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Natural Resource Stewardship and Science

Sagebrush Steppe Vegetation Monitoring in John Day Fossil Beds National Monument

2014 Annual Report

Natural Resource Data Series NPS/UCBN/NRDS—2015/797

ON THE COVER
Photograph of Sheep Rock Unit of John Day Fossil Beds
Photograph courtesy of Dan Esposito

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Dan M. Esposito
University of Idaho
Fish and Wildlife Department
Moscow, ID 83844

Thomas J. Rodhouse
National Park Service, Upper Columbia Basin Network
63095 Deschutes Market Road
Bend, OR 97701

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The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Executive Summary

Monitoring the condition of sagebrush steppe within the John Day Fossil Beds National Monument (JODA) was conducted in June and July 2014. Four units of the monument were monitored: Clarno, Foree, Painted Hills, and Sheep Rock. Cover of exposed soil and of principal native and non-native plants was estimated following methods detailed in the Upper Columbia Basin Network's (UCBN) protocol for sagebrush steppe monitoring (Yeo et al. 2009). Spring and early summer weather in 2014 was generally drier than the long-term average while temperature records varied by location.

Invasive annual grasses, principally cheatgrass (*Bromus tectorum*), dominate the sagebrush steppe landscape in all 4 units. Medusahead (*Elymus caput-medusae*), another invasive annual grass, is abundant in patches. Other invasive annual grasses, Japanese brome (*B. japonicus*) and bulbous bluegrass (*Poa bulbosa*), were occasionally abundant and generally widespread. Cover of big sagebrush (*Artemisia tridentata*) overall was low and many areas that once supported sagebrush have burned. Broom snakeweed (*Gutierrezia sarothrae*) was the prominent shrub of these rangelands and always in association with cheatgrass. Cover of native bunchgrasses, which define the steppe aspect of sagebrush steppe, was low to moderate. Principal native grasses included: Sandberg's bluegrass (*Poa sandbergii*), bluebunch wheatgrass (*Pseudoroegneria spicata*), needlegrasses (*Stipa* spp.), and Idaho fescue (*Festuca idahoensis*). There were occasional stands, mostly in mesic habitat, where native bunchgrasses dominated. Native forb cover generally was low. Principal native forb species included: milk-vetch (*Astragalus* spp.), yarrow (*Achillea millefolium*), buckwheats (*Eriogonum* spp.), and desert parsley (*Lomatium* spp.). Numerous weedy forbs were recorded across the monument. Brief comparisons were made between results of 2014 monitoring at JODA and monitoring conducted in 2011 at Clarno, Foree, Painted Hills and Sheep Rock. Invasion by non-native annual grasses such as cheatgrass and medusahead, is evident following wildfire or prescribed burning events. As a result, fire incidence and subsequent invasion by non-native annual grasses are posing a significant threat to the integrity of sagebrush ecosystems in the monument.

Acknowledgments

We greatly appreciate the assistance of Shirley Hoh, JODA Resource Manager, who helped us with logistics, maps, access through locked gates, and access to river tramways. Meghan Lonneker, UCBN GIS analyst, created the study area maps. Gordon Dicus, UCBN Program Manager, developed the database and enabled efficient field data entry into tablet PCs and prompt data retrieval and analysis.

Introduction

Prior to Euro American settlement, sagebrush steppe ecosystems in the Upper Columbia Basin extended across the eastern half of Washington and Oregon, and across the northern Great Basin of southern Idaho. Currently much of that ecosystem has been lost to development or substantially degraded as a result of livestock grazing, fire, non-native invasive plants, and recreational use. UCBN has identified the ecological condition of sagebrush steppe vegetation as a high priority vital sign and monitoring of its condition is central to its monitoring program (Garrett et al. 2007). A long-term monitoring program that provides for regular evaluation of the status of the health of sagebrush steppe communities and for identification of trends of ecosystem condition over time within and among parks within the network was implemented in 2008 (Yeo et al. 2009). The foundation of the sagebrush steppe monitoring protocol is a view of ecosystem health sustained by natural succession or natural variability within communities of native plants. Divergence of sagebrush steppe communities from these natural states (e.g., invasion of non-native plants, increased fire frequencies, long-term trends of increasing cover of exposed soil, declines in cover of principal native plants) signifies a loss of health and provides the feedback to park managers for effective adaptive management strategies. Simple monitoring objectives follow directly from this view:

• Determine the status (current condition) and trends (change in condition over time) in the composition and abundance (cover) of principal native plant species in UCBN sagebrush steppe communities.

• Determine the status and trends in composition and abundance (cover) of principal invasive plant species, including annual grasses, in UCBN sagebrush steppe communities.

• Determine the status and trend in the amount of exposed soil (cover), a fundamental indicator of soil stability.

This report summarizes the data collected in 2014 for JODA and discusses comparisons with data collected in 2011 (Yeo and Rodhouse 2012).

Study Area and Methods

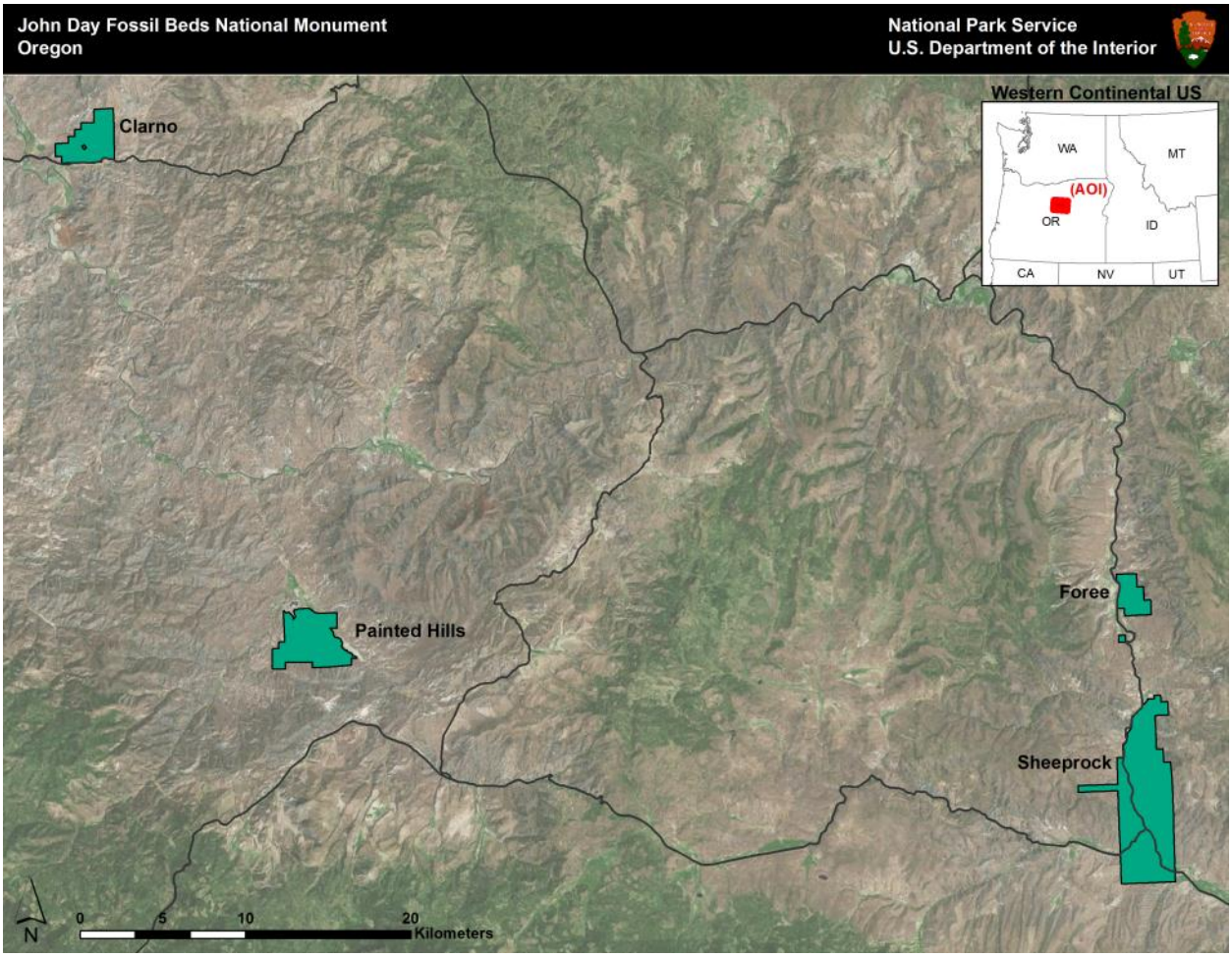


Figure 1. Sample area showing the four distinct units of John Day Fossil Beds National Monument monitored in 2014.

Four units within JODA were sampled: Clarno, Foree, Painted Hills, and Sheep Rock (Figure 1).

Sample sizes within each unit were proportional to the area within each park unit. Some plot locations were dropped prior to sampling because either we discovered that they were on private land, or because access to the plot locations would have necessitated crossing private land or treacherous terrain.

Sampling procedures followed Yeo et al. (2009). Within each unit, 1-m² square plots were located using the generalized random tessellation stratified (GRTS) spatially-balanced sampling design (Stevens and Olsen 2004). The GRTS approach provides for randomly located plots and good spatial dispersion across each site. Within each 1-m² plot, we estimated cover of exposed bare ground, principal native plants, and non-native invasive plants. Cover estimates were categorized into the following cover classes: 0, 1-5%, 5-25%, 25-50%, 50-75%, 75-95%, and 95-100% (Daubenmire 1959). Plant cover was defined as the natural spread of current year's growth. The natural spread is visually outlined using a minimum convex polygon with small gaps included in the cover estimate.

Exposed bare ground was defined as soil surface not overlain by plant cover, litter, and rock. A complete list of recorded species and their common names can be found in Appendix A.

Weather

Because of the geographic separation of park units for JODA, two weather stations were used to depict weather patterns for each park unit. Regionally, weather during spring and early summer 2014 was dry with lower than average precipitation. There was variability in spring weather between the Fossil weather station (Clarno and Painted Hills) (Appendix B) and the John Day weather station (Sheep Rock and Foree) (Appendix C). Both stations showed patterns of wetter than average winters followed by spring precipitation below the long-term averages. Spring temperatures recorded by the Fossil weather station were cooler than the long-term average, while spring temperature recorded by the John Day weather station were warmer than the long-term average. Weather records for 2011 for both weather stations are presented in Appendices B-C.

Results and Discussion

Clarno Unit

The Clarno Unit was sampled from June 9-11, 2014. After receiving above average precipitation in February and March the spring weather (April-June) in Clarno was drier and cooler in 2014 than long-term (1981-2010) averages. Spring weather during the 2011 sampling season was also cooler and drier than long-term averages, however spring 2014 was warmer and drier than spring 2011. In July of 2014 temperature and precipitation increased above the long-term average. Increased precipitation continued through August of 2014 with temperatures again dropping below the long-term average.

Exposed soil cover was generally ≤ 25% with only a small (6%) proportion of plots exceeding 25% cover. Big sagebrush was not observed in any plots sampled in 2014. This species does not recover well after fire, and the frequency of fire in this unit of the Monument is very likely a contributing factor to the paucity of this species. Most recently, a wildfire burned most of the monument in 2011. Snakeweed, which resprouts after fire, accounted for the majority of shrub cover in Clarno but with less than 1% of plots showing cover >25%. Sandberg's bluegrass, bluebunch wheatgrass, and needlegrasses were the most abundant native perennial bunch grasses. Although the frequency of bluebunch wheatgrass was 47%, plots with >25% cover occurred in a relatively small (14%) proportion of plots. Needlegrasses occurred with the same frequency (47%) but with only 2% of plots exceeding 25% cover. Native forb cover was generally low. Yarrow, vetch, buckwheat, and desert parsley were the most abundant forbs observed and rarely exceeded 5% cover.

Invasive forb species were found in a large (>40%) proportion of plots. Species recorded were filaree, tumble mustard, and western salsify. Invasive annual grass species were observed in most plots. Cheatgrass occurred in 97% of plots sampled with 39% of plots containing >25% cover. Medusahead was recorded in 49% of sampled plots with 15% of plots containing >25% cover of this species. Two other invasive annual grasses, bulbous bluegrass and Japanese brome, were found in a small (<10%) percentage of plots.

During the 2011 survey, big sagebrush cover was recorded as present but sparse (<50% cover) within a small (<6%) proportion of plots. In August, 2011, Clarno experienced a wildfire which removed sagebrush cover. Frequency of cheatgrass was high (93%) in 2011 similar to 2014 (97%). Medusahead frequency was 34% in 2011, and 49% in 2014, a worrisome trend. Filaree frequency rose from 11% in 2011 to 40% in 2014.

In Figures 2-4, we compare summaries of 2014 results for bluebunch wheatgrass, cheatgrass, and medusahead with previous years (reports available on-line at http://science.nature.nps.gov/im/units/ucbn/index.cfm).

Table 1. Clarno Unit 2014. Percentage of plots (n=215) within each cover class for exposed bare ground and principle plant species organized by species guilds.

	0	1-5%	>5-25%	>25-50%	>50-75%	>75-95%	>95-100%
Bare ground	20	59	15	4	1	1	0
Sagebrush							
Artemisia tridentata	100	0	0	0	0	0	0
Shrubs							
Atriplex spp	100	0	0	0	0	0	0
Gutierrezia sarothrae	90	7	2	0	0	0	0
Purshia tridentata	100	0	0	0	0	0	0
Native Perenial Grasses							
Achnatherum spp	53	27	18	2	0	0	0
Elymus elymoides	99	1	0	0	0	0	0
Festuca idahoensis	98	0	1	0	0	0	0
Poa secunda	38	41	16	5	0	0	0
Pseudoroegneria spicata	53	13	20	13	1	0	0
Sporobolus cryptandrus	95	4	0	0	0	0	0
Native Forbs							
Achillea millefolium	78	20	2	0	0	0	0
Agoseris spp	98	2	0	0	0	0	0
Antennaria spp	99	1	0	0	0	0	0
Arabis spp	100	0	0	0	0	0	0
Astragalus spp	86	10	3	0	0	0	0
Brodiaea douglasii	99	1	0	0	0	0	0
Calochortus spp	95	5	0	0	0	0	0
Castilleja spp	99	1	0	0	0	0	0
Cirsium spp	97	2	1	0	0	0	0
Cryptantha spp	100	0	0	0	0	0	0
Dalea ornata	93	5	2	0	0	0	0
Erigeron spp	99	1	0	0	0	0	0
Eriogonum spp	88	11	1	0	0	0	0
Helianthella uniflora	98	1	0	0	0	0	0
Lithophragma spp	100	0	0	0	0	0	0
Lomatium spp	88	12	0	0	0	0	0
Phacelia spp	97	2	0	0	0	0	0
Phlox spp	98	1	0	0	0	0	0
Sphaeralcea munroana	99	1	0	0	0	0	0
Non-native Invasive Forbs							
Descurainia spp	100	0	0	0	0	0	0
Erodium cicutarium	60	22	12	5	0	1	0
Salsola kali	100	0	0	0	0	0	0
Sisymbrium altissimum	88	10	2	0	0	0	0
Tragopogon dubius	95	5	0	0	0	0	0

Note: not all rows sum to 100% because of the error inherent in rounding to whole numbers.

Table 1. Clarno Unit 2014. Percentage of plots (n=215) within each cover class for exposed bare ground and principle plant species organized by species guilds (continued).

	0	1-5%	>5-25%	>25-50%	>50-75%	>75-95%	>95-100%
Non-native Invasive Grasses							
Bromus japonicus	92	6	2	1	0	0	0
Bromus spp	95	5	0	0	0	0	0
Bromus tectorum	3	31	27	17	16	5	1
Elymus caput-medusae	51	30	3	3	6	5	2
Poa bulbosa	93	5	2	0	0	0	0

Note: not all rows sum to 100% because of the error inherent in rounding to whole numbers.

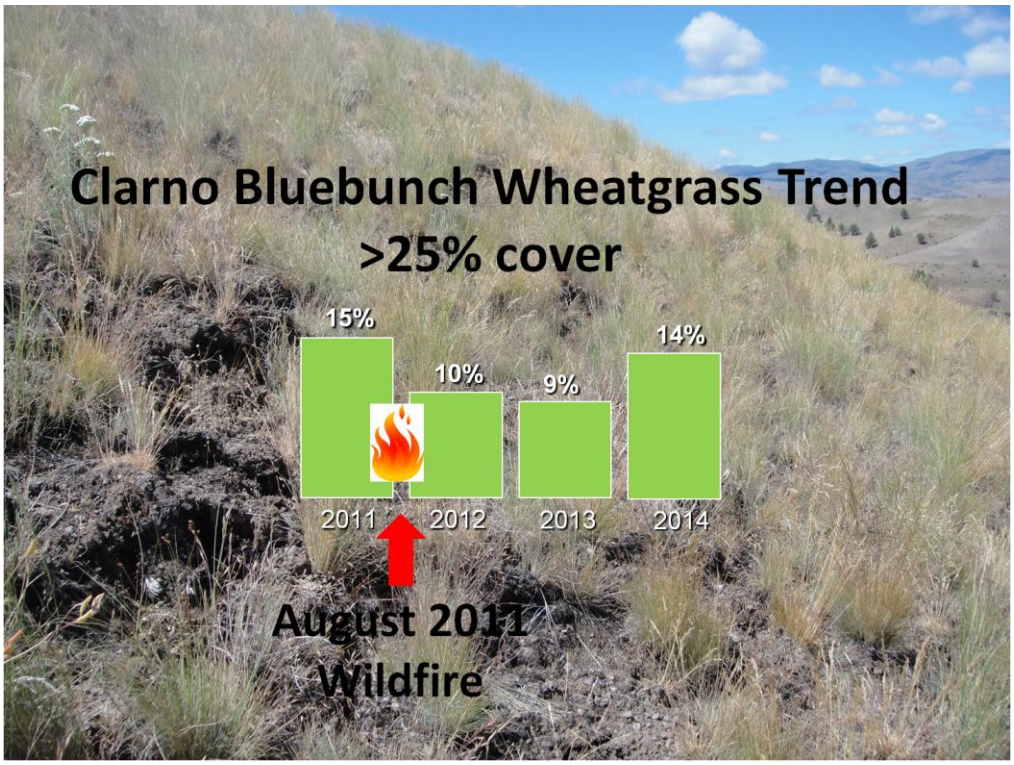


Figure 2. Clarno 2011-2014. Proportion of plots with >25% cover of bluebunch wheatgrass.

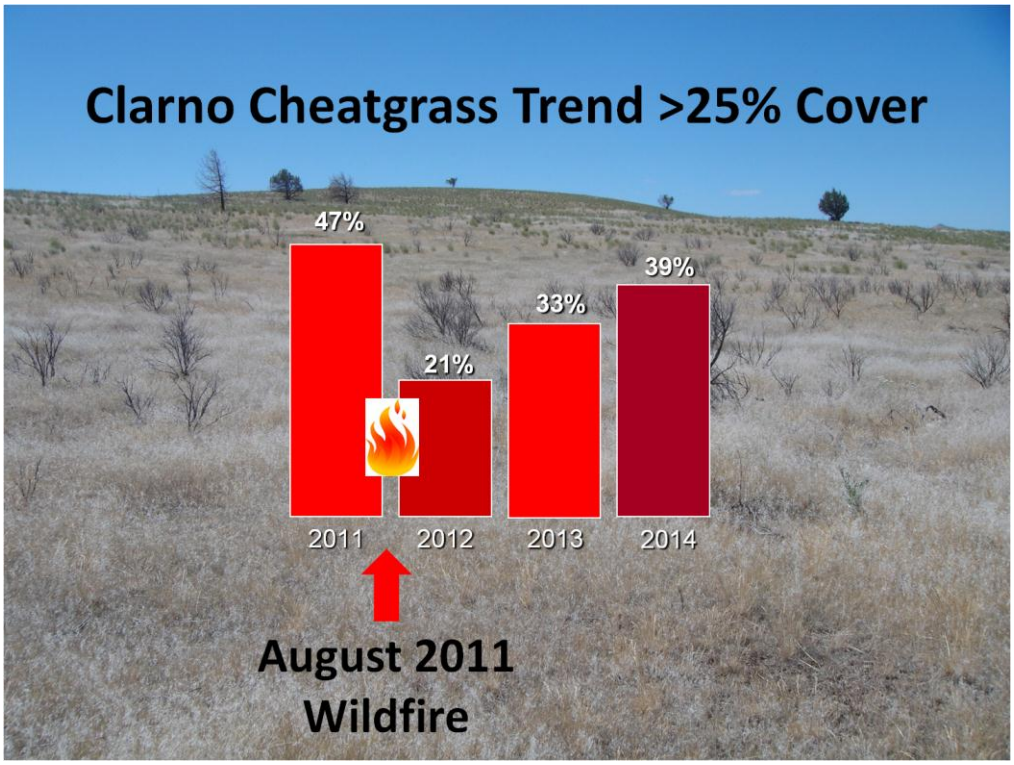


Figure 3. Clarno 2011-2014. Proportion of plots with >25% cover of cheatgrass.

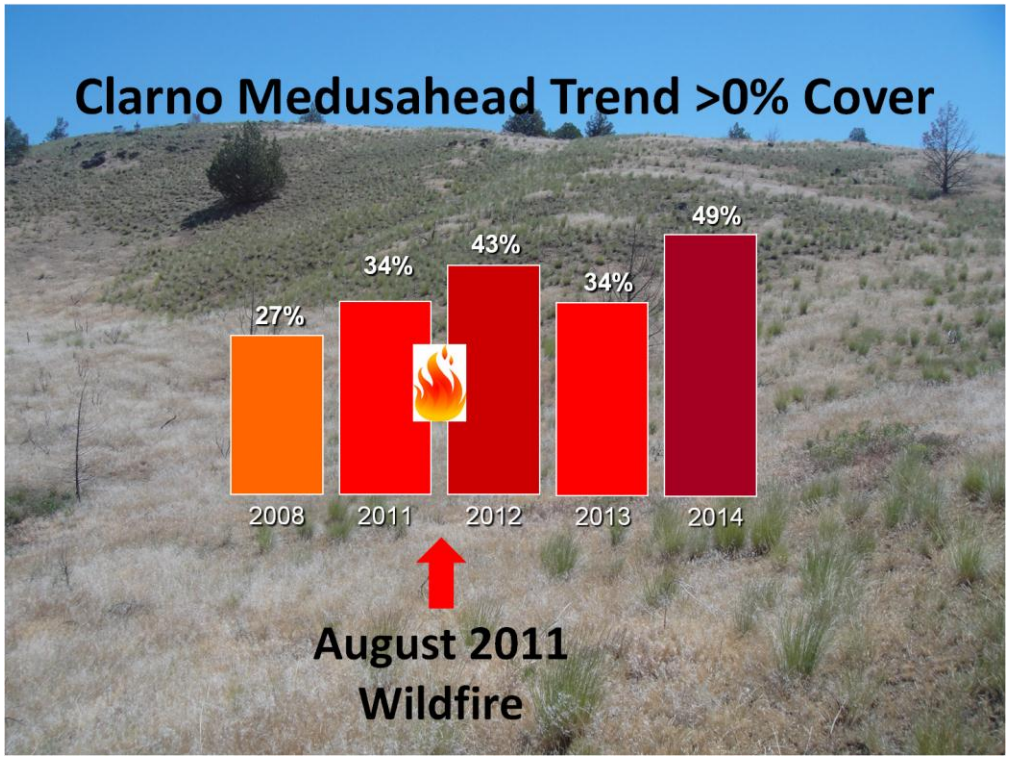


Figure 4. Clarno 2008-2014. Proportion of plots >0% cover of medusahead.

Foree Unit

The Foree Unit was sampled from June 16-17, 2014. After receiving above average precipitation in February and March, the spring weather (April-June) in Foree was drier and warmer in 2014 than long-term (1981-2010) averages. Spring weather during the 2011 sampling season was also cooler and wetter than spring 2014. In August of 2014 precipitation increased above the long-term average, dropping again in September.

Exposed soil cover was generally ≤ 25% with only a small (2%) proportion of plots exceeding 25% cover. Big sagebrush was sparse and observed in a small (2%) proportion of plots sampled in 2014. Snakeweed accounted for the majority of shrub cover in Foree with a frequency of 50% and with 8% of plots showing cover >25%. Sandberg's bluegrass, bluebunch wheatgrass and needlegrasses were the most abundant native perennial bunch grasses. Although the frequency of bluebunch wheatgrass was 32%, samples with >25% cover occurred in a relatively small (17%) proportion of plots. Needlegrasses occurred at lower frequency (13%), with only 1% of plots exceeding 25% cover. Native forb cover was generally low. Yarrow and vetch were the most abundant forbs observed and rarely exceeded 5% cover.

Invasive forb species were found in a large (68%) proportion of plots. The most abundant species recorded were, filaree, tumble mustard, and western salsify. Dalmatian toadflax, tansymustard, scotch thistle, and Russian thistle were also recorded. Invasive annual grass species were observed in most plots. Cheatgrass occurred in 99% of plots sampled with 34% of plots containing >25% cover. Bulbous bluegrass was recorded in 8% of plots, and rarely exceeded 5% cover. Medusahead was recorded in 1% of sampled plots, all with ≤25% cover of this species. Japanese brome and crested wheatgrass (an introduced perennial), were also recorded but sparse. Crested wheatgrass is non-native but is commonly seeded on rangelands and along roadsides for forage and erosion control.

During the 2011 survey, big sagebrush cover was also recorded as having a low (5%) frequency, with only 1% of plots at >25% cover. Frequency of cheatgrass was high (98%) in 2011 similar to 2014 (99%). Medusahead frequency was 1% in both 2011 and 2014. Filaree frequency rose from 24% in 2011, to 40% in 2014 and tumble mustard rose from 8% frequency in 2011 to 29% in 2014.

Table 2. Foree Unit 2014. Percentage of Plots (n=167) within each cover class for exposed bare ground and principle plant species organized by guilds.

	0	1-5%	>5-25%	>25-50%	>50-75%	>75-95%	>95-100%
Bare Ground	19	65	14	2	0	0	0
Sagebrush							
Artemisia tridentata	98	1	1	0	0	0	0
Shrubs							
Atriplex spp	99	1	0	1	0	0	0
Chrysothamnus viscidiflorus	99	1	1	0	0	0	0
Gutierrezia sarothrae	50	25	18	8	0	0	0
Native Perennial Grasses							
Achnatherum spp	87	8	4	1	0	0	0
Elymus cinereus	99	1	0	0	0	0	0
Oryzopsis hymenoides	98	2	1	0	0	0	0
Poa secunda	29	47	23	2	0	0	0
Poa spp	99	1	0	0	0	0	0
Pseudoroegneria spicata	68	6	10	13	3	1	0
Sporobolus cryptandrus	97	2	1	0	0	0	0
Native Forbs							
Achillea millefolium	86	13	1	1	0	0	0
Aster spp	99	1	0	0	0	0	0
Astragalus spp	75	18	6	1	0	0	0
Balsamorhiza sagittata	99	1	1	0	0	0	0
Calochortus spp	97	3	0	0	0	0	0
Cirsium spp	97	2	1	0	0	0	0
Erigeron spp	96	4	0	0	0	0	0
Eriogonum spp	94	5	1	0	0	0	0
Lomatium spp	96	4	1	0	0	0	0
Lupinus spp	99	1	0	0	0	0	0
Phacelia spp	98	2	0	0	0	0	0
Sphaeralcea munroana	99	1	0	0	0	0	0
Non-native Invasive Forbs							
Descurainia spp	98	2	0	0	0	0	0
Erodium cicutarium	60	28	10	2	0	0	0
Linaria dalmatica	87	8	5	0	0	0	0
Onopordum acanthium	99	1	0	0	0	0	0
Salsola kali	99	1	0	0	0	0	0
Sisymbrium altissimum	71	21	6	2	0	0	0
Tragopogon dubius	81	19	0	0	0	0	0
Non-native Invasive Grasses							
Agropyron cristatum	99	1	0	1	0	0	0
Bromus japonicus	99	1	0	0	0	0	0
Bromus spp	99	1	0	0	0	0	0
Bromus tectorum	1	40	25	17	8	7	1
Elymus caput-medusae	99	1	1	0	0	0	0
Poa bulbosa	92	7	1	0	0	0	0

Note: not all rows sum to 100% because of the error inherent in rounding to whole numbers

Painted Hills Unit

The Painted Hills Unit was sampled from June 30 to July 02, 2014. After receiving above average precipitation in February and March the spring weather (April-June) in Clarno was drier and cooler in 2014 than long-term (1981-2010) averages. Spring weather during the 2011 sampling season was also cooler and drier than long-term averages, however spring 2014 was warmer and drier than spring 2011. In July of 2014 temperature and precipitation increased above the long-term average. Increased precipitation continued through August of 2014 with temperatures again dropping below the long-term average.

Exposed soil cover was generally ≤ 25% with only a small (4%) proportion of plots exceeding 25% cover. Out of the four JODA units, Painted Hills had the highest recorded frequency of big sagebrush (17%), with 7% of plots exceeding 25% cover. Snakeweed accounted for the majority of shrub cover in Painted Hills with 20% frequency. Sandberg's bluegrass, bluebunch wheatgrass and needlegrasses were the most abundant native perennial bunch grasses. Frequency of bluebunch wheatgrass was 57%, and samples with >25% cover occurred in 25% of plots. Needlegrasses occurred with low frequency (15%) but with 0% of plots exceeding 25% cover. Native forb cover was generally low (<5% cover). Buckwheat, lilies (*Calochortus spp.*), Blue Mountain prairie clover, yarrow, vetch, and desert parsley were the most abundant forbs observed and rarely exceeded 5% cover.

Invasive forb species were found in a moderate (27%) proportion of plots. Species recorded were, filaree, western salsify, dalmatian toadflax, Russian thistle, and tumble mustard. Invasive annual grass species were observed in most (88%) plots. Cheatgrass occurred in 86% of plots sampled with 15% of plots containing >25% cover. Medusahead was recorded in 18% of sampled plots with 5% of plots containing >25% cover of this species. Bulbous bluegrass was found in 15% of plots sampled and rarely exceeded 5% cover.

During the 2011 survey, big sagebrush cover had a 10% frequency, similar to 2014 (17%) with a small (<5%) proportion of plots exceeding 25% cover. Frequency of cheatgrass was high (76%) in 2011 similar to 2014 (86%). Medusahead frequency was 22% in 2011, and 49% in 2014.

Table 3. Painted Hills Unit 2014. Percentage of Plots (n=215) within each cover class for exposed bare ground and principle plant species organized by guilds.

	0	1-5%	>5-25%	>25-50%	>50-75%	>75-95%	>95-100%
Bare Ground	18	64	15	4	0	0	0
Sagebrush							
Artemisia tridentata	83	5	6	4	3	0	0
Shrubs							
Atriplex spp	97	2	0	0	0	0	0
Chrysothamnus viscidiflorus	99	1	0	0	0	0	0
Ericameria nauseosa	100	0	0	0	0	0	0
Gutierrezia sarothrae	80	16	3	1	0	0	0
Juniperus occidentalis	93	3	0	1	1	1	1
Purshia tridentata	100	0	0	0	0	0	0
Salvia dorrii	100	0	0	0	0	0	0
Sarcobatus vermiculatus	99	0	0	0	0	0	0
Native Perenial Grasses							
Achnatherum spp	85	9	6	0	0	0	0
Elymus elymoides	98	1	0	0	0	0	0
Festuca idahoensis	94	0	3	1	1	0	0
Poa secunda	13	65	19	2	0	0	0
Pseudoroegneria spicata	43	12	20	21	4	0	0
Sporobolus cryptandrus	99	1	0	0	0	0	0
Native Forbs							
Achillea millefolium	91	9	0	0	0	0	0
Agoseris spp	94	6	0	0	0	0	0
Allium spp	99	1	0	0	0	0	0
Antennaria spp	95	5	0	0	0	0	0
Astragalus spp	91	6	3	0	0	0	0
Calochortus spp	89	11	0	0	0	0	0
Crepis acuminata	99	1	0	0	0	0	0
Dalea ornata	89	8	2	0	0	0	0
Erigeron spp	98	2	0	0	0	0	0
Eriogonum spp	80	18	1	0	0	0	0
Helianthella uniflora	99	0	0	0	0	0	0
Lomatium spp	93	7	0	0	0	0	0
Opuntia polyacantha	99	1	0	0	0	0	0
Phacelia spp	100	0	0	0	0	0	0
Phlox spp	95	4	0	0	0	0	0
Sphaeralcea munroana	98	2	0	0	0	0	0
Non-native Invasive Forbs							
Erodium cicutarium	81	10	6	2	0	0	0
Lepidium perfoliatum	93	5	2	0	0	0	0
Salsola kali	99	1	0	0	0	0	0
Sisymbrium altissimum	100	0	0	0	0	0	0
Tragopogon dubius	93	6	1	0	0	0	0

Note: not all rows sum to 100% because of the error inherent in rounding to whole numbers

Table 4. Painted Hills Unit 2014. Percentage of Plots (n=215) within each cover class for exposed bare ground and principle plant species organized by guilds (continued).

	0	1-5%	>5-25%	>25-50%	>50-75%	>75-95%	>95-100%
Non-native Invasive Grasses							
Bromus spp	89	9	1	0	0	0	0
Bromus tectorum	14	53	18	8	7	0	0
Elymus caput-medusae	82	10	3	2	2	1	0
Poa bulbosa	85	11	4	0	0	0	0

Note: not all rows sum to 100% because of the error inherent in rounding to whole numbers

Sheep Rock Unit

The Sheep Rock Unit was sampled from July 7-10, 2014. After receiving above average precipitation in February and March, the spring weather (April-June) in Sheep Rock was drier and warmer in 2014 than long-term (1981-2010) averages. Spring weather during the 2011 sampling season was also cooler and wetter than spring 2014. In August of 2014 precipitation increased above the long-term average, dropping again in September.

Sampling in Sheep Rock was divided into two subsections delineated by the John Day River: Sheep Rock East and Sheep Rock West.

Sheep Rock East

Exposed soil cover was generally ≤ 25% with only a small (3%) proportion of plots exceeding 25% cover. Big sagebrush was sparse and only observed in 5% of plots sampled in 2014. Snakeweed accounted for the majority of shrub cover in Sheep Rock East with 2% of plots showing cover >25%. Sandberg's bluegrass and bluebunch wheatgrass were the most abundant native perennial bunch grasses. Although the frequency of bluebunch wheatgrass was 63%, samples with >25% cover only occurred in a moderate (19%) proportion of plots. Sandberg bluegrass occurred with a similar frequency (68%) but with only 2% of plots exceeding 25% cover. Native forb cover was generally low. Vetch and yarrow were the most abundant forbs observed and rarely exceeded 5% cover.

Invasive forb species were found in a large (58%) proportion of plots. Species recorded were, filaree, tumble mustard, clasping pepperweed, western salsify, dalmatian toadflax, Russian thistle, and spotted knapweed. Invasive annual grass species were observed in most plots. Cheatgrass occurred in 98% of plots sampled with 30% of plots containing >25% cover. Medusahead was recorded in 11% of sampled plots with 4% of plots containing >25% cover of this species. Bulbous bluegrass was found in 21% of plots but rarely (<1%) exceeded 25% cover.

During the 2011 survey, big sagebrush had the same frequency (5%) as in 2014. Frequency of cheatgrass in 2011 was the same as 2014 (98%). Medusahead frequency was higher in 2011 (20%) than 2014 (11%).

Sheep Rock West

Exposed soil cover was generally ≤ 25% with only a small (2%) proportion of plots exceeding 25% cover. Big sagebrush was in 17% of plots sampled in 2014, 7% of plots exceeding 25% cover. Snakeweed accounted for the majority of shrub cover in Sheep Rock West, with 38% frequency and 5% of plots showing cover >25%. Sandberg's bluegrass and bluebunch wheatgrass were the most abundant native perennial bunch grasses. Although the frequency of bluebunch wheatgrass was 46%, samples with >25% cover only occurred in a small (11%) proportion of plots. Sandberg bluegrass occurred with 72% frequency, with only 2% of plots exceeding 25% cover. Native forb cover was

generally low. Vetch and desert parsley were the most abundant forbs observed and rarely exceeded 5% cover.

Invasive forb species were found in a large (72%) proportion of plots. Species recorded were, filaree, tumble mustard, western salsify, dalmatian toadflax, clasping pepperweed, and Russian thistle. Invasive annual grass species were observed in most plots. Cheatgrass occurred in 98% of plots sampled with 54% of plots containing >25% cover. Medusahead was recorded in 5% of sampled plots with <1% of plots containing >25% cover of this species. Bulbous bluegrass was also found in 5% of plots and rarely (<1%) exceeded 25% cover.

During the 2011 survey, big sagebrush had a similar frequency (13%) to 2014 (17%). Frequency of cheatgrass in 2011 (96%) was similar to 2014 (98%). Medusahead frequency in 2011 (4%) was also similar to 2014 (5%).

Table 5. Sheep Rock Unit. Percentage of Plots (n=489) within each cover class for exposed bare ground and principle plant species organized by guilds.

	0	1-5%	>5-25%	>25-50%	>50-75%	>75-95%	>95-100%
Bare Ground	18	62	18	2	0	0	0
Sagebrush							
Artemisia arbuscula	100	0	0	0	0	0	0
Artemisia tridentata	89	4	3	2	1	0	0
Shrubs							
Atriplex spp	99	0	1	0	0	0	0
Chrysothamnus viscidiflorus	100	0	0	0	0	0	0
Ericameria nauseosa	99	0	0	0	0	0	0
Gutierrezia sarothrae	69	17	11	3	0	0	0
Juniperus occidentalis	94	2	1	1	1	1	0
Salvia dorrii	100	0	0	0	0	0	0
Tetradymia canescens	99	0	0	0	0	0	0
Native Perenial Grasses							
Achnatherum spp	88	9	2	0	0	0	0
Elymus elymoides	100	0	0	0	0	0	0
Festuca idahoensis	96	1	1	1	0	0	0
Poa secunda	30	49	19	2	0	0	0
Poa spp	100	0	0	0	0	0	0
Pseudoroegneria spicata	45	14	25	14	2	0	0
Sporobolus cryptandrus	99	1	0	0	0	0	0
Native Forbs							
Achillea millefolium	89	10	1	0	0	0	0
Agoseris spp	99	1	0	0	0	0	0
Antennaria spp	100	0	0	0	0	0	0
Arabis spp	100	0	0	0	0	0	0
Astragalus spp	82	14	4	0	0	0	0
Balsamorhiza sagittata	100	0	0	0	0	0	0
Calochortus spp	96	4	0	0	0	0	0
Cirsium spp	99	1	0	0	0	0	0
Crepis acuminata	99	0	0	0	0	0	0

Table 6. Sheep Rock Unit. Percentage of Plots (n=489) within each cover class for exposed bare ground and principle plant species organized by guilds (continued).

	0	1-5%	>5-25%	>25-50%	>50-75%	>75-95%	>95-100%
Erigeron spp	98	2	0	0	0	0	0
Eriogonum spp	97	2	1	0	0	0	0
Lithospermum ruderale	100	0	0	0	0	0	0
Lomatium spp	91	9	0	0	0	0	0
Lupinus spp	98	1	0	0	0	0	0
Penstemon spp	100	0	0	0	0	0	0
Phacelia spp	99	1	0	0	0	0	0
Phlox spp	96	4	0	0	0	0	0
Sedum lanceolatum	100	0	0	0	0	0	0
Sphaeralcea munroana	98	2	0	0	0	0	0
Non-native Invasive Forbs							
Centaurea maculosa	100	0	0	0	0	0	0
Erodium cicutarium	55	33	10	2	0	0	0
Lepidium perfoliatum	94	5	1	0	0	0	0
Linaria dalmatica	95	3	1	0	0	0	0
Salsola kali	98	2	0	0	0	0	0
Sisymbrium altissimum	80	14	5	0	0	0	0
Tragopogon dubius	90	10	0	0	0	0	0
Non-native Invasive Grasses							
Bromus spp	93	7	0	0	0	0	0
Bromus tectorum	2	33	24	23	12	6	0
Elymus caput-medusae	92	5	1	1	1	1	0
Poa bulbosa	87	10	3	1	0	0	0

Note: not all rows sum to 100% because of the error inherent in rounding to whole numbers

The sagebrush steppe landscape at JODA is dominated by invasive annual grasses and scattered cover of invasive noxious weeds. Cheatgrass dominates with medusahead widely present, sometimes in dense patches. Fire, principally wildfire at Clarno, and prescribed fire at Painted Hills, Foree, and Sheep Rock, has played an extensive role in shaping the composition of vegetation in sagebrush steppe in this park (Rodhouse et al. 2014). Two wildfires burned the entire Clarno unit in 1994 and 1995 (Rodhouse et al. 2014). The entire Clarno unit burned again in August 2011. Prescribed fires used to remove sagebrush and juniper occurred in the southern portion of the Painted Hills unit in 2002, and across Foree in 2005 and 2007 (Rodhouse 2009). Much of the Sheep Rock Unit was burned in 1999, 2001, 2002, and 2004 (Rodhouse 2010). Annual grasses are most prevalent in areas that have experienced recent fires based on our sampling and observations. Abundance of medusahead seems clearly tied to past fire. Fire poses a significant threat forexpanding the dominance of invasive plants and further reducing the remaining stands of predominantly native vegetation. This is the situation across much of sagebrush steppe in western North America, particularly at low elevations such as in JODA (Chambers et al. 2014). There are a few small stands in JODA still dominated by native bunchgrasses that have burned suggesting some resilience to disturbance (Rodhouse et al. 2014). However, as experienced over much of sagebrush steppe in the Upper Columbia Basin, the increase of annual grasses coupled with shorter intervals between fires is most likely going to lead to the continuing loss of native plants and loss of the characteristics of the bunchgrass steppe ecosystem that historically dominated the landscapes in and around JODA (Chambers et al. 2014).

A multivariate analysis of the 2009 and 2011 sampling data revealed that the cover of bluebunch wheatgrass and cheatgrass was correlated to the combined effect of slope and aspect (Esposito 2014). These findings indicated higher cover of bluebunch wheatgrass on more mesic steep, north-facing slopes, while cheatgrass cover increased on more xeric steep, south-facing slopes. Based on patterns of bunchgrass abundances, Rodhouse et al. (2014) also noted meaningful variation in apparent resilience within JODA. JODA exists almost exclusively in the Wyoming big sagebrush ecotype which has been noted as the least resilient of sagebrush ecotypes (Chambers et al. 2014). The distribution of cheatgrass and bluebunch wheatgrass across topographic gradients in JODA is further supported by ecological resistance theory which states that resistance (to invasion) increases from xeric to mesic conditions (Chambers et al. 2014).

Monitoring at JODA has occurred in both wet and dry years. Vegetation cover generally appears similar between wet and dry years, or at least differences between sample years do not appear attributable to annual variability in precipitation. For the most part, increased precipitation seems to result in reduced cover in exposed soil coupled with some increase in annual grass cover. The large areas within park units disturbed by fire with current cover dominated by annual grasses may be reducing variability among ecological sites so that the effects of weather are less apparent. Ongoing research directed by the UCBN I&M Program to analyze permanent fire effects plots will increase future understanding of the long term effects of fire on vegetation dynamics in JODA.

Literature Cited

Chambers, J.C., B.A. Bradley, C.S. Brown, C. D'Antonio, M.J. Germino, J.B. Grace, S.P. Hardegree, R.F. Miller, and D.A. Pyke. 2014. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems 17(2):360-375.

Daubenmire, R.F. 1959. A canopy coverage method. Northwest Science 33:43-64.

Esposito, D.M. 2014. Geographic variation in distribution and cover of principle native and non-native plant species along gradients of topography, climate, and disturbance in protected-area sagebrush steppe communities of the Columbia Plateau. Thesis. Oregon State University, Corvallis, Oregon.

Garrett, L.K., T.J. Rodhouse, G.H. Dicus, C.C. Caudhill and M.R. Shardlow. 2007. Upper Columbia Basin Network vital signs monitoring plan. Natural Resource Report NPS/UCBN/NRR-2007/002. National Park Service, Fort Collins, CO.

Rodhouse, T.J. 2009. Monitoring sagebrush-steppe vegetation in the Upper Columbia Basin Network: 2008 annual monitoring report for City of Rocks National Reserve, Hagerman Fossil Beds National Monument, and John Day Fossil Beds National Monument. Natural Resource Technical Report NPS/UCBN/NRTR-2009/182. National Park Service, Fort Collins, Colorado.

Rodhouse, T.J., 2010. Sagebrush steppe vegetation monitoring in Craters of the Moon National Monument and Preserve, Hagerman Fossil Beds National Monument, John Day Fossil Beds National Monument, and Lake Roosevelt National Recreation Area: 2009 annual report. Natural Resource Technical Report NPS/UCBN/NRTR-2010/302. National Park Service, Fort Collins Colorado.

Rodhouse, T.J., K.M. Irvine, R.L. Sheley, B.S. Smith, S. Hoh, D.M. Esposito, and R. Mata-González. 2014. Predicting foundation bunchgrass species abundances: model-assisted decision-making in protected-area sagebrush steppe. Ecosphere 5:108.

Stevens, D.L., and A.R. Olsen. 2004. Spattail balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

The Climate Analyzer. Climate graph and table website. Available at: http://www.climateanalyzer.org (accessed 3 March 2015).

Yeo, J.J., T.J. Rodhouse, G.H. Dicus, K.M. Irvine, and L.K. Garrett. 2009. Upper Columbia Basin Network sagebrush steppe vegetation monitoring protocol: Narrative version 1.0. Natural Resource Report NPS/UCBN/NRR-2009/142. National Park Service, Fort Collins, Colorado.

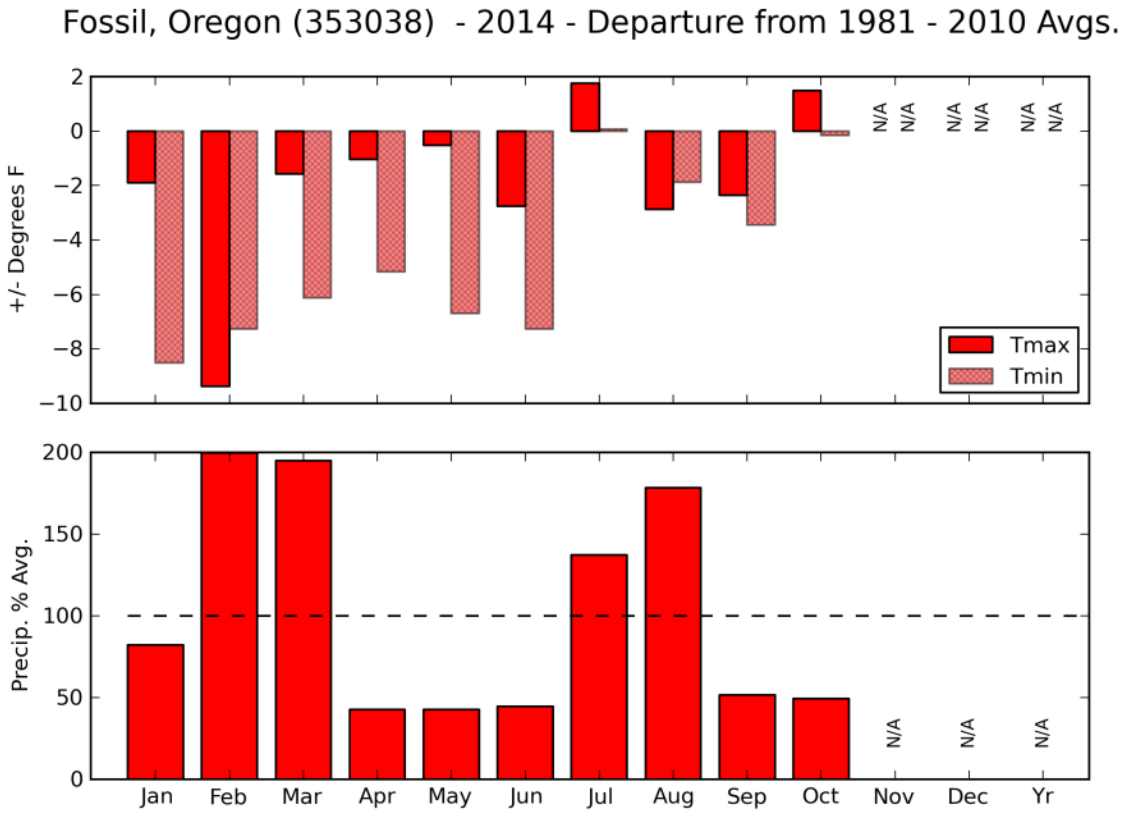
Appendix A. List of species surveyed at JODA in 2014 with common and scientific names.

Common Name	Scientific Name
Sagebrush	
Low sagebrush	*Artemisia arbuscula*
Big sagebrush	*Artemisia tridentata*
Shrubs	
Shadscale	*Atriplex spp*
Green rabbitbrush	*Chrysothamnus viscidiflorus*
Grey rabbitbrush	*Ericameria nauseosa*
Broom snakeweed	*Gutierrezia sarothrae*
Bitterbrush	*Purshia tridentata*
Purple sage	*Salvia dorrii*
Greasewood	*Sarcobatus vermiculatus*
Spineless horsebrush	*Tetradymia canescens*
Trees	
Juniper	*Juniperus occidentalis*
Native Perennial Grasses	
Needlegrasses	*Achnatherum spp*
Basin wildrye	*Elymus cinereus*
Squirreltail	*Elymus elymoides*
Idaho fescue	*Festuca idahoensis*
Indian ricegrass	*Oryzopsis hymenoides*
Sandberg's bluegrass	*Poa secunda*
Bluegrass	*Poa spp*
Bluebunch wheatgrass	*Pseudoroegneria spicata*
Sand dropseed	*Sporobolus cryptandrus*
Native Persistent Forbs	
Yarrow	*Achillea millefolium*
Pussytoes	*Antennaria spp*
Aster	*Aster spp*
Vetch	*Astragalus spp*
Arrowleaf balsamroot	*Balsamorhiza sagittata*
Indian paintbrush	*Castilleja spp*
Native thistle	*Cirsium spp*
Tapertip hawksbeard	*Crepis acuminata*
Prairie-clover	*Dalea ornata*
Daisy	*Erigeron spp*

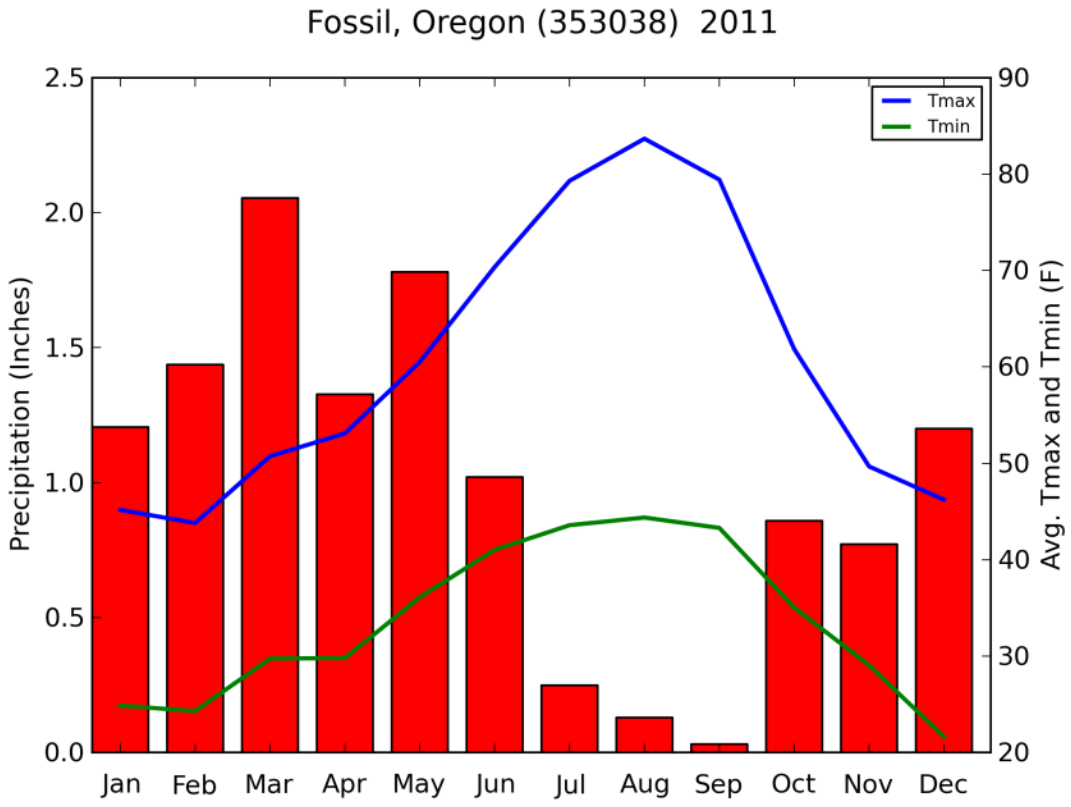
Appendix A. List of species surveyed at JODA in 2014 with common and scientific names (continued).

Common Name	Scientific Name
Native Persistent Forbs (continued)	
Buckwheat	*Eriogonum spp*
Oneflower helianthella	*Helianthella uniflora*
Western stoneseed	*Lithospermum ruderale*
Desert parsely	*Lomatium spp*
Lupine	*Lupinus spp*
Prickly pear cactus	*Opuntia polyacantha*
Penstemon	*Penstemon spp*
Phacelia	*Phacelia spp*
Phlox	*Phlox spp*
Orange globe mallow	*Sphaeralcea munroana*
Native Other Forbs	
Agoseris	*Agoseris spp*
Onion	*Allium spp*
Rockcress	*Arabis spp*
Douglas' brodiaea	*Brodiaea douglasii*
Mariposa lily	*Calochortus spp*
Cryptantha	*Cryptantha spp*
woodland-star	*Lithophragma spp*
Stonecrop	*Sedum lanceolatum*
Non-native Invasive Forbs	
Spotted knapweed	*Centaurea maculosa*
Tansey mustard	*Descurainia spp*
Filaree	*Erodium cicutarium*
Clasping pepperweed	*Lepidium perfoliatum*
Dalmatian toadflax	*Linaria dalmatica*
Scotch thistle	*Onopordum acanthium*
Russian thistle	*Salsola kali*
Tumble mustard	*Sisymbrium altissimum*
Western salsify	*Tragopogon dubius*
Non-native Invasive Grasses	
Crested wheatgrass	*Agropyron cristatum*
Japanese brome	*Bromus japonicus*
Bromes	*Bromus spp*
Cheatgrass	*Bromus tectorum*
Medusahead	*Elymus caput-medusae*
Bulbous bluegrass	*Poa bulbosa*

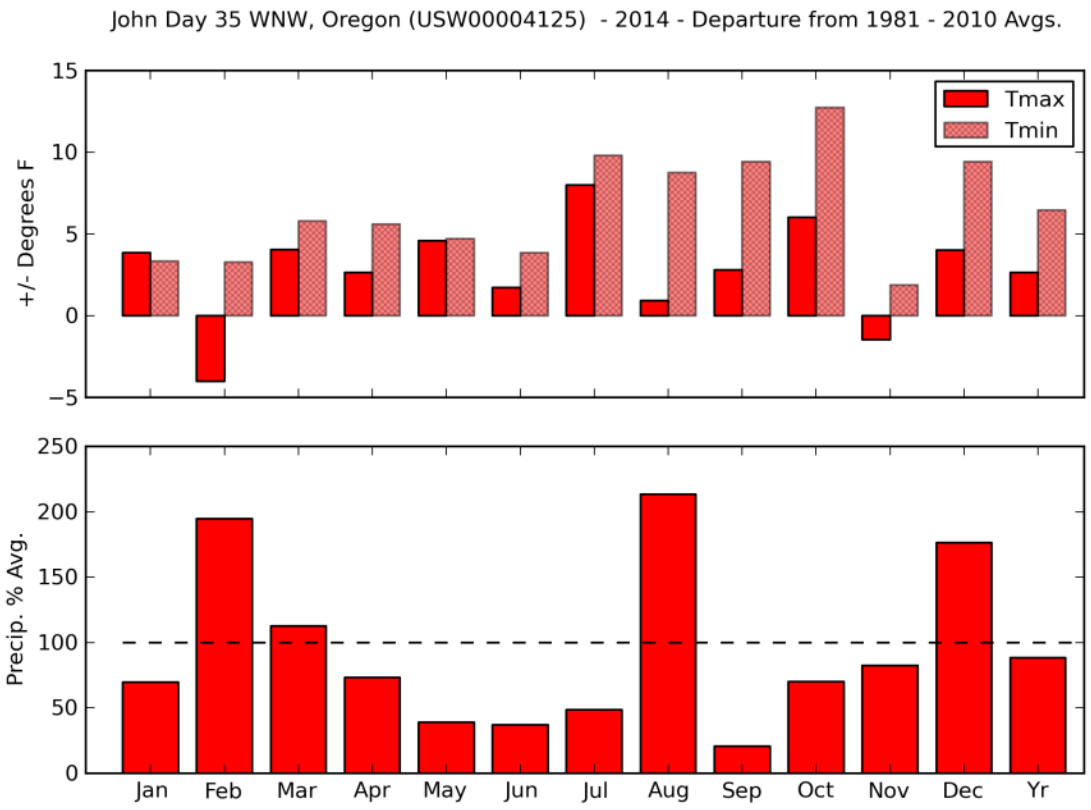
Appendix B. Climate diagrams from the Fossil weather station, for the Clarno and Painted Hills Units. Showing 2014 departures from long-term averages and 2011 weather patterns.



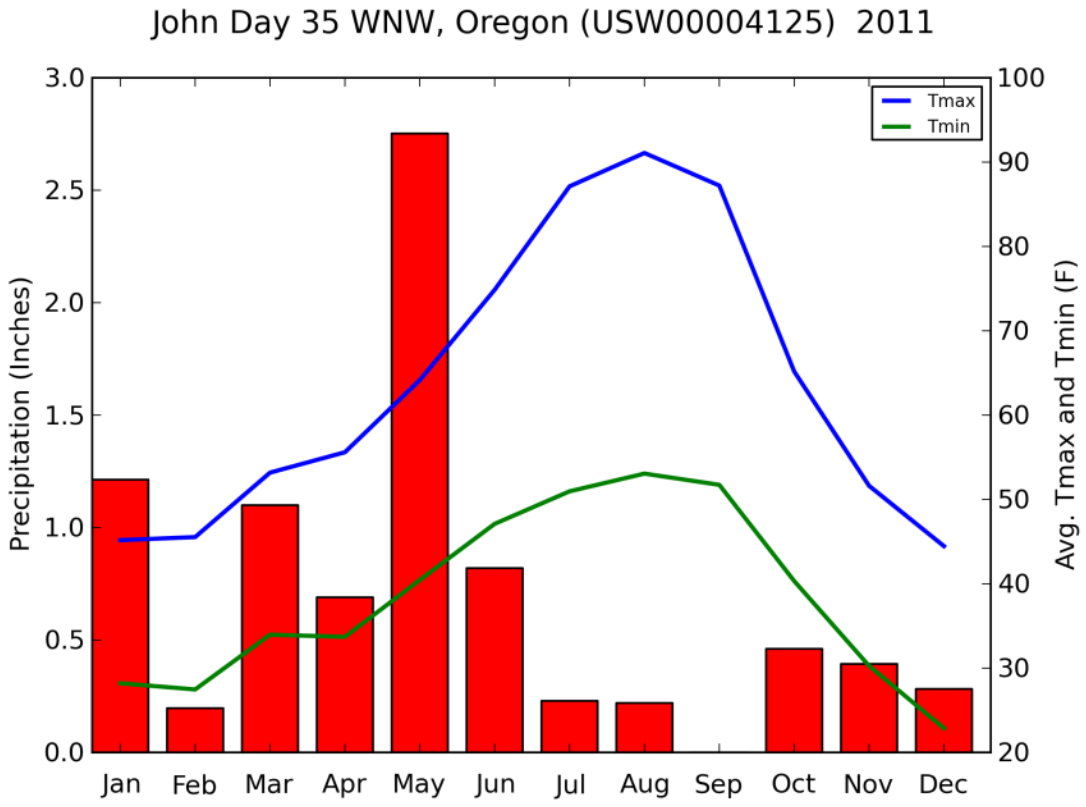
Appendix B. Climate diagrams from the Fossil weather station, for the Clarno and Painted Hills Units. Showing 2014 departures from long-term averages and 2011 weather patterns (continued).



Appendix C. Climate diagrams from the John Day 35 WNW weather station, for the Foree and Sheep Rock Units. Showing 2012 departures from long-term averages and 2011 weather patterns.



Appendix C. Climate diagrams from the John Day 35 WNW weather station, for the Foree and Sheep Rock Units. Showing 2012 departures from long-term averages and 2011 weather patterns (continued).



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Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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