis (analysis of deviance). When sample size permits, distribution data will be tested against a uniform distribution via goodness of fit tests (Zar 1996).

Results

In 2004, time-area constrained search effort totaled 18 hours each in NC and NS sites, 37 – 38 in OC and OS sites, and 40 – 41 in SC and SS site types (192 hours total). Pooling the 2003 and the early-season survey data in 2004, 68.4 person hours of area-search effort were spent in NC and NS plots. No individuals of any species were observed at any NC site, while 2 individuals (short-horned lizard, western skink) were observed at NS sites, for a cpu of 1 observation per 34.2 hours search time in new CRP sites. Therefore, after the first round of surveys area-searches were discontinued in new CRP sites for the remainder of 2004.

Funnel traps were opened for 788 trap nights during 23 April – 19 August, with effort per site type ranging from 108 trap nights (NS) – 129 trap nights (OS sites). We observed 154 individuals representing 10 species when data from all observation methods were pooled (Table 1). Pooling across species and site types, area searches generated an average of 1.9 observations / 10 hrs (range of cpu / 10 hrs = 0 in NC – 4.2 in SS sites), while funnel traps averaged 0.4 individuals / 10 trap nights (range of cpu / 10 hrs = 0.1 in OS – 1.0 in SS sites). Both sampling methods were less effective than during 2003 (2.7 and 1.4 obs/10 trap nights, respectively).

Table 1. Frequency of occurrence of reptiles and amphibians* within site types, pooled among survey methods, Adams, Douglas, Grant, and Lincoln Counties, WA 2004.

	Treatment						
	NC	NS	OC	OS	SC	SS	Total
Short-horned lizard	3	4	13	30	9	15	74
Western rattlesnake	0	2	0	1	0	18	21
Western skink	1	2	0	4	3	3	13
Gopher snake	0	4	0	6	0	4	14
Racer	0	2	0	3	0	6	11
W. terrestrial garter snake	0	1	0	0	1	0	2
Night snake	0	0	0	0	0	1	1
Great-basin spadefoot toad	0	0	3	0	1	6	10
Long-toad salamander	0	0	0	0	1	0	1
Tiger salamander	1	0	1	0	0	0	2
Total Abun	5	15	17	45	15	57	154
No. Spp.	3	6	3	5	5	7	10

* Scientific names appear in Appendix A

Survey methods varied in efficiency in detecting different species (Table 2). Level of effort was not quantified for either incidental observation method, so valid comparison with formal methods is difficult. It is noteworthy that two species were observed during incidental observations that would otherwise not have been documented during 2004 (Table 2). Short-horned lizards and western skinks were readily detected by both formal survey methods, while rattlesnakes were not detected by funnel trapping, and racers, Great-basin spadefoot toads, and tiger salamanders were detected most frequently by funnel trapping.

Table 2. Frequency of occurrence of herptiles* within survey methods, pooled among sites, Adams, Douglas, Grant, and Lincoln Counties, WA 2003.

	Survey Type				
	Area search	Funnel trap	Incidental obs[a]	incidental obs[b]	Total
Short-horned lizard	15	12	12	35	74
Western rattlesnake	8	0	6	7	21
Western skink	7	5	1	0	13
Gopher snake	2	1	4	7	14
Racer	1	4	1	5	11
W. terrestrial garter snake	0	0	2	0	2
Night snake	0	1	0	0	1
Great-basin spadefoot toad	0	7	3	0	10
Long-toad salamander	0	0	1	0	1
Tiger salamander	0	2	0	0	2
UI observation	3	0	1	1	5
Total Abun	36	32	31	55	154
No. Spp	5	7	8	4	10
% effectiveness[c] ea. method	0.5	0.7	0.8	0.4	

* See Appendix for scientific names
[a] Herptile crew incidental observations
[b] Bird and mammal crew observations
[c] No. species observed by each method divided by no. observed using all methods

Summary results presented here were drawn from all observation methods pooled and using raw count data. Formal statistical analysis has not yet been conducted on 2004 data. Short-horned lizards were again the most abundant and widely distributed species, and the only species documented in all site types (Fig. 1). As in 2003, short-horned lizards were observed most frequently at OS sites (n = 30), then SS (n = 15) and OC (n = 13) sites, with remaining sites supporting fewer individuals. As was the case in 2003, western rattlesnakes were found more in SS sites than in any other site type. Western rattlesnakes were not observed in NC or OC plots in either year. Together, short-horned lizards and western rattlesnakes comprised 62% of all observations in 2004. Western skinks were observed in low numbers in all site types except OC sites, where they were not documented.

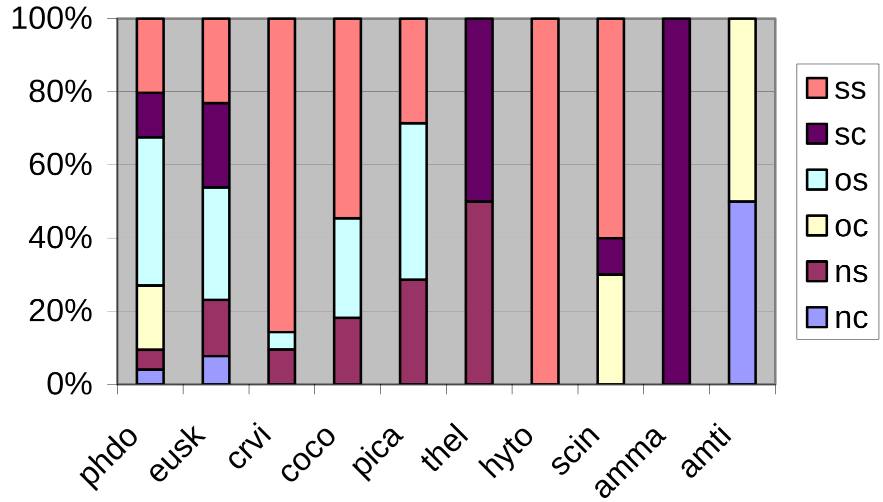

Figure 1. Percent distribution of herpetofauna species among site types, CRP shrubsteppe study area, 2004. 4-letter codes are based on scientific names (Append A.).

The three amphibian species were rare throughout all study sites, but collectively occurred more frequently at SS and OC sites than at the other site types (Table 2). Similar to the trend seen in 2003, total abundance of all species was again highest at SS sites (n = 57) and was next highest at OS sites (n = 45). NS, OC, and SC sites supported intermediate numbers of individuals (n = 15 - 17), while NC plots supported fewest (n = 5). Species richness was again highest at SS sites (n = 7) but was next highest at NS sites (n = 6). Species composition appeared to differ among sites types, however.

Summary

We increased sampling effort in 2004 relative to 2003 by doubling the number of sites sampled, beginning the sampling season in April (rather than June), almost doubling hours of area-search effort (to 192), and conducting 788 nights of funnel trapping (550% increase). Consequently, number of species observed increased from 8 to 10 and individuals observed increased from 94 to 154 (160% increase) in 2004.

Most important, several trends observed during 2003 remained in 2004. Short-horned lizards remained widely distributed among all site types, and western rattlesnakes remained largely restricted to SS sites. Snakes in general were more abundant at sites within shrubsteppe landscapes than at sites in agricultural settings. Trends in total abundance and species richness again suggest that shrubsteppe sites within shrubsteppe landscapes have the highest conservation value for herpetofauna in central Washington, but also that old CRP plots set in shrubsteppe landscapes and shrubsteppe fragments support a substantial proportion of the herpetofaunal community. New CRP plots within shrubsteppe landscapes supported higher numbers of individuals and species than observed in 2003, while new CRP plots in agricultural settings were again herptile-depauperate.

Small Mammals

Introduction

As part of a larger investigation in the northern Columbia Basin ("Wildlife Communities in Shrubsteppe and Conservation Reserve Program (CRP) Lands in Eastern Washington"), we are comparing small mammal species composition and abundance among CRP and shrubsteppe habitat types. In this report, we summarize our methods and present preliminary results and data status for our 2004 sampling. We briefly discuss the main trends in our results so far. We suggest additions to the sampling protocols that would improve our understanding of variation in small mammal communities across these habitats.

Methods

Field—The 2004 sampling was the 2nd year of data collection for the small mammal component of the CRP study. We repeated the protocol used in autumn 2003 to resample the 48 study sites in autumn 2004. Eight blocks were sampled during September 29 to November 8): Black Rock (BR), Chester Butte (CB), Coyote Canyon (CC), Jameson Lake (JL), Pine Canyon (PC) , Pacific Lake (PL), Swanson "Lake" (SL), and Tracy Rock (TR). Each block contained six, 25-ha sites in six habitat categories: shrubsteppe in a shrubsteppe landscape context (SS), shrubsteppe in a cropland landscape (SC), newer CRP fields in a shrubsteppe-dominated landscape (NS), newer CRP sites in cropland landscape (NC), and older CRP fields in a shrubsteppe (OS) or cropland (OC) landscape.

As in 2003, transects were established in reference to the four permanent stations, but 2004 transects were perpendicular to the autumn 2003 transects to minimize overlap in the portions of the site sampled each year. Four 300-m transects were established on each site. Two transects extended between permanent stations 1 and 2, and between 3 and 4 (Fig. 1). A supplemental transect ran parallel to each of these transects, spaced 50 m towards the site boundary. Each transect included 31 stations at 10-m intervals. A single Museum Special snap trap was placed at each station. Transects were open for 4 consecutive nights and checked daily, producing a nominal trap effort of 496 trap nights per site (124 traps x 4 nights). Each site was trapped once in 2004, with nearly simultaneous sampling of sites within a block (all sites open on at least two of the same nights).

Traps were baited with a mixture of peanut butter and rolled oats, and set within 1.5 m of the station. Traps were checked each of the following 4 days. Sprung, stuck, or missing traps were reset or replaced; bait was added as necessary; and dead animals were collected. Animals that were paralyzed or mortally wounded but still alive were euthanized with halothane and collected. A small percentage of animals were alive with minor injuries. These animals were given temporary marks with a Sharpie marker and released. Preliminary species identification was recorded for all animals in the field, and each was assigned a unique identification number. Animals were frozen until lab processing.

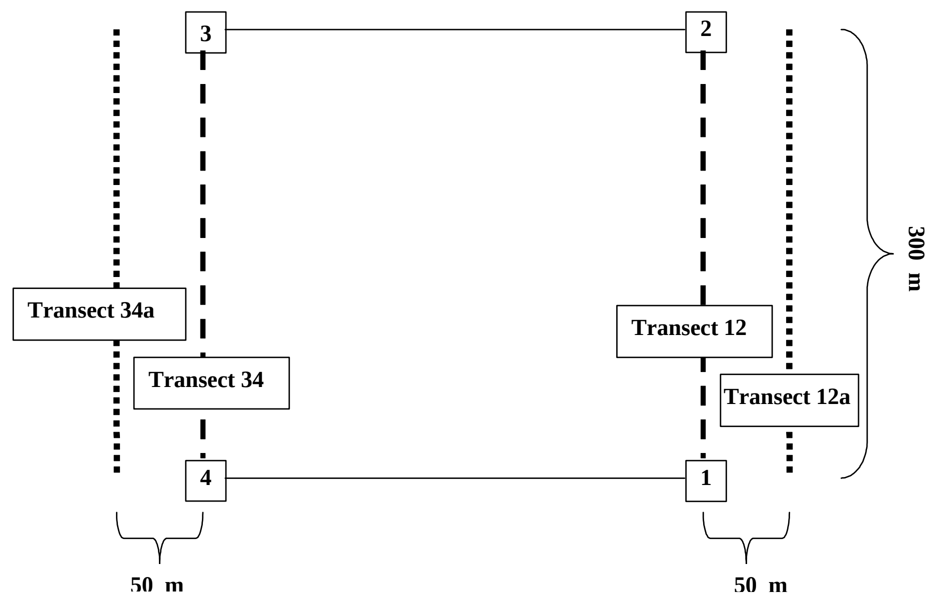

Figure 1. Schematic diagram of plot and transect layout. Boxed numbers (1, 2, 3, 4) indicate permanent site reference points. Snap trap transects are indicated by lines. Autumn 2004 transects extended from 1 to 2 and 3 to 4 (transects 12 and 34), with additional transects established parallel to these lines (12a and 34a). Transects in autumn 2003 extended perpendicular to 2004 transects, overlapping them only at the permanent reference points.

Lab Curation—During lab processing, we recorded standard external measures (mass, total length, and lengths of tail, ear, and hind foot), sex, and reproductive information (size and condition of nipples or testes, size of seminal vesicles, size and number of embryos, and number of distinct placental scars on the uterine horns. Species were identified based on external characters and dental characteristics, following Ingles (1965), Verts and Carraway (1998), and Nagorsen (2002). Identification of shrews other than definite *Sorex vagrans* is being confirmed at the Burke Museum, University of Washington.

Current Data Status and Analysis—We report preliminary capture numbers by species and habitat type, but urge caution in interpreting these numbers. Although we report capture numbers (based on number of unique animals captured during 4 trap days per site), additional work is needed to derive the estimates to be used for statistical analysis. Capture numbers will be standardized as captures per 100 trap nights (Catch per unit effort; CPUE) to account for sprung, stuck, and missing traps, and those sprung by other species. For the deer mouse and other species when feasible, we will examine whether capture probabilities vary by habitat. If such variation is present, abundance will be estimated for each site using removal estimators, and these estimates will be used for statistical comparisons (Skalski and Robson 1992). Verification of species identifications have been completed for most shrews and for approximately half of the voles. Lab processing of specimens will continue during winter and spring 2005 and final capture numbers will be verified when this is complete.

Results

During autumn 2004, we captured approximately 2669 small mammals during 23,800 trap nights on eight blocks (48 sites; Table 1). Overall, we captured at least nine small mammal species. Three species, the deer mouse (*Peromyscus maniculatus*), Great Basin pocket mouse (*Perognathus parvus*), and western harvest mouse (*Reithrodontomys megalotis*) made up 81% of captures. The deer mouse was captured most frequently. Other species captured were the least chipmunk (*Tamias minimus*), sagebrush vole (*Lemmiscus curtatus*), montane vole (*Microtus montanus*), northern pocket gopher (*Thomomys talpoides*), Merriam's shrew (*Sorex merriami*), and vagrant shrew (*S. vagrans*). One shrew has been identified preliminarily as the masked shrew (*S. cinereus*) based on dental characteristics, but additional examination of cranial features is needed. Unless this shrew is identified as a *S. merriami* or *S. vagrans* with atypical teeth, it will be a species not captured in 2003. Two additional voles, the long-tailed vole (*M. longicaudus*) and meadow vole (*M. pennsylvanicus*) may be identified during lab curation of unprocessed voles. The long-tailed vole was captured in 2003, but no definite meadow voles have been identified so far. Final identification is needed for two 2003 voles preliminarily identified as meadow voles, but now believed to be montane voles. No birds, reptiles, or amphibians were captured in 2004.

As in 2003, the western harvest mouse and sagebrush vole showed trends toward higher average relative abundance in CRP fields than on shrubsteppe patches (Table 2), the Great Basin pocket mouse had similar captures across all habitat conditions, and least chipmunks were captured mainly in shrub-steppe habitats. Although the deer mouse was captured most frequently in CRP fields in 2003, in 2004 captures were similar between CRP fields and shrub-steppe sites. At least twelve Merriam's shrews were captured in 2004, compared with two captures in autumn 2003. Most (10/12) 2004 captures of Merriam's shrew were in CRP fields. In addition to seven definite vagrant shrews, two probable vagrant shrews require additional examination to confirm that they are not Merriam's shrews. Merriam's shrews were captured on 6 of 48 sites in 2004 (JL, PC, and SL blocks). Although only one northern pocket gopher was captured in 2004, we observed its excavations frequently.

Additional analysis is needed to compare abundances between old and new CRP fields and between sites in a shrubsteppe vs. cropland landscape context. Although the deer mouse repeated its 2003 trend of higher captures in sites surrounded by cropland, variability in raw capture numbers was high (coefficient of variation of deer mouse captures among replicates of each habitat type = 71-150%). The least chipmunk was present in low numbers on three CRP sites. Two of these were the older CRP fields in a shrubsteppe landscape context where chipmunks had been captured in 2003. The third CRP site had lower shrub cover and was in a cropland landscape (CCOC). As in 2003, we observed chipmunks in sagebrush stands within a few hundred meters of several other CRP grassland sites, but did not capture or see any individuals in these CRP fields.

Captures per site of all small mammal species varied widely (range 3-171 mammals per site), similar to the 2003 spread (3-192). Overall, we captured approximately 550 more animals in autumn 2004 than in autumn 2003. Although one site was not sampled in 2003, we captured only 16 animals there in autumn 2004, so it contributed little to the increase. Although captures of most species increased, voles contributed the most to this change. Captures in 2004 were approximately 3.1 times greater than in autumn 2003 for all voles pooled, compared to 1.3 times greater for least chipmunks, pocket mice, and harvest mice, and 1.1 times greater for deer mice).

Discussion

As in 2003, we observed contrasting occurrence across habitat types for two shrub-steppe species. The sagebrush vole appeared to be more abundant on CRP sites than shrub-steppe habitats. Despite its name, CRP grasslands with no shrub cover supported reproductively active populations of this species. The least chipmunk showed the strongest association with remnant shrub-steppe patches or CRP sites with high shrub cover. The importance of shrub cover to least chipmunks is a general trend in shrub-steppe areas of North America (Verts and Carraway 2001). However, we cannot explain its absence from large shrub-steppe habitats in some study areas (e.g., Black Rock and Pacific Lake shrub-steppe sites and adjacent patches).

The three-fold increase in vole captures is the most noteworthy difference between 2003 and 2004 results, based on initial examination of data. Due to multi-year fluctuations, results from two autumns may not capture long-term averages in relative habitat occupancy for any of the species we sampled. However, this risk may be most pronounced for the voles. Both the sagebrush and montane voles may show population irruptions and crashes (Verts and Carraway 1998). For the sagebrush vole, there is limited data available throughout its range to assess how much populations may fluctuate over a several-year period. Data on multi-year fluctuations are anecdotal (Moore 1943), from short-term studies (e.g., 13 months for Mullican and Keller 1986), or from areas that support low densities and are at local distribution boundaries (e.g., Rattlesnake Mountain, O'Farrell 1972). *Microtus* often demonstrate extreme yearly variations in abundance. The montane vole may have three-year cycles in some areas, although this is speculative (Verts and Carraway 1998:324). During a four-year study of montane voles in British Columbia (Sullivan et al. 2003), there was up to a three-fold difference in abundance across years in higher-density old field habitats, and up to a 100-fold difference in lower-density orchard sites. Old fields had 1.5-3 times greater abundance than orchards when abundance was highest, and 24-116 times greater abundance when abundance was lowest. As noted earlier, one of the most interesting aspects of the 2003-2004 data is the high occurrence of sagebrush voles on CRP grasslands. Further study is needed to assess yearly variation, and whether the numerical dominance of sagebrush voles compared to *Microtus* on the CRP sites persists beyond these two years of sampling.

In both years of sampling, variability in capture rates and species occurrence among sites of the same habitat type or landscape composition has been high among and within blocks. Future analyses will address variation contributed by sampling effects, such as differences in capture probabilities and trap availability (e.g., variable number of traps sprung or occupied by other mammals) across sites. In addition, much of the overall variability may be driven by site-specific factors (planting mix, successional variation, and other random factors) that affect habitat characteristics of greatest importance to small mammals. Regression modelling of abundance vs. habitat data (vegetation structure and gross soil characteristics) for each site is needed both to understand better the variation in small mammal communities across the general habitat categories and to determine how specific habitat variables (e.g., shrub cover) could be managed to affect these communities on CRP sites. In addition, landscape characteristics used to define the two landscape categories (cropland vs. shrub-steppe) should be further examined as continuous variables in the regression analysis. Variation in these characteristics (e.g., percent of surrounding patches in cropland) appears to be high among replicates of the same landscape context, and obtaining continuous values for these predictors may provide better insight into effects on small mammal communities.

Recommendations for Additional Sampling

- A third year of sampling would be valuable to gain a better measure of the yearly variation of small mammal abundance in this system, and yearly variation in comparative patterns across the six study habitats. This is particularly important for voles, which showed three times higher captures in 2004 compared to autumn 2003. There are a low number of multi-year studies on sagebrush voles and huge fluctuations in abundance for *Microtus* are likely. A 3rd year of sampling would give some insight into whether vole abundance in 2004 was part of a multi-year increase. Sampling should repeat the protocol used in autumn 2003 and 2004.
- Once relative abundance or abundance estimates for 2003-2004 are calculated, a regression analysis of abundance vs. habitat variables measured by WDFW in 2004 should help explain variation in small mammal populations between and among habitats.
- We are continuing to collect contents of pocket mouse cheek contents in hopes of comparing food habits (cheek pocket contents) across the study habitats.
- As discussed last year, other relatively small additions to the sampling would be of value, but are not feasible currently. Budget and time limitations prevented us from pursuing these in 2004. First, additional sampling with pitfall traps on a subset of sites would be valuable to provide supplemental data on shrew abundance and species composition. Second, even a small amount of sampling in cultivated croplands would help assess the value of CRP fields. We assume that CRP fields are supporting small mammals that are absent or in low abundance on adjacent active croplands. Even a few hundred trap nights on wheat fields, regardless of their growth stage, would provide some qualitative insight about this assumption. However, a larger sampling effort comparing crop fields in different stages (e.g., wheat fields in freshly harvested, fallow, or green conditions) with a subset of the CRP habitat types would be necessary and valuable for detailed insight. Third, our survey methods do not adequately sample northern pocket gophers or ground squirrels, reducing our insight into how the small mammal prey base varies across the habitats. Additional methods that may index abundance of these species should be considered.
- Broader study is needed of the least chipmunk's distribution in shrub-steppe patches of eastern Washington, and patch- and landscape-level features affecting this distribution.

Table 1. Preliminary number of small mammals captured by species and study area during autumn 2004.

Species	Black Rock	Chester Butte	Coyote Canyon	Jameson Lake	Pine Canyon	Pacific Lake	Swanson Lake	Tracy Rock	Total
Masked shrew	0	0	0	0	1	0	0	0	1
Merriam's shrew	0	0	0	4	2	0	6	0	12
Vagrant shrew	0	0	0	4	0	0	0	6	10
Least chipmunk	0	13	7	17	0	0	8	12	57
Northern pocket gopher	0	0	0	0	1	0	0	0	1
Great Basin pocket mouse	108	65	61	25	33	51	73	19	435
Deer mouse	114	139	59	143	187	122	308	409	1481
Western harvest mouse	80	16	39	3	29	34	22	26	249
Sagebrush vole	6	27	11	66	24	50	75	84	343
Montane vole	1	0	4	0	0	3	0	0	8
Unidentified *Microtus*	0	1	0	2	0	0	25	45	73

Table 2. Preliminary mean (SE) number of individuals captured for common rodents by habitat condition during autumn 2004. Sample size = eight sites for each habitat/landscape context combination.

Habitat/Landscape context	Merriam's shrew	Least chipmunk	Great Basin pocket mouse	Deer mouse	Western harvest mouse	Sagebrush vole	*Microtus* voles
New CRP/Cropland	0.6 (0.4)	0.0 (0.0)	7.0 (2.3)	40.4 (10.2)	7.9 (4.2)	7.1 (2.4)	2.5 (1.6)
New CRP/Shrubsteppe	0.0 (0.0)	0.0 (0.0)	12.3 (4.6)	29.3 (16.2)	7.9 (3.6)	3.4 (2.3)	0.1 (0.1)
Old CRP/Cropland	0.1 (0.1)	0.3 (0.3)	8.5 (2.4)	36.5 (14.5)	3.4 (2.0)	9.4 (2.9)	1.5 (1.0)
Old CRP/Shrubsteppe	0.5 (0.5)	0.8 (0.6)	10.5 (2.4)	21.0 (6.9)	7.8 (4.1)	14.4 (5.8)	2.8 (1.7)
Shrubsteppe/Cropland	0.1 (0.1)	2.5 (1.3)	10.0 (2.1)	38.0 (9.6)	2.3 (1.6)	6.0 (1.9)	1.4 (1.4)
Shrubsteppe/Shrubsteppe	0.1 (0.1)	3.6 (1.6)	6.1 (1.1)	20.0 (5.2)	2.0 (1.3)	2.6 (1.5)	1.4 (1.0)

Pellet Surveys

Objectives

Our objectives were to quantify use of the 6 site types by wildlife species of interest that were not sampled adequately by other methods (e.g., Greater-Sage Grouse, Sharp-tailed Grouse, mule deer, and lagomorphs). These species leave fecal pellets of sufficient size to be identified and counted to derive an index of abundance.

Methods

In fall of 2004 we established sampling plots for a systematic pellet-count survey. Plots were established in 24 of the study sites; 4 replicates of the 6 different site types. Circular sample plots ($50m^2$) were centered on the 4 50-m flags of each survey point (total of 16 plots /site) and were cleared of all pellets. Pellets were counted and attributed to different species based on size and shape. Avian pellets too small to be produced by prairie grouse were attributed to "game birds" (Ring-Necked Pheasant, Chukar, and Gray Partridge). Sites will be visited in spring of 2005 and surveyed again for pellets deposited over the winter.

Results

A total of 21879 pellets or pellet groups were counted on 24 sites. Figure 1. shows the relative distribution of pellets among the different site types for each species. As this was the first sampling for these sites, pellets were deposited over an unknown length of time; however, there were distinct patterns for some species. Further sampling of these sites, by season, may reveal different trends.

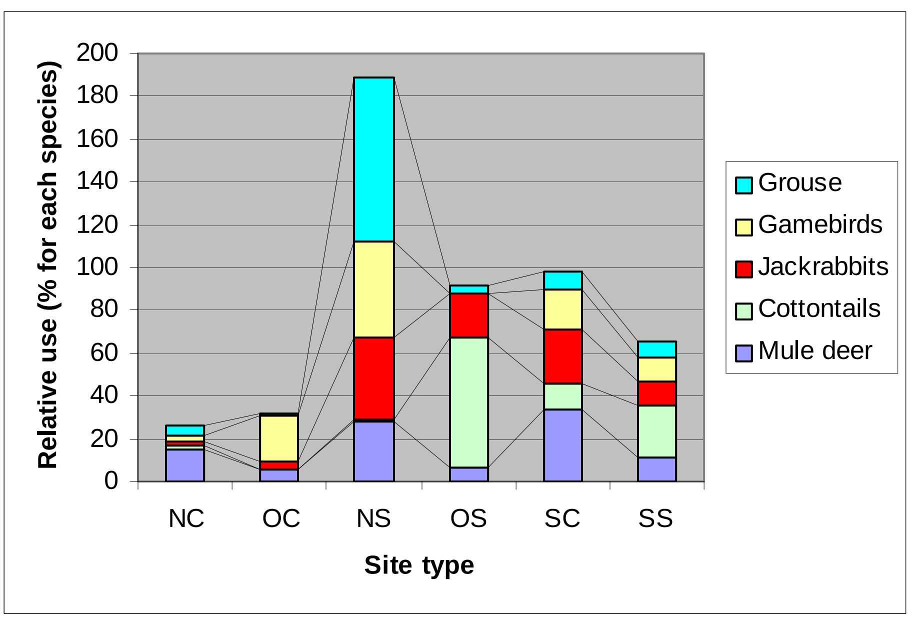

Figure 1. Relative distribution of pellets among different site types, by species.

AN INVESTIGATION OF BIOLOGICAL CRUSTS IN GRASSLAND AND SHRUB-STEPPE ECOSYSTEMS FOR THE CONSERVATION RESERVE PROGRAM, WASHINGTON STATE

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1. Introduction

1.1 Background and Purpose

Biological crusts, also known as cryptogamic or microbiotic crusts, are common and ecologically important components of the shrub-steppe and grassland plant communities of the intermountain west. In undisturbed and lightly disturbed sites, biological crusts cover much of the soil surface in the interspaces between vascular plants, performing a number of essential ecological functions (Belnap et al. 2001, McIntosh 2003).

Shrub-steppe was the dominant habitat type preceding settlement in eastern Washington (Daubenmire 1970, Vander Haegen et al. 2003). Widespread agriculture, especially crop production, is principally responsible for the loss of over 60% of the original shrub-steppe in eastern Washington. Much of the remaining shrub-steppe is degraded and fragmented, isolated from other similar habitats (Vander Haegen et al. 2000). Thus, because of threats to the remaining sites from human-associated causes, it warrants special management considerations. Shrub-steppe is considered a Priority Habitat in Washington State.

The Conservation Reserve Program (CRP) is currently the only large-scale effort in the Columbia River Basin that is designed to restore shrub-steppe for use by native wildlife. The CRP offers landowners, operators, and tenants the opportunity to voluntarily convert land to permanent and native vegetative cover. The overall program goals are to reduce soil erosion, enhance fish and wildlife habitat, improve water quality, protect the soils on the nation's cropland base, demonstrate good land stewardship, and improve rural aesthetics. The current acreage of CRP land in eastern Washington is equal to almost 15% of the Washington's total agricultural lands.

Research, in particular by the Washington Department of Fish and Wildlife, has been designed to evaluate the potential role of CRP in long-term shrub-steppe conservation in the Columbia River Basin. To date, this research has mainly focused on wildlife, in particular birds, mammals, and reptiles (Vander Haegen et al. 2003).

The present study has been designed to compliment ongoing wildlife research in the Conservation Reserve Program. The study's main aim is to determine the successional status of biological crusts in different age sites of former cropland within the CRP mandate around Coulee City, Washington. Although the ultimate aim of this research is to examine all eight CRP sites in the Coulee City area, funding only allowed for sampling five of the sites (and 30 treatments) in 2004.

1.4 Biological Soil Crusts

Biological soil crusts are complex groupings of organisms that grow over the soil surface in many arid and semi-arid landscapes (Belnap et al. 2001, Ponzetti 2000). The dominant organisms that comprise crusts are lichens, bryophytes (principally mosses but also a few liverworts; McIntosh 1986), single-celled algae, and cyanobacteria (Belnap et al. 2001, Belnap 2003, McIntosh 2003). These organisms are intermixed with fungal hyphae, plant roots, litter, and soil, and are often thin and compact. Because of the numerous organisms that typically comprise them, biological crusts are an important component of arid land biodiversity.

Biological crusts perform a number of ecologically important roles that contribute to ecosystem integrity and health (Belnap et al. 2001, Evans and Johansen 1999, Ponzetti 2000). For example, they contribute to soil stability. Open soils are often in constant movement, as particles are displaced by wind and water. As a biological crust develops, the soil stabilizes and soil displacement is reduced or eliminated, mainly due to the binding of soil particles by the various crust organisms (Belnap 2003, Belnap and Gardner 1993, Schulten 1985). The complex surficial microtopography of a crust creates a boundary of still air and further protects the soil from wind erosion (Eldridge and Kinnell 1997, Neuman and Maxwell 1999, Lehrsch et al. 1988). The presence of intact biological crusts may also inhibit the establishment of cheatgrass (*Bromus tectorum*) and other invasive species (Belnap et al. 2001, Kaltenecker et al. 1999).

Biological crusts influence surficial hydrology as well. It appears that, at least in some areas, water infiltration rates are increased when a crust is present, although the degree of infiltration is influenced by a number of factors, including soil type, crust composition, and climate (Eldridge 1993, Ponzetti 2000).

Lichens, bryophytes, cyanobacteria, and green algae in the crust fix atmospheric carbon, contributing to the overall productivity of a plant community. Free-living cyanobacteria and those lichens with a cyanobacterial component are capable of fixing atmospheric nitrogen, which is subsequently released into the soil and used by the associated vascular plants and fungi, enhancing the ecosystem (Belnap et al. 2001, Evans and Belnap 1999). In some cases, vascular plants that grow in areas of well developed crusts have higher accumulations of phosphorus, potassium, iron, calcium, magnesium, and manganese than in sites that lack crusts (Belnap et al. 2001, Ridenour and Callaway 1997).

Most biological soil crusts are fragile and readily disturbed, although susceptibility to disruption is related to factors such as soil type, local climate, and vascular plant community composition (Belnap et al. 2001, Ponzetti 2000). Over the past century, most biological crusts in the Pacific northwest have been heavily altered or destroyed by livestock, crop production, fire, and off-road vehicle use. There is evidence that the biological crusts in the Pacific northwest evolved in low disturbance environments, where impacts by large herbivores and landscape-wide fires were much less severe than at present (Mack and Thompson 1982).

1.5 Previous Soil Crust Research in the Region

Very little research has been completed on the biological soil crusts in the Columbia River Basin, partly because crusts are often overlooked in shrub-steppe studies. For over 20 years, the author (McIntosh 1986, 1989, 2003) has been investigating biological crusts, in particular their bryophyte and lichen components, across semi-arid habitats from Oregon north into British Columbia, as well as in the southern Yukon where crusts very similar to those of the Columbia River Basin are found. Limited early studies include Daubenmire (1970) who discussed crusts in his seminal work on shrub-steppe, Johansen et al. (1993) who studied the effects of fire on the algal and cyanobacterial crust components of crusts on the Arid Lands Ecology Reserve near Richland, and Link et al. (2000) who completed a survey of lichens and bryophytes in the same area. Ponzetti et al. (2000) completed an extensive grazing management-related ecological study of the biotic crust communities in the Horse Heaven Hills, in Benton County south of the Yakima River.

Some research has been completed in the Columbia River Basin regarding the succession of biological crusts from the colonization of bare soil to a 'climax' crust (Ponzetti 2000, McIntosh 2003 and pers. obs.) General observations about crust succession include:

1. succession is related to soil composition and other factors (slope, aspect, elevation, etc.).
2. cyanobacteria and mosses (rarely lichens) appear to be the principal early colonizers, with mosses more dominant on sandier/stonier soil types.
3. distinct successional patterns of species occur, with lichens tending to dominate in mid to late succession on silt and clay rich soils, and mosses tending to dominate in mid to late succession on sandier soils.
4. mature ('climax') crusts rarely completely cover the soil surface; micro-perturbations frequently occur across the shrub-steppe that continually disturb the crust at a small scale.
5. although some species are prevalent (or only found) in early successional crusts, and others mainly in late seral crusts, other species (in particular the moss *Ceratodon purpureus*) are present across the successional cline reflecting either their wide range of tolerances and competitive ability, or the continual micro-disturbance of the crust itself.
6. species composition tends to vary place to place with more northern elements dominating north of the Hanford area, and more southern elements at Hanford and southwards.

1.6 Constraints on the Identification of Lichens and Bryophytes

Many species of lichens and bryophytes are difficult to determine with confidence in field studies. There are a number of reasons for these difficulties, including:

1. Taxonomic problems and lack of experts: These two groups of organisms have relatively few specialists who fully understand specific genera, let alone the full suite of taxa that are present in a particular arid land ecosystem. This is partly

due to the inherent difficulties in their identification, such as the necessity for microscopic examination or, in the case of many lichens, chemical testing of specimens before conclusive identifications can be made. Few taxonomic keys and little illustrative material is available for most groups. Some species must be sent away to experts before confirmation can be made. Because of this, a number of species from this survey remain tentatively identified or identified only to genus.

2. Small size and intermixing of taxa in the field: Most species of arid land lichens and bryophytes are small in stature. Lichen thalli, apothecia, and many mosses often range from >1mm to 2mm in size at maturity, are often difficult to see in the field, and often must be collected for positive identification. Even then, the small stature of many species leads to difficulties in identification, even with the use of microscopes; most species of arid land mosses must have cross-sections of their leaves made and lichen spores must be examined before identifications can be made. Further, bryophyte and lichen taxa are often intermixed over the soil surface, with, often, over 10 species being present on ~2 cm^2 patches of soil, and this may lead to some species being missed during fieldwork.

3. Species variation: Identification of many species of dryland lichens and bryophytes often depends on the maturity of the organism. Mature specimens with reproductive structures, at least with respect to many of the lichens, are most readily identified. However, many specimens lack reproductive organs, or are juvenile and difficult or impossible to identify, such as the case with many taxa found in the more heavily disturbed areas. Also, many species have a variety of growth forms that may be related not only to age but to environmental conditions. This can lead some researchers to identify multiple collections as one or more species, depending on their experience and taxonomic background.

2. Methods

2.1 Timing and Site Location

A reconnaissance field visit to selected CRP sites west of Coulee City was made on June 8, 2004, accompanied by M. Vander Haegen. Site orientation and potential sampling designs were discussed at this time. Spot collections of bryophytes and lichens were made in order to initiate species lists.

Biological crusts were measured during two sessions: from July 21 to 22, and from September 21 to 23. Table 2 lists each CRP site in which biological crusts were measured and the locations of their corresponding treatments .

Table 2: Locations of CRP Treatment Sites.

CRP Site	Treatment Location (start of transect; all UTMs E / N and 11T)
Jameson Lake	JLSS: 0306776 / 5283269 JLSC: 0312849 / 5286035 JLNS: 0307655 / 5284496 JLNC: 0319562 / 5280795 JLOS: 0306336 / 5284499 JLOC: 0319011 / 5281055
Coyote Canyon	CCSS: 0298046 / 5274506 CCSC: 0302411 / 5253672 CCNS: 0297276 / 5263970 CCNC: 0305828 / 5265047 CCOS: 0301366 / 5274385 CCOC : 0301685 / 5266409
Tracy Rock	TRSS: 0390471 / 5278409 TRSC: 0396983 / 5268918 TRNS: 0388694 / 5270077 TRNC: 0403729 / 5272361 TROS: 0395083 / 5272521 TROC: 0407779 / 5270033
Swanson Lake	SLSS: 0385004 / 5273408 SLSC: 0359404 / 5256639 SLNS: 0384747 / 5267885 SLNC: 0375516 / 5261338 SLOS: 0380708 / 5268958 SLOC: 0354142 / 5264857
Pacific Lake	PLSS: 0366352 / 5252834 PLSC: 0393376 / 523149X PLNS: 0369614 / 5254575 PLNC: 0372362 / 5249360 PLOS: 0380919 / 5253426 PLOC: 0371576 / 5248338

2.2 Biological Crust Sampling Protocols

i. General Protocols and Transect Site Selection

Following a site reconnaissance, the most homogeneous part of the site closest to a central pin was selected for transect placement. Each transect start location was randomly selected within a 5 m area, and a 50m tape was stretched out parallel to a slope, if present. UTMs (NAD27) were logged at the start of each transect (Table 2). Photographs were taken using a Nikon Cool Pix 950 digital camera down the center of each transect from the origin, as well as across the community.

Other representative photographs were also taken in order to fully document the character of the plot and the surrounding vascular plant community. Descriptive notes were made at all sites. Appendix 1 describes all of the treatment sites, and provides photographs.

A collection of all moss and lichens was also made adjacent to the transect at each treatment site for identification later. A number of references were used in the identification process. Because of the relatively early stage in the investigation of arid land lichens, there are no complete references available for this group, although Goward et al. (1994), McCune and Rosentreter (1995), and Brodo et al. (2001) are useful guides. There are more references available for the bryophytes, including Flowers (1973), Lawton (1971), McIntosh (1986, 1989), Rossman (1977), and some of the recently published works for the Bryophytes of North America Project (2004; available at http://www.buffalomuseumofscience.org /BFNA/).

Representative specimens of all species will be packaged, labeled, and sent to the US Fish and Wildlife offices in Seattle, or to the herbarium at the University of Washington, Seattle. Additional specimens will be housed at the University of British Columbia, Vancouver, Canada.

ii. Transect/Plot Sampling Protocols

Twenty 20 X 20 cm plots (microplots) were sampled at 1m intervals along each transect (this relatively small plot is considered to be an effective method for measuring cover of microbiotic species; Belnap et al. 2001); if a plot was located on a spot that was not representative of the site (i.e., heavily disturbed, under a shrub, or in a grass tussock) it was moved either to the opposite side of the transect, or 1m along the transect if the opposite side was also not representative[1].

Cover of mineral soil, litter, total biological crust, vascular plant bases, stones or rock, and individual species, or species groups, were estimated using the sampling scale of Ponzetti (2000; Table 3), and data recorded on plot sheets. This sampling scale is most useful in this work with small species in small plots, as it reduces errors that would arise if actual percent were estimated. Also, it speeds up sampling and data entry. One observer was used for all plots in order to reduce potential estimation errors. In some sites, there were ambiguous taxa that were lumped into two categories: unidentified bryophytes or unidentified lichens. At most sites (except some of the early seral O_ and N_ sites), the great majority of the species present along or near the transect were captured in the sampling plots. Microbiotic species that were not encountered in the plots during the sampling but are representative of the habitat near the transect are listed in Table 4.

[1] The ground at all sites, even shrub-steppe sites, exhibited a more or less irregular mosaic of patterning from patches of open soil to patches of crust, mainly as a result of past or ongoing disturbance of some kind. Thus, it is difficult to be confident that the transects were placed in an area fully representative of that site.

Table 3. Sampling Cover Scale (from Ponzetti 2000)

Scale Value	Representative % Cover
1	< or = 1
2	> 1 - 4
3	> 4 – 10
4	> 10 – 25
5	> 25 – 50
6	> 50 – 75
7	> 75 – 95
8	> 95 - 100

Collections of representative species from a few of the plots were stored in small coin packets in order to confirm identifications later, and to see if smaller taxa were missed and could be added to the data sheets. Some species will be sent to experts for identification.

2.3 Data Manipulation and Analysis

Prior to analysis, cover data of the environmental variables, lichens, and bryophytes, were totaled for the 20 plots from each transect at each site. Data were then entered in to an EXCEL file and, in order to assess site and species relationships, analyzed using Detrended Correspondence Analysis (DCA). This is one of many ordination methods designed to produce a graphical representation of a set of data points (in our case sites and species; Fig. 1 and 2 below)[2]. Basically, ordination techniques identify similarity or dissimilarity between points (sites or species). They summarize 'community' data and produce an ordination or swarm of points (based on species presence and cover values at respective transects, or sites). On the ordination, sites and species are projected in two dimensions in such a way that sites and species most similar to one another will be close together, and sites and species most dissimilar from one another will appear farther apart.

The cover values of the five environmental variables (mineral soil, litter, total biological crust, plant bases, and stones/rock) are then assessed as to their 'importance' with respect to the ordination of the sites and species (by comparing the totals of the cover values of the variables with the representative site and species data).

The DCA was run four times, the first time including all of the taxa that were recorded during sampling (34 taxa), and three subsequent times, eventually reducing

[2] DCA resembles principal components analysis, but is based on a different type of similarity matrix. Like other forms of ordination, results from correspondence analysis often plot along a marked curve, or horseshoe, when seen in two dimensions. DCA is a correspondence analysis with a subsequent procedure, detrending, to remove this tendency.

the number of taxa by 16, to 18 taxa (twelve distinct species and six groups of species). Taxa were excluded for two reasons:

1. some were lumped into one taxon, for example all species of the mosses *Didymodon* and the *Syntrichia ruralis* complex (because of field identification difficulties and similar ecological preferences), or
2. low values or in one plot only (the removal of these species did not markedly affect the ordination but allows for a clearer representation of points in the species ordination).

A further analysis, HyperNiche (McCune and Mefford 2004) was investigated as a tool for the nonparametric multiplicative regression of species abundances along environmental gradients.

3. Results and Discussion

3.1 Introduction

This study represents a preliminary investigation of biological crusts in CRP sites of eastern Washington. It is not complete, mainly because the need to measure the crust in the remaining three CRP sites in the area, but also because a few, possibly, critical, *Didymodon* and lichen taxa need to be identified to species. Further, it is important to note that a number of the sites may not be necessarily readily comparable; that is, sometimes comparisons may be made between N_ or O_ sites with shrub-steppe sites (S_) quite distant from the N_ or O_ site. A refinement or supplementary study should measure crusts adjacent to the O_ or N_ sites.

3.2 Description of the Biological Crust

Based on the sampling for this project, as well as through inspections of shrub-steppe communities at other sites in the area, the mature biological crusts across the study area, for example at the CCSS site, can be considered a northern (and wetter) variation of the *Trapeliopsis steppica - Bryoerythrophyllum columbianum* Biological Crust Community described in McIntosh (2003) for the Hanford Reach National Monument to the south of the study area. At Hanford, this community is described as characteristic of sandy-loam to silt-loam soils, and is associated with big sagebrush, blue-bunch wheatgrass, Sandberg’s bluegrass, and Carey’s balsamroot. Associated indicator crust species at Hanford that are present in the present study include the lichens *Acarospora schleicheri*, *Arthonia glebosa*, *Aspicilia* sp., *Cladonia* sp., *Diploschistes muscorum*, *Leptochidium albociliatum*, *Leptogium* cf. *lichenoides*, and *Trapeliopsis bisorediata*, and the mosses *Bryoerythrophyllum columbianum*, *Syntrichia ruralis*, and *Trichostomopsis australasiae*. One of the principal crust lichen species from the Hanford area, *Trapeliopsis steppica*, is absent in CPR steppe crusts; this may reflect this species' restriction to hotter and/or drier sites.

Table 4 lists the species encountered during the transect surveys as well as those taxa that were used in the ordination (the acronyms are bolded following the names of these taxa).

A number of fairly common taxa were not identifiable to species during plot sampling, except occasionally. Thus, they were grouped during the analysis either as genera or, once, as species. These include:

1. Species in the lichen genus *Aspicilia* (Asp): this is a relatively common genus, especially on or near litter and in some mossy sites; it also has a number of growth forms that confuse identifications; at least one species, *A. reptans* is present in CRP sites, although others are probably present.
2. Species in the lichen genus *Cladonia* (Cl): although common, these species rarely produce podetia (reproductive columns that are critical for positive identification) in arid environments. However, some fertile collections were made in a few sheltered sites in shrub-steppe habitats near CRP sites. They include *C. cariosa*, *C. chorophaea*, *C. poxillum*, and *C. pyxidata* (they are not listed in Table 4 as they were not found near the transects).
3. Species in the lichen genus *Collema* (Co): this genus, characterized by small, blackish thalli (referred to as 'black scum' by some researchers), is considered to be one of the most difficult genera to identify, even with mature and fertile material. At least *C. tenax* and, probably, *C. coccophorum* are present in the CRP crusts. Also, *Placynthiella uliginosa*, another small black species is also likely present.
4. Species in the moss genus *Didymodon* (Di): Sterile specimens in this genus are common, especially in early seral sites. At least three species, *D. australasiae*, *D. brachyphyllus*, and another unidentified taxon have been confirmed for CRP sites.
5. Species in the lichen genus *Lecanora* (Le): This genus is relatively common on litter or soil near litter. Only *L. muralis* was confirmed although *L. zosteri* was collected in other habitats near the CRP sites.
6. The moss species *Syntrichia ruralis* (commonly known as *Tortula ruralis*) The variety *papillosissima* , sometimes considered a species in its own right, was also found in the study area and is included within *S. ruralis* here.

Table 4: Lichen and Bryophyte Taxa Reported from Five CRP Sites (L = lichen, M = moss, and L = liverwort; X represents presence at a site, but not recorded in microplot sampling; numerical values represent combined cover data in the 20 sampling microplots along each transect)

SITES TAXA	**JL SC**	**JL OS**	**JL SS**	**JL NS**	**JL OC**	**JL NC**	**CC SC**	**CC NS**	**CC OC**	**CC NC**	**CC SS**	**CC OS**	**TR SS**	**TR OS**	**TR NS**	**TR SC**	**TR NC**	**TR OC**
(L) Acarospora schleicheri **(AS)**	5						1				1		1					
(L) Aspicilia reptans																		
(L) Aspicilia spp. **(Asp)**	2						9				8							
(L) Arthonia glebosa												X						
(M) Bryoerythrophyllum columbianum **(Bco)**	7						X				91							
(M) Bryum argenteum **(BA)**	7		11	5	6	1	1	6	12	4	7	1	1	2	18	13	3	5
(M) Bryum cf. caespiticium **(Bce)**	8	13	6	14	15	25		13	3	23	10		2		116		16	18
(M) Brachythecium albicans																		1
(L) Caloplaca jungermanniae																		
(L) Caloplaca tominii			X															
(L) Candelariella terrigena																1		
(L) Cephaloziella divaricata **(CD)**	10				1						9		X					
(M) Ceratodon purpureus **(CP)**	16	68	73	25	91	51	11	23	117	49	24	X	10	30	30	41	49	46
(L) Cladonia sp. (+/- 3 spp.) **(Cl)**	56	8	46		1		48		12		36	3	23	50	X			6
(L) Collema spp. **(Co)**	6	28	33		31		7		20		5	1	2	7		1		
(M) Didymodon australasiae	X		1				X											
(M) Didymodon brachyphyllus	X		X	X			X	X	X			X						X
(M) Didymodon spp. **(Di)**			7	1			X	6	15		1	1						1
(L) Diploschistes muscorum **(DM)**	18		12		X		10				11		5	1				1
(L) Endocarpon pusillum			X															
(M) Funaria hygrometrica																		
(M) Grimmia alpestris (usually on stones)	X										X							
(L) Lecanora sp. **(Le)**			X													X		
(L) Lecanora muralis											1							
(L) Lecidiella stigmatea			X															
(L) Leptochidium albociliatum																		

Table 4 (continued)

SITES TAXA	JL SC	JL OS	JL SS	JL NS	JL OC	JL NC	CC SC	CC NS	CC OC	CC NC	CC SS	CC OS	TR SS	TR OS	TR NS	TR SC	TR NC	TR OC
(L) Leptogium lichenoides																		
(L) Leptogium spp.																		
(L) Mannia fragrans (MF)	2																	
(L) Peltigera lepidophora																		x
(L) Peltigera rufescens	X													X				
(L) Phaeorrhiza sareptana	6																	
(M) Polytrichum piliferum																		
(L) Psora globifera **(PG)**	5		6				3				7							
(L) Pterygoneurum ovatum **(PO)**			1					6		X								
(M) Pterygoneurum subsessile								6										
(L) Riccia sorocarpa																		
(M) Syntrichia caninervis				X							4							
(M) Syntrichia ruralis **(SR)**	53		2				8		1	1			28	5		99		1
(M) Tortula atrovirens											X							
(M) Tortula brevipes **(ToB)**		1						1		X		2	3	1			X	
(L) Trapeliopsis bisorediata **(TrB)**	13	X	3		2		10		10		12							
Unidentified lichen spp. **(L)**		13	6				3									1		
(L) Xanthoparmelia wyomingica																X		

Table 4 (continued)

SITES / TAXA	SL SC	SL OC	SL OS	SL NC	SL SS	SL NS	PL NS	PL NC	PL SS	PL SC	PL OC	PL OS
(L) Acarospora schleicheri **(AS)**									X			
(L) Aspicilia reptans												
(L) Aspicilia spp. **(Asp)**		1								19		
(L) Arthonia glebosa									X			5
(M) Bryoerythrophyllum columbianum **(Bco)**												
(M) Bryum argenteum **(BA)**		X	3		1		1	1			6	3
(M) Bryum cf. caespiticium **(Bce)**		15	34		2	64	5	50		X	5	7
(M) Brachythecium albicans												
(L) Caloplaca jungermanniae												
(L) Caloplaca tominii												
(L) Candelariella terrigena												
(L) Cephaloziella divaricata **(CD)**	X				13				X			
(M) Ceratodon purpureus **(CP)**	43	110	72	17	89	14	29	80	92	73	28	58
(L) Cladonia sp. (+/- 3 spp.) **(Cl)**	70	4	32	X	83				83	81		1
(L) Collema spp. **(Co)**	15	8	19	X	23				39	75	1	18
(M) Didymodon australasiae (DA)					X							
(M) Didymodon brachyphyllus (DB)		X		X	X						X	X
(M) Didymodon spp. **(Di)**	10	8		19	2		11	1	1	1	16	8
(L) Diploschistes muscorum **(DM**	11			X	4				7	X		
(L) Endocarpon pusillum												
(M) Funaria hygrometrica								9				
(M) Grimmia alpestris (usually on stones)				X								
(L) Lecanora sp. **(Le)**	8								1	X		
(L) Lecanora muralis												
(L) Lecidiella stigmatea												
(L) Leptochidium albociliatum									1			
(L) Leptogium lichenoides									X			
(L) Leptogium spp.	X								X			

Table 4 (continued)

SITES	**SL**	**SL**	**SL**	**SL**	**SL**	**SL**	**PL**	**PL**	**PL**	**PL**	**PL**	**PL**
TAXA	**SC**	**OC**	**OS**	**NC**	**SS**	**NS**	**NS**	**NC**	**SS**	**SC**	**OC**	**OS**
(L) Mannia fragrans (MF)												
(L) Peltigera lepidophora												
(L) Peltigera rufescens				X	X							
(L) Phaeorrhiza sareptana												
(M) Polytrichum piliferum					X					5		
(L) Psora globifera **(PG)**				X					X			
(L) Pterygoneurum ovatum **(PO)**				21			21	4			13	
(M) Pterygoneurum subsessile												
(L) Riccia sorocarpa												1
(M) Syntrichia caninervis												
(M) Syntrichia ruralis **(SR)**	2	7	1		9		1		9			
M) Tortula atrovirens												
(M) Tortula brevipes **(ToB)**	8	1							1		X	
(L) Trapeliopsis bisorediata **(TrB)**	X	X							X			
Unidentified lichen spp. **(L)**	4	1	4						1	1		

3.3 Site and Species Relationships

Figure 1 shows the results from the DCA ordination analysis of the 30 treatment sites and Figure 2 shows the results from the ordination of the 18 species or species groups used in the analysis.

Both ordinations show the relationships and relative importance of two environmental vectors considered most significant in separating sites and species by DCA: herbaceous plant basal cover (H) is correlated with sites and species to the left of the ordinations, and mineral soil (M) is correlated with sites and species to the left of the ordinations. Further, they are both correlated with the first axis of the ordination which is the most important axis with respect to variation in the data set. This makes sense ecologically, as bare soil is predominant in early successional stages in natural shrub-steppe habitats (for example following severe fire), and, as succession continues, the grasses grow forming tussocks interspaced between the shrubs and the mature crust.

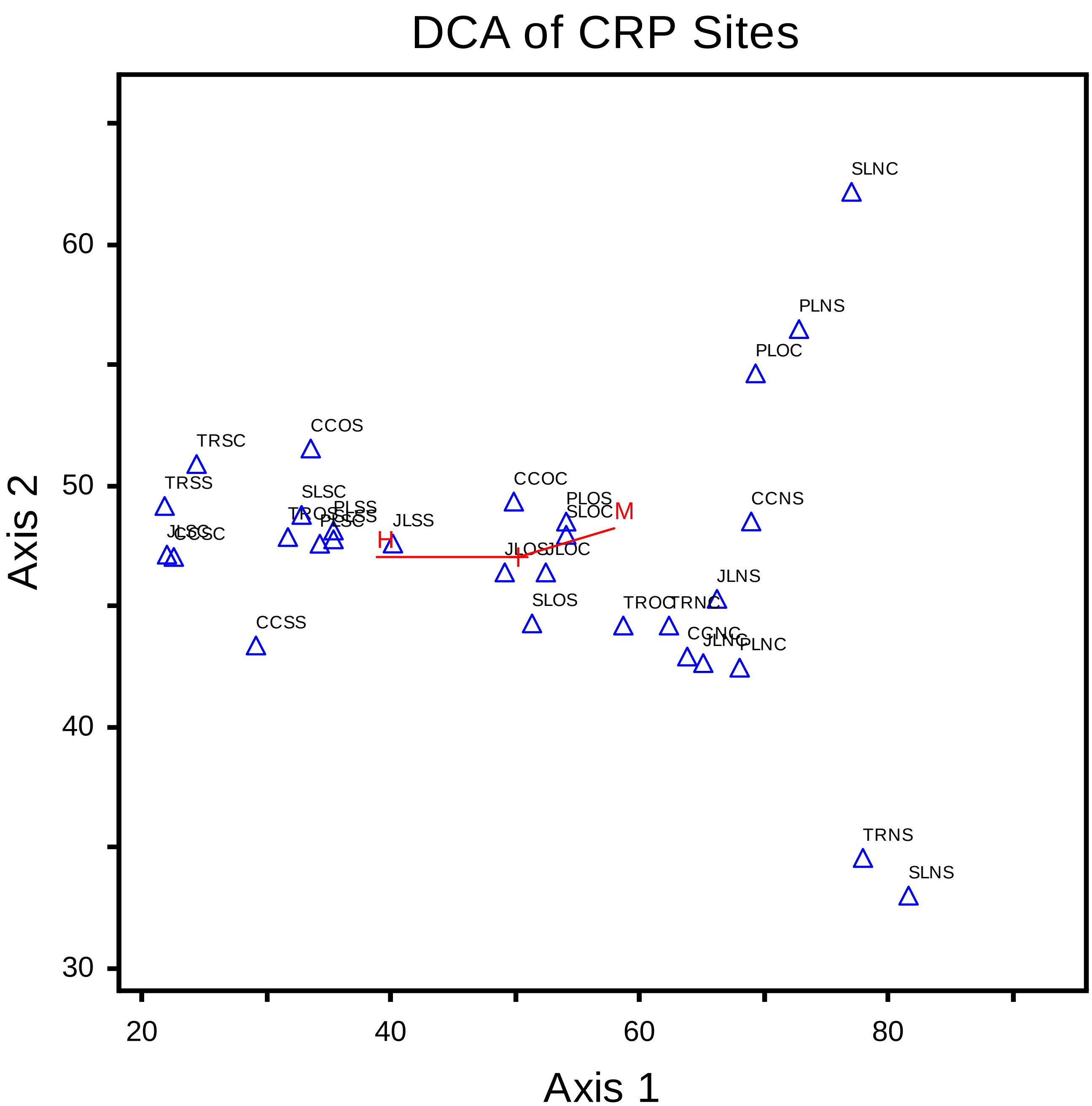

Figure 1. DCA Ordination of CPR Sites where the crust was measured, and the positions of two environmental vectors (H = percent cover of the herbaceous bases; M = percent total cover of mineral soil).

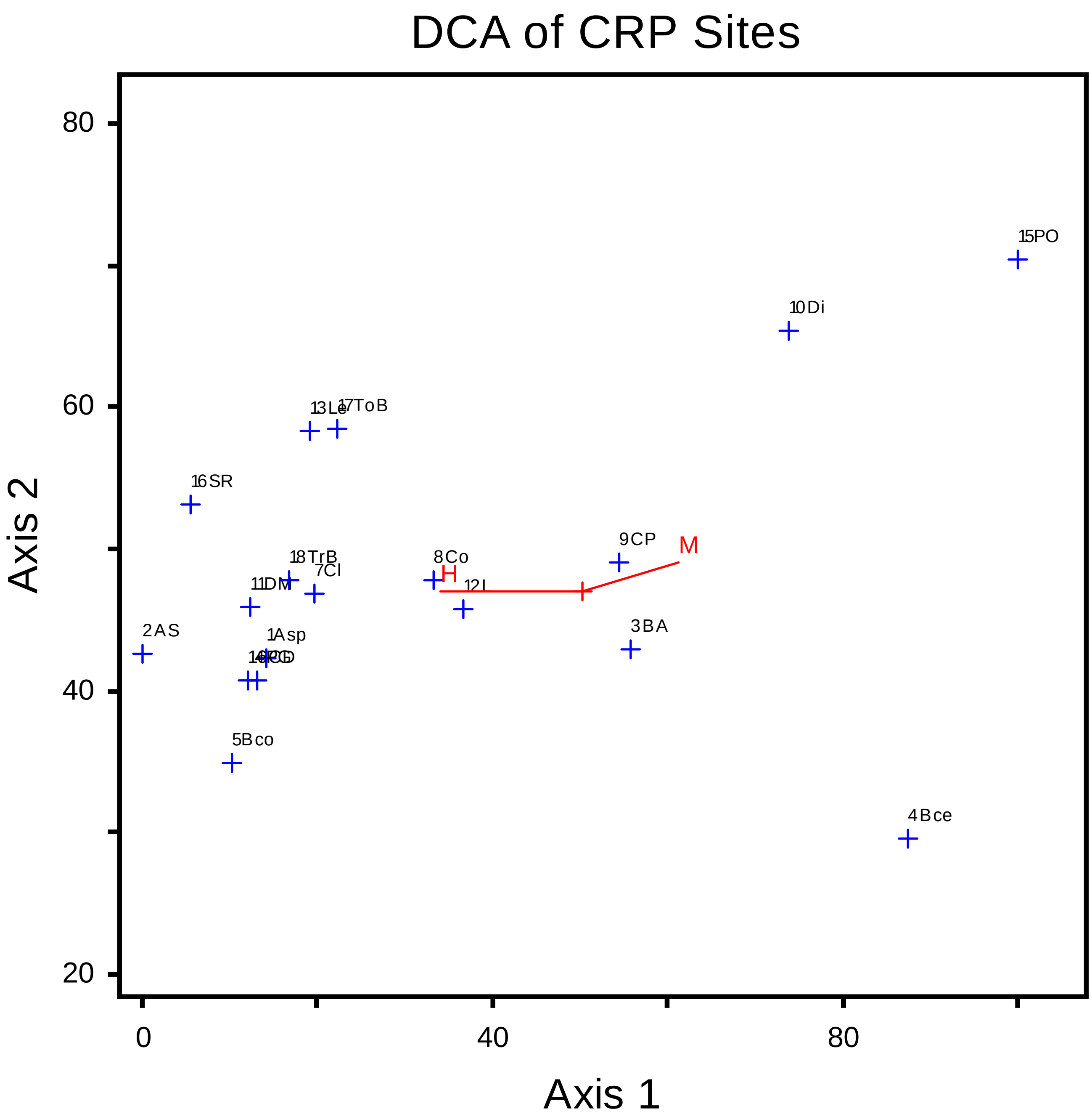

Figure 2. DCA Ordination showing the relative locations of 18 taxa (12 known species, 5 genera (species groups), and unidentified lichens (L), and the positions of two environmental vectors (H = percent cover of the herbaceous bases; M = percent total cover of mineral soil).

Some preliminary observations that can be made from Figure 1, the ordination of the 30 sites, include:

1. The environmental vectors indicate a successional trend along Axis 1: the higher the basal cover of herbs indicates later succession, and the greater the cover of mineral soils indicates earlier succession. This is supported by the shrub-steppe (S_) treatment sites being to the left of the matrix, and the new field (N_) sites to the right. O_ sites are more difficult to interpret as they are spread across the central portion of the ordination, although the location of the CCOS and TROS sites towards the left probably indicates successional influence (propagule availability) of the adjacent shrub-steppe.
2. Earlier successional sites to the right of the ordination are more spread out than the later seral sites to the left. This represents a difference in species composition between sites that may reflect either environmental differences and, thus species preferences, or, simply, stochastic events (that is chance availability of spores, for example). The clustering of the sites to the left of the ordination indicates a successional trend towards, possibly, a common climax-type community.

Some preliminary observations that can be made from Figure 2, the ordination of the 18 species, include:

1. Species relationships reflect known ecological tendencies of most of the species, yet show some relatively unexpected trends. For example, *Pterygoneurum ovatum*, *Bryum caespiticium*, *B. argenteum*, species of *Didymodon*, and *Ceratodon purpureus* are often early-successional (colonizing) taxa, especially on bare mineral soil. However, *Ceratodon purpureus* is also an important component of mature crusts in most sites, although it appears to be a longer-awned variety, ssp. *conicus*. The lichen genus *Collema* is in many ways similar to *C. purpureus* in that is usually considered an early successional species, yet, in some of the sites, it is an important component of the mature crust, and is absent or has very low cover in early successional sites. The importance of these species in a late successional environment is rarely acknowledged in the literature. The lichens *Aspicilia* sp. (Asp; probably *A. reptans*), *Acarospora schleicheri* (AS), and *Diploschistes muscorum* (DM), and the mosses *Bryoerythrophyllum columbianum* (Bco) and *Syntrichia ruralis* (SR) are all considered to be late successional species, and this is expressed in their placement to the left of the diagram. *Aspicilia reptans* is well known as a species that, in part, colonizes stable litter and mosses characteristic of late successional crusts. *Acarospora schleicheri* (AS) is known to parasitize *Diploschistes muscorum* (DM), a mid- to late successional species (*Diploschistes muscorum* parasitizes species of *Cladonia* at an earlier successional stage).
2. Axis 2 represents differences in species composition that may represent soil differences or stochastic variables (e.g., propagule availability). For example, on the right side of the diagram, *Pterygoneurum ovatum* (PO), *Bryum caespiticium* (Bce), and *Didymodon* spp. (Di), all colonizers of bare soil, appear to 'dominate' at different locations.

Figure 3, using the HyperNiche program of McCune and Mefford (2004), illustrates the distribution of *Ceratodon purpureus* (CP) along two environmental gradients (C = biological crust cover; and R = rock or large stone cover). From this illustration, it can be inferred that *C. purpureus* prefers less rocky sites, especially in early successional stages, and is common along the successional gradient. It supports the observation that it is both a primary colonizer as well as an important component in mature crusts.

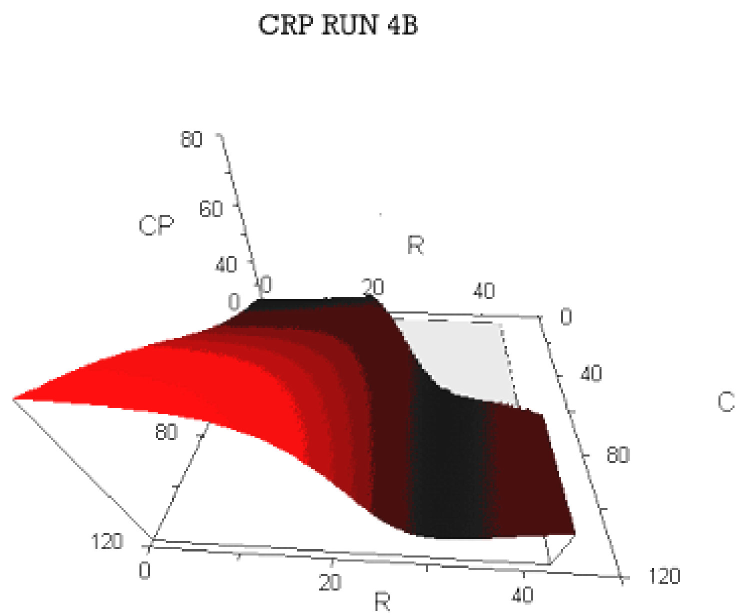

Figure 3. Species/environmental relationship graph using HyperNiche program (McCune and Mefford 2004) showing the distribution of *Ceratodon purpureus* (CP) along two environmental gradients (C = biological crust cover; and R = rock or large stone cover).

4. Recommendations

This report provides and summarizes preliminary data from the sampling of six CRP sites in central Washington State. We recommend at least the following activities be undertaken in order to complete this research (confirmation of unknown taxa is ongoing and will be completed regardless):

1. Sample the biological crusts in the remaining three CRP sites in the area.
2. Re-visit all sites and make detailed notes on the sites based on the analyses and data provided here; for example, shrub-steppe sites adjacent to N_ and O_ sites should be investigated to see whether the S_ sites already sampled are readily comparable to these early seral sites (this will aid in the final discussions and conclusions); also, restricted field time this year did not allow for more detailed notes on soil etc. to be made, and this information may benefit the final comparative analyses.

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Plans for 2005

Field data collection for passerine birds and small mammals will continue in 2005. The small mammal component likely will focus on trapping for small mammals in a sample of cultivated croplands to further assess the value of CRP fields. The biological soil crust will be sampled in the remaining 24 sites to complete the characterization across all treatments. Pellet sampling will be repeated in order to assess use by lagomorphs, deer, and prairie grouse. Data analysis and preparation of reports and publications will take place during fall and winter.

Acknowledgements

This project was made possible by the private landowners and public land managers of eastern Washington who allowed us access to their lands. We thank the staff of Region one and Region 2, WDFW, and the Wildlife Area staff within those regions for their assistance. We thank the following field and lab assistants for their dedicated work: Scott Anderson, Catherine Engelman, Greg Falxa, Melissa Hill, Meghan Horne-Brine, Angela Hyder, Wendy Jessop, Eric Kroeger, Mike Kroeger, Jim Lawrence, Susan Lundsten, Lindsay Malone, Ann Manning, Tate Mason, Joanne McDonald, Ann Peterka, Leslie Robb, Audrey Sanfacon, Jeff Scales, Ashley Spenceley, Jen Stebbins, Mike Walker, Laura Weisel, and Sheri Whitfield. Crew leaders Scott Downes and John Slotterback provided logistical guidance and kept the fieldwork on track. Julie Anderson and Mike Finch at the Swanson Lake Wildlife Area were extremely helpful in facilitating sampling of the eastern study areas. Jeff Bradley at the Burke Museum is helping to confirm species identification of shrews. The Blue Top motel and Swanson Lake Wildlife Area were gracious hosts. This research was funded by the U.S. Fish and Wildlife Service and the U.S. Department of Agriculture.

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Appendix. Common and scientific names of wildlife species mentioned in text.

Common Name	Scientific name
Birds	
Black-billed magpie	*Pica pica*
Brown-headed cowbird	*Molothrus ater*
Brewer's sparrow	*Spizella brewerii*
Brewer's blackbird	*Euphagus cyanocephalus*
Burrowing owl	*Athene cunicularia*
Cliff swallow	*Hirundo pyrrhonota*
Columbian sharp-tailed grouse	*Tympanuchus phasianellus columbianus*
Common nighthawk	*Chordeiles minor*
Grasshopper sparrow	*Ammodramus savannarum*
Greater sage-grouse	*Centrocercus urophasianus*
Horned lark	*Eremophila alpestris*
House finch	*Carpodacus mexicanus*
Lark sparrow	*Chondestes grammacus*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Mourning dove	*Zenaida macroura*
Red-winged blackbird	*Agelaius phoeniceus*
Ring-necked pheasant	*Phasianus colchicus*
Rock wren	*Salpinctes obscoletus*
Sage sparrow	*Amphispiza belli*
Sage thrasher	*Oreoscoptes montanus*
Savannah sparrow	*Passerculus sandwichensis*
Say's phoebe	*Sayornis saya*
Vesper sparrow	*Pooecetes gramineus*
Western meadowlark	*Sturnella neglecta*
Herptiles	
Gopher snake	*Pituophis catenipher*
Great-basin spadefoot toad	*Scaphiopus intermontanus*
Long-toed salamander	*Ambystoma macrodactylum*
Northern leopard frog	*Rana pipiens*
Racer	*Coluber constrictor*
Sagebrush lizard	*Sceloporus graciosus*
Sharptail snake	*Contia tenuis*
Short-horned lizard	*Phrynosoma douglasii*
Striped whipsnake	*Masticophis taeniatus*
Tiger salamander	*Ambystoma tigrinum*
Western rattlesnake	*Crotalus viridis*
Western skink	*Eumeces skiltonianus*
Western terrestrial garter snake	*Thamnophis elegans*

Continued

Appendix (continued). Common and scientific names of wildlife species mentioned in text.

Common Name	**Scientific name**
Small mammals	
Deer mouse	*Peromyscus maniculatus*
Great Basin pocket mouse	*Perognathus parvus*
Least chipmunk	*Tamias minimus*
Long-tailed vole	*Microtus longicaudus*
Meadow vole	*Microtus pennsylvanicus*
Merriam's shrew	*Sorex merriami*
Montane vole	*Microtus montanus*
Northern pocket gopher	*Thomomys talpoides*
Sagebrush vole	*Lemmiscus curtatus*
Vagrant shrew	*Sorex vagrans*
Western harvest mouse	*Reithrodontomys megalotis*