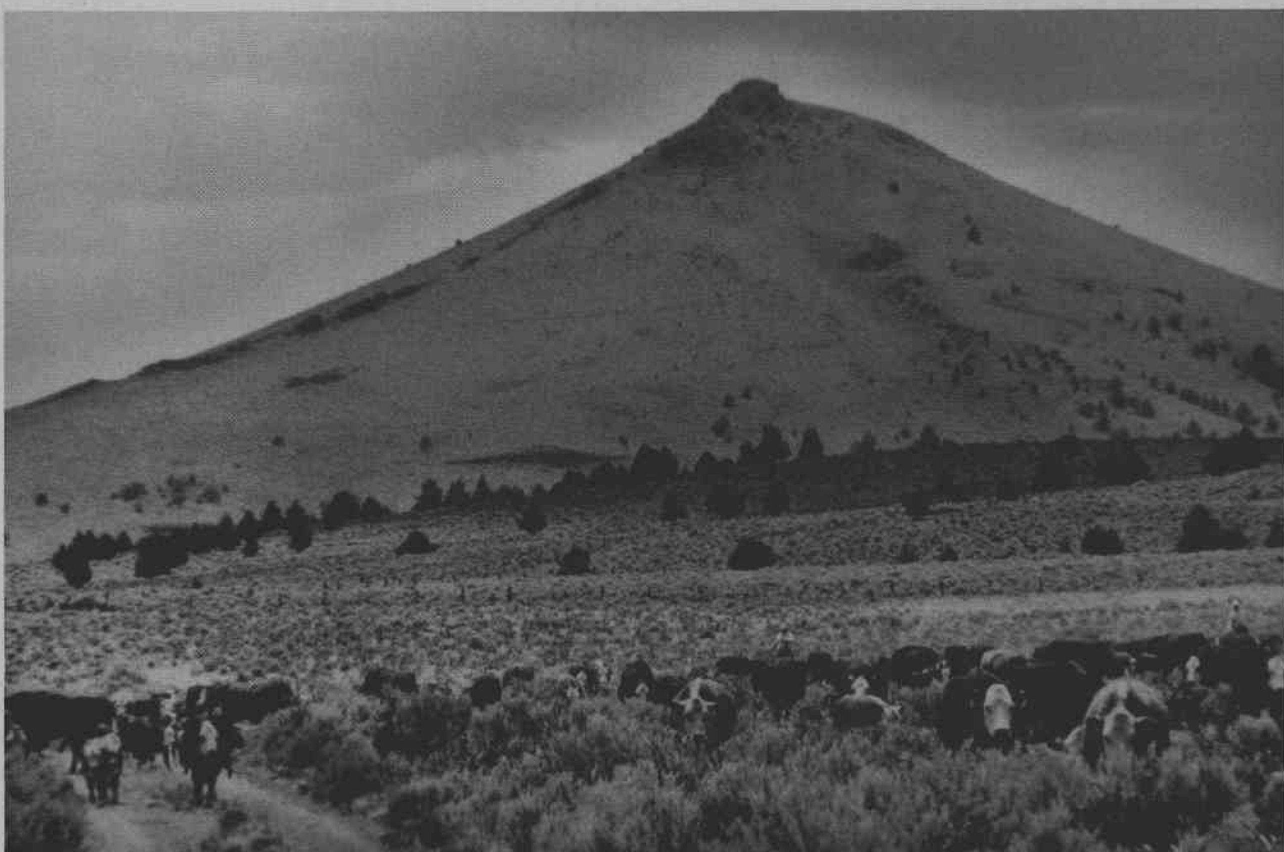
Special Report 935
June 1994

Management of Great Basin Rangelands Annual Report, 1994



Agricultural Experiment Station
Oregon State University
and the U.S. Department of Agriculture
Agricultural Research Service

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HC 71, 4.51 Hwy 205
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Front Cover: Paiute Butte on Northern Great Basin Experimental Range
Harney County, Oregon

Photo By Larry G. Hammond

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This special report is a cooperative effort of the Department of Rangeland Resources at Oregon State University and the Eastern Oregon Agricultural Research Center. Any mention of commercial products does not constitute endorsement by Oregon State University. The Eastern Oregon Agricultural Research Center, which includes the Burns and Union Stations, is jointly operated and financed by the Oregon Agricultural Experiment Station, Oregon State University, and the U.S. Department of Agriculture, Agriculture Research Service. We wish to thank Carol McDonald and Carol Savonen for their help in preparing and editing this report.

AUTHORS

RAYMOND ANGELL
Range Scientist, USDA Agricultural Research Service, Burns, Oregon

MACK R. BARRINGTON
Graduate Student, Department of Rangeland Resources, Oregon State University

ROXANE BARTON
Research Assistant, Eastern Oregon Agricultural Research Center, Burns, Oregon

JON BATES
Graduate Student, Department of Rangeland Resources, Oregon State University

STEVE BEVERLIN
Ecologist, USDI, Bureau of Land Management, Salmon, Idaho

STEVE BRANDYBERRY
Graduate Student, Department of Animal Sciences, Oregon State University

RUBEN CRUZ
Graduate Student, Department of Rangeland Resources, Oregon State University

TIM DELCURTO
Assistant Professor, Eastern Oregon Agricultural Research Center, Union, Oregon

LEE E. EDDLEMAN
Professor, Rangeland Resources, Oregon State University

DAVID GANSKOPP
Range Scientist, USDA Agricultural Research Service, Burns, Oregon

NORMAN R. HARRIS
Graduate Student, Department of Rangeland Resources, Oregon State University

GARY KIEMNEC
Associate Professor, Department of Crop and Soil Science, Oregon State University

KIRBY M. KRUEGER
Student, Oregon State University

(Continued)

LARRY L. LARSON
Associate Professor, Department of Rangeland Resources, Oregon State University

MICHAEL L. MCINNIS
Assistant Professor, Department of Rangeland Resources, Oregon State University

RICHARD F. MILLER
Professor, Eastern Oregon Agricultural Research Center, Burns, Oregon

DAVID PACIORETTY
Range Conservationist, USDI, Bureau of Land Management, Lakeview, Oregon

KARA PAINTNER
Research Assistant, Eastern Oregon Agricultural Research Center, Burns, Oregon

JEFFREY A. ROSE
Research Assistant, Eastern Oregon Agricultural Research Center, Burns, Oregon

DONALD W. WOLF
Graduate Student, Department of Rangeland Resources, Oregon State University

Forward

This year, our Range Field Day concerns management of Great Basin Rangelands. The region consists of two major vegetation types, the sagebrush grassland and salt-desert shrub. Ownership of this 183 million acre parcel is roughly 74 percent public and 26 percent deeded property. Within the last decade the public has become more aware of the value of water, forage, recreation, minerals, and wildlife derived from these lands, and has demanded a greater role in their management. Now, more than ever, creative and biologically sound principles must be applied to avoid conflicts and challenges over these resources.

Our objective in this report is to contribute to a greater understanding this environment and to stimulate innovative approaches in our management of this region. Areas of focus include: weed and woody plant invasions, watershed issues, plant-animal interactions, livestock management, bio-diversity concerns, and new research and management technology. Our Range Field Day is being held in conjunction with the summer meeting of Pacific Northwest Section of the Society for Range Management. This gathering brings together a diverse array of individuals, all sharing a common concern for the well-being of our natural resources. To those visiting the area, we ask that you share your experiences with us and hope that you enjoy your stay.

David Ganskopp
Range Scientist
USDA-ARS

History and Mission of the Squaw Butte Experiment Station

Tony Svejcar

At its inception, our facility was called the Squaw Butte Range Experiment Station. The station is located about 40 miles west of Burns, and is about 16,000 acres in size. The idea for the Experiment Station was officially conceived in Vale, Oregon on December 15, 1934, at the first meeting to set up grazing districts for Oregon (Klemme 1984). Such meetings were held in most western states after passage of the Taylor Grazing Act. In his book on the early days of the Grazing Service in Oregon, Klemme (1984) summed up the push for the Squaw Butte Range Experiment Station as follows:

> "The people at Oregon State Agricultural College at Corvallis had long been looking for an opportunity to get hold of a sizeable block of semidesert rangeland somewhere in eastern Oregon where they could carry on range experiments. They already had stations where research was being carried on in animal husbandry, agronomy, and irrigation from wells, but nothing pertaining to the grazing of livestock on wild sagebrush lands. Consequently, when the Taylor Grazing Act was passed, in June of 1934, these people thought they saw their chance".

A committee was formed to select a site and develop a plan of research. Since there were twelve million acres of public land in Oregon, F.R. Carpenter, the head of the Grazing Service, assumed that setting aside a few thousand for research would not cause any major problems. However, as it turned out, selection of the site "stirred up a real hornet's nest on the part of cattlemen on the one side and sheepmen on the other (Klemme 1984)". Apparently, the area had been used primarily by sheep because larkspur infestations were high enough to make cattle grazing risky (larkspur is more toxic to cattle than to sheep). The sheep producers felt that the location of the Experiment Station was part of a plot by the cattlemen to remove sheep from the range.

Despite the controversy over site selection, a formal agreement between the Secretary of the Interior and the School of Agriculture was signed on October 22, 1935. Under the agreement, the Division of Grazing would do the necessary construction (roads, buildings, wells, fences, etc.) and the School of Agriculture would furnish the livestock and provide the personnel to operate the facility. The Grazing Service (Dept. of Interior) contribution was to consist primarily of funds and personnel routed through the Civilian Conservation Corp. (C.C.C.). In an attempt to deal with unemployed youths, Congress passed legislation authorizing the Civilian Conservation Service program in 1934. As fate would have it, the C.C.C. was being planned about the time the Taylor Grazing Act was passed. The decision was made to allow a given number of C.C.C. camps to operate in each of the western states. The goal was to use the labor to help meet the objectives of the Taylor Grazing Act. Across the west the C.C.C. was active in reseeding, fencing, water development, etc. In eastern Oregon, one of the camps was devoted to building the Experimental Station. Most of the buildings at the present day Experimental Range were originally built by the C.C.C., and many of the original pastures and fencelines have been maintained.

Initially, the College of Agriculture purchased sheep to use on the larkspur-infected portion of the station. However, after two years, the sheep were sold because they were considered economically impractical (Klemme 1984). It seems unclear as to whether economics or politics influenced the selection of livestock. Once the station converted entirely to cattle, it became necessary to find a means of maintaining the cattle during the five months they were not on rangeland. Again quoting from Klemme (1984):

> "Cattlemen in this area were required to produce enough hay, and have enough private pasture, to take care of their animals five months. If range was available, they could run the other seven months on public lands. Therefore, in order to make the Squaw Butte setup a practical demonstration, it was merged with the Harney Branch Experiment Station, which was located a few miles east of Burns. This station, which had been operating for a number of years, put up enough hay and grain to take care of the Squaw Butte cattle through the five winter months. The two stations complemented each other, one serving as Public Domain range and the other as the required commensurate private property."

The Harney Branch Experiment Station, located six miles east of Burns, was established in 1911 to determine which crops were suited to the high desert. Sawyer (1980) lists three distinct phases of the units' research program: 1) dryland farming, 2) pump irrigation, and 3) livestock and feed production (as part of the Squaw Butte Experiment Station). The crops research was terminated in 1944; the unit's focus was then directed toward livestock and forage work, until the Station was closed in 1954.

During the late 1930s, ranchers from Harney County made a case for conducting research on the native flood-irrigated meadows (Sawyer 1980). At that time, the meadows provided 90 percent of the winter feed used in southeastern Oregon. Quoting from Sawyer (1980), "The Section 5 meadow unit of the Squaw Butte Experiment Station had its beginning with a survey conducted in the summer of 1940 when a site for the meadow unit of the station was located". Section 5 was leased with an option to buy beginning June 1, 1941. In 1948, the State exercised the option to buy and the land became part of the Squaw Butte Experiment Station. The Harney Branch, Squaw Butte, and Section 5 were operated as a single unit up until the closure of the Harney Branch Experiment Station in 1954. The Station was closed because the prevailing opinion was that the Harney Branch could not adequately contribute to solving the agricultural problems of southeastern Oregon, and funds could be better used at the other two sites.

During the first twenty years of operation there were relatively frequent changes in jurisdiction over the Squaw Butte Experiment Station. Sawyer (1980) gives the following chronology of organizations responsible for operating Squaw Butte: Grazing Service, 1935 to June 30, 1946; Oregon State University, July 1 to August 15, 1946; U.S. Forest Service, Forest and Range Experiment Station, August 16 to October 9, 1946; Bureau of Land Management, October 10, 1946 to June 30, 1956; and Agricultural Research Service, July 1, 1956 to the present. Since 1956, the Agricultural Research Service (ARS) and Oregon State University (OSU) have managed Squaw Butte and Section 5 as a self-contained ranch unit.

Prior to 1944, there were separate offices at Squaw Butte and Harney Branch, and each unit had a superintendent. When the two land units were merged, the decision was made to appoint one superintendent, and move the offices to the old Post Office Building in Burns. Office headquarters remained in Burns until the construction of an office complex at Section 5 in 1980. The number of state and federal scientists has fluctuated over the years; at the present there are three state and three federal scientists assigned to the unit.

To keep the general public sufficiently confused, several name changes have been adopted over the years. In 1974, the Squaw Butte Experiment Station, which consisted of the Squaw Butte Experimental Range and Section 5, was renamed the Eastern Oregon Agricultural Research Center (EOARC). This title applies to the whole unit, including both the state and federal programs. A more recent change occurred in 1992, when the Squaw Butte Experimental Range was renamed the Northern Great Basin Experimental Range. The change was precipitated by the renaming of the "Squaw Butte" landmark. The name was offensive to some. We decided not to use the name of a landmark in the title (since landmark names can be changed), but rather chose to name the experimental range after the region it represents.

PAST MISSION AND RESEARCH

The historic mission of the Experiment Station was to increase production and economic return of range livestock and related industries. The research could be more-or-less separated into range, meadow, and livestock research, although there were many overlapping studies. Much of the range work focused on control of weeds and woody plants, evaluation of forage plants and seeding techniques, and grazing management. The development of 2,4-D during WWII, advances in machinery, and impact of new plant species provided new tools for managing rangelands during the early stages of the research program.

As Section 5 became a more integral part of the program, a good deal of research was conducted on quality and production of meadow hay. Studies were conducted on fertility, cutting height, cutting time, irrigation management, tillage, and hay storage. The quality of meadow hay was evaluated for micronutrients, as well as the more routine forage quality parameters.

Much of the range and meadow research was geared toward livestock management. But there was also a distinct livestock research component that included studies on various supplements, winter management of cows and calves, weaning times, micronutrient problems, heifer management, dystocia, and animal health.

PRESENT AND FUTURE MISSION AND RESEARCH

The mission of EOARC has become much broader in recent years. Issues such as public land grazing, endangered species, and water quality often receive more attention than commodity production. Thus, the research has expanded to include studies addressing water issues, biodiversity, ecosystem function, riparian management, wildlife/livestock interactions, in addition to the more traditional range/meadow/livestock studies. From the commodity standpoint, there is more emphasis on efficiency and integration, and less on increasing production per acre or per animal unit.

Several years ago, the mission of EOARC was revised and we worked on developing a framework for integrating our diverse research programs. The results of that planning effort appear in Figure 1. The top row of boxes represent the diversity of projects. The forage/livestock research may be integrated with environmentally compatible range livestock research, or the range livestock research may be used in restoration of wildlife systems. For example, research on spring/early summer grazing of meadows (alternative livestock system) might be combined with research on winter grazing (environmentally compatible range livestock system) to provide a nontraditional management system that is both economically and environmentally sound. Or, short periods of grazing might be used in an attempt to reduce competition of a weedy species on a desirable species. Under such a scenario, livestock would be used as tools to manipulate rangeland. The goal of the whole program is to improve or maintain ecosystems, whether they be agricultural or native.

This field day report will provide a good indication of recent research, and the direction of the EOARC. We welcome input from interested individuals on the direction of the program and anticipated needs in the future.

Acknowledgements

In writing the historical part of this report I drew heavily from the following publications:

Klemme, M. 1984. Home rule on the range. Early days of the grazing service. Vantage Press, Inc. 516 West 34th Street, New York, NY 10001.

Sawyer, W.A. 1980. The Squaw Butte Experiment Station: its development, program, and accomplishments 1935-1969. Oregon State Univ. Agric. Experiment Station, Special Report 599.

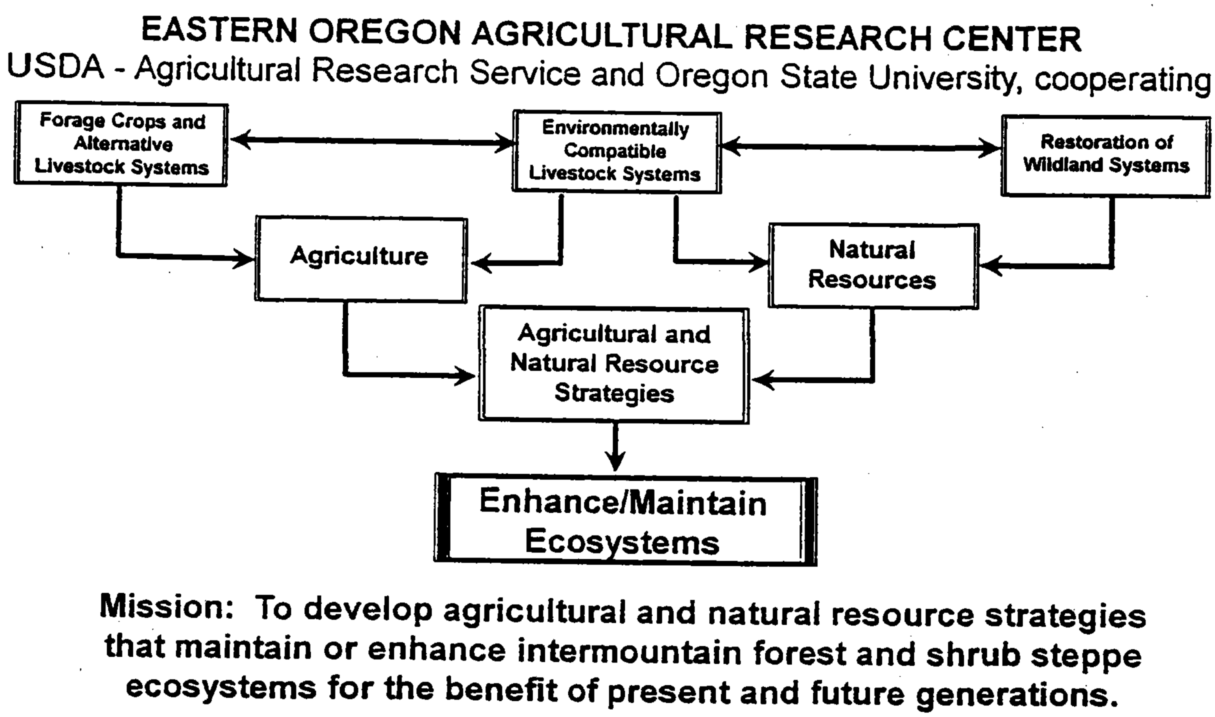

Figure 1. Current mission statement and research thrusts for the Eastern Oregon Agricultural Research Center, Burns, Oregon, 1994.

Fall Defoliation Of Bluebunch Wheatgrass: Tiller Growth and Development

Ray Angell, Tim DelCurto, and Roxane Barton

Winter grazing is a common practice in some parts of the sagebrush steppe which have less harsh winter weather. Traditionally, resource managers have felt that livestock grazing in the fall and winter had little or no impact on grasses such as bluebunch wheatgrass, because the plants were in a quiescent state with little or no growth taking place. Recent research has shown that plants such as bluebunch wheatgrass can develop tillers in the fall if rainfall is adequate. These fall-produced tillers then overwinter and provide a significant portion of the next growing season's forage production. There is speculation that standing dead stems from the previous growing season provides some benefit to newly produced fall tillers, perhaps by minimizing environmental stress. This study was undertaken to determine the effect of fall clipping upon later growth and development in the subsequent growing season. Responses of interest were tiller survival, tiller density, aboveground yield, and leaf photosynthetic rate.

METHODS

Two sites were selected for the study, with one on a south facing slope and the other on an east-facing slope. Soils are frigid Lithic or Aridic Argixerolls on the east slope and frigid, shallow Xerollic Durargids on the south slope. Bluebunch wheatgrass was the dominant grass on both sites.

The study was set up with four replications and four treatments at each site using 6 x 6 yard plots separated by 1 yard alleys. One of four treatments was applied to each plot. Treatments were no clipping (NC), 4-inch clipping height (4C), 2-inch clipping height, (2C) and clipping to ground level (GC). These treatments provided for no alteration of the bunch (NC), minimal alteration by clipping just above the height of live tillers (4C), moderate alteration by removing some live tissue (2C) and maximum alteration by removing all live leaf tissue (GC). Clipping was accomplished the first week of November, after fall tillers had developed. Because no precipitation was received in September, plots were sprinkler-irrigated in late September to provide one inch of water to all plots.

Plants were measured before clipping treatments. Tiller density in two plants in each plot was determined by inserting a 2 x 4 inch open ended frame into the bunch and counting all live tillers within the frame. Additionally, five live tillers were marked at the base with wire loops to provide data on tiller growth and winter mortality. In June, seven months post-treatment, final tiller measurements were made. All topgrowth in each of the two plants per plot was clipped to ground level, oven dried, and weighed to determine aboveground biomass.

Photosynthetic rate of individual bluebunch wheatgrass leaves was determined on two plants in each plot beginning in April. Individual leaves were placed into a leaf cuvette and CO_2 uptake was determined using a LICOR 6200 Portable Photosynthesis System.

RESULTS

Irrigation stimulated tiller development in early October, and by November 1 all plants had developed about 2.7 inches of new growth and averaged 2 leaves per tiller. Prior to clipping there were no differences between treatments, with plant growth and tillering activity being similar in all plots.

Winter survival was essentially complete for all treatments, at about 98 percent (Table 1). No significant increase in tiller mortality was associated with clipping in November, even at ground level. Additionally, there were no differences noted between east and south sites for overwinter survival of tillers. While tiller survival was similar, there was a tendency toward increased flowering effort for clipped treatments over unclipped treatments.

Table 1. Overwinter survival (%) and floral tiller formation (%) of bluebunch wheatgrass plants either left untreated or clipped at one of four intensities in November 1992, Northern Great Basin Experimental Range.

Treatment	Tiller Survival	Flowering Tillers
Unclipped	98	49
Clipped to 4 in. height	96	54
Clipped to 2 in. height	98	55
Clipped to ground level	98	54

Tiller density, as measured by frames inserted into the bunches tended to be higher for plants in treatment 4C, with an average 775 tillers/yd^2 more tillers in 4C than NC, although the difference was determined to be statistically nonsignificant (Table 2). Biomass within bunches tended to be higher in clipped treatments than in unclipped treatments (Table 2).

Table 2. Live tiller density (tillers/ft^2) and live biomass per unit basal area (lb/ft^2) of bluebunch wheatgrass plants either left untreated or clipped at one of four intensities in November 1992, Northern Great Basin Experimental Range.

Treatment	Tiller density	Live biomass
Unclipped	529.8	0.35
Clipped to 4 inch height	616.0	0.54
Clipped to 2 inch height	513.9	0.60
Clipped to ground level	466.7	0.53

After clipping in November, maximum height of live leaves in unclipped plots averaged about 2.7 in. By definition, plant height of treated plots was 4-, 2-, and 0-inches for the three respective clipping treatments. Four months later, in March, unclipped plants and plants clipped at 4-inch height had grown about 0.4 inches. By contrast, plants which had been clipped to 2 inches or ground level had grown .7 and 2 inches, respectively. Even with this significant growth increment by intensively clipped plants, they remained significantly shorter than unclipped plants in March. Later, in June, these differences were not significant, although plants clipped to ground level the previous fall were still about 2 inches shorter than unclipped plants.

Photosynthetic rate of bluebunch wheatgrass was not affected by clipping treatment (Table 3). Photosynthesis in late April was about 18 µmole/m^2/sec. and decreased in a uniform fashion across all treatments as soil water was depleted. Plants were in severe water stress by midday in the last week in May, and we were unable to obtain reliable measurements of photosynthesis at that time. Drought stress appeared to lower net photosynthesis early in spring, and may have served to cover any potential differences attributable to treatments. As would be expected, photosynthetic rates for plants on the south facing site decreased earlier than for plants on the east site because water stress developed more rapidly on that site.

Table 3. Net photosynthetic rate (µmole/m^2/sec) of bluebunch wheatgrass leaves in spring following clipping treatment the previous November 1992, Northern Great Basin Experimental Range.

Treatment	April 23	May 7	May 21
Unclipped	19.0	13.5	9.0
Clipped to 10 cm	16.1	14.5	8.8
Clipped to 5 cm	16.8	12.1	8.5
Clipped to ground	16.0	13.1	9.1

DISCUSSION

Bluebunch wheatgrass showed minimal response to clipping in fall. Foliar height was reduced during the growing season following clipping in November, however this did not appear to have measurable impact on tiller development or yield. Flowering and seed production was similar for both clipped and unclipped plants.

Plants clipped to ground level were able to replace lost leaf tissue, and showed a significantly increased growth increment between November and March, when measurements were first taken in spring. Apparently the plants were able to mobilize sufficient carbohydrate reserves to initiate new growth as soon as soil temperature was high enough. We did not measure carbohydrate reserves, however research at other locations has clearly demonstrated that carbohydrate storage is decreased, at least temporarily, following intensive clipping or grazing. After March, the growth increment was similar for all treatment groups and it is likely that photosynthesis was providing carbohydrates needed for growth.

While clipping during the growing season can stimulate development of new tillers, no evidence of that effect was found after clipping in fall. In spring following clipping, density of live tillers was the same for all clipping treatments. This, coupled with the almost 100 percent survival of marked tillers points to the fact that essentially all of the early spring growth of bluebunch wheatgrass was obtained from tillers initiated the previous fall. Removal of tillers in fall therefore has important implications relating to competitive interactions between bluebunch wheatgrass and neighboring plants the following spring. Complete removal of live leaves in fall will delay the start of active growth, because the plant is forced to develop new leaves before active photosynthesis can begin.

Photosynthetic rate was highest in April when conditions for growth were best. No changes in rate were attributable to clipping treatment. The predominant factor influencing photosynthesis was water stress caused by the rapid decrease in soil water that year.

In this experiment we found no evidence that clipping at moderate levels caused any negative impact on bluebunch wheatgrass. While clipping to ground level did show some effects the following growing season, responses in terms of tiller survival and development were somewhat less than expected. This lack of response may have resulted from the fact that tillers were small at the time of clipping in November, which may have minimized negative impacts on the plant.

A Digital Elevation Model and Associated GIS Data Bases for the Northern Great Basin Experimental Range

Mack R. Barrington, Douglas E. Johnson, Norman R. Harris, and Kirby M. Krueger

INTRODUCTION

An information system is a formalized series of operations that are performed on data. Data collection, storage, analysis, and presentation are the steps normally associated with information systems. Geographic Information Systems (GIS) link a database with spatial or geographic locations. GIS is not a new concept. Cartographers were developing manual Geographic Information Systems in the 12th century using paper maps with semi-transparent paper overlays. Today, with the advent of desktop computers, electronic Geographic Information Systems are an important tool in many scientific and managerial decisions. Electronic processing of spatial information allows us to combine data and examine it in ways that were very slow and costly just a few years ago.

Our objective in this study was to establish an electronic, geographic database for the Northern Great Basin Experimental Range which is located 56 kilometers west of Burns, Oregon. This project was undertaken for several reasons; first, there are numerous themes or data layers available for this range; second, researchers at the experiment station can utilize data layers in numerous research endeavors; and third, information generated can be used in courses at Oregon State University to enrich the teaching curriculum.

We chose IDRISI, a geographic analysis system from Clark University Graduate School of Geography as our GIS because it is user friendly, inexpensive, and widely available. IDRISI has the added advantage of containing numerous translation routines within the program. Export of data files to other software such as Arc/Info, GRASS, ERDAS, MAP, ODYSSEY, ROOTS, AutoCAD, spreadsheets, and dBASE III+ is relatively easy. This increases the usefulness of one's work to other researchers.

GIS Functional Elements

Geographic information systems have five principle elements: data acquisition, preprocessing, data management, manipulation and analysis, and output generation (Star and Estes 1990). Data acquisition is the process of identifying and gathering information necessary for an application. This is a time-consuming and important phase in developing a GIS database. A GIS is useless without relevant, accurate data and the old computer adage "GIGO" (Garbage In, Garbage Out) is especially true. The usefulness of a GIS database is a function of the accuracy and precision of the original information.

Preprocessing is the manipulation of data into a form suitable for entry into the GIS. This phase is the most time-consuming part of database formation. The original data must be converted into a format handled by the GIS software. All data must be referenced or geo-referenced so the same location in each data layer can be superimposed forming an accurate data set for all locations.

Data management are software functions that control creation of, and access to, the database. These functions provide consistent methods of data entry, update, deletion, and retrieval. There are over 30 different GIS software packages in widespread use and the ease and smoothness of this operation varies among them.

Manipulation and analysis is the process that most people associate with GIS. Analytic operators, often mathematical formulas, work with a database to generate new information. Examples of this manipulation are land slope and aspect, or watershed projections generated from elevational data. Output generation is the final stage of GIS analysis. Output can be in the form of "hard copy", statistical reports, color maps, or "soft copy" computer images. This output is the information on which management decisions can be based.

Raster vs. Vector

GIS packages generally utilize two fundamentally different data structures: raster and vector. With the raster format the display is composed of cells and there is a value for each cell. This display resembles the cells of a computer spreadsheet program and, in fact, can be generated by placing a value in each cell of a spreadsheet and importing the file into a GIS. The image is displayed from the top left corner, the first row fills, then the second row fills from the left, and so on. All cells or "pixels" (picture elements) must contain a value.

A vector display or format is composed of lines originating at points or lines connecting points. Each line has a direction and a magnitude, thus the term vector. Points are located according to their displacement and direction from a starting coordinate. Often specific "pixels" contain no values. The vector data format is especially useful for such linear features as streams, roads, trails, pipelines, contours, etc.

Scale

In a raster based system such as IDRISI all pictures are composed of cells or pixels. These cells are the smallest image/information that can be recorded. A picture that shows a large area is composed of pixels that represent an area of a certain scale. A picture that shows a smaller area is composed of pixels that display a smaller area. For example, a digital map of 1 to 250,000 is composed of pixels representing an area 68.7 meters by 68.7 meters, while a map of 1 to 24,000 is composed of pixels representing an area 27.8 meters by 27.8

meters. An object appears larger on the 1 to 24,000 map; this is a large-scale map. The same principle applies to satellite imagery as opposed to low-level aerial photography. A Landsat image is composed of pixels 30 meters on a side, while an aerial photo taken from a platform 100 feet above the ground can show an object less than 1/2 inch in size.

The scale of a data set is therefore dependent upon the size of the area being mapped, the quality of data available for input, the level of resolution desired, and the capability of the computer hardware/software system. Ranch-sized properties are generally mapped with a cell size of about 30 meters.

Northern Great Basin Experimental Range

We developed a series of data layers for the Northern Great Basin Experimental Range (Table 1) using the IDRISI GIS package (Clark University Graduate School of Geography 1992). Our initial map was composed of contour vectors representing elevations above mean sea level (Figure 1). This was digitized from four USGS 7.5 min. Quadrangle paper maps (Suntex, Squaw Butte, Hay Lake, and Potato Hills). Contours were entered in vector format using TOSCA, a digitizing software package. An initial raster file was then created with zeros in each of 957 columns and 777 rows. Each of these 743,589 cells represents a square, 10 m by 10 m on the ground. Contour lines were then rasterized and data entered onto the blank map. Values between lines were calculated using an interpolation algorithm (INTERCON) which was modified from the algorithm CONSURF developed by David Douglas at the University of Ottawa, Canada.

Slope was calculated in degrees by determining the maximum slope around each pixel from the local slopes in the X and Y directions. Neighbors above, below, and on either side are used in this procedure. A raster file containing slope information for each cell was created to hold this information. From the DEM, aspect was also calculated and output to a computer file. The aspect file contains standard azimuth designations of from 0 to 360 degrees.

Hydrological features of the Experiment Station were digitized from the USGS 7.5 minute quadrangle maps and have been retained as vector files. These files can be overlain onto raster maps. Vector files are useful for calculating elevational profiles for both intermittent and permanent streams or for determining stream length, watersheds, and the like. In a similar fashion but with different vector data, profiles of roads, animal trails, and fencelines can also be generated. Springs and watering points were entered as point data while intermittent lakes were entered as polygons.

Roads and trails of various classes were digitized from either paper maps or from aerial photographs. The maps and photos had a scale of 1:24,000 and 4 inches to the mile respectively. Section lines, Universal Transverse Mercator (UTM) grid (kilometer) lines and Experiment Station boundaries were likewise input from paper maps and are maintained as vector overlays.

A soils theme or layer with 54 distinct mapping units was constructed from the mapping work done by R.D. Lentz and G.H. Simonson (1986). Each soil mapping unit is linked to a data base that contains such information as the following:

1. major soils and land areas
2. physiography
3. parent materials
4. textural classes (by depth)
5. permeability
6. shrink-swell potential
7. structure
8. pH

This database has not been entered into electronic format, as attribute files, at this time.

Vegetative associations (Table 1) are those identified from extensive work done by Dr. Charles Poulton and his remote sensing group (ERSAL) in the Range Management Program, Agricultural Experiment Station, Oregon State University in the late 1960s (Culver and Poulton 1968). Maps of the dominant plant species by form layer (tree, shrub and herbaceous), were constructed from Poulton's maps. He classed as dominant those species that had 15 percent or more crown cover. Poulton's map also includes soil surface characteristics, depth of soils, and other site characteristics. This map and its associated report describes 320 classified polygons on the Northern Great Basin Experimental Range.

Current pasture layout and the location of long-term exclosures have been entered into the spatial model of the Experimental Range. The Department of Rangeland Resources has additional information that should prove useful to researchers. This includes historic air photos of the station. These can be geo-referenced, compared to recent photos, and analyzed for shrub and tree canopy coverages on a site basis. A 1970 photo set for a portion of the Experiment Station was flown at a series of altitudes that represent the following photographic scales:

A. 1 : 1,345
B. 1 : 2,966
C. 1 : 9,450
D. 1 : 12,000
E. 1 : 24,750

The above mentioned databases and photographic records represent a tremendous information resource for researchers and managers alike.

Table 1. Electronic data layers constructed for the Northern Great Basin Experimental Range in the late 1960s.

Data Layer	Source
1) Digital Elevation Model	Digitized from USGS 7.5 min. Quadrangle Maps Hay Lake Potato Hills Squaw Butte Suntex
2) Slope of Cells (10 m)	Generated from DEM
3) Aspect of Cells (10 m)	Generated from DEM
4) Hydrology of Area a) seasonal streams b) seasonal lakes and ponds c) springs d) tanks	Digitized from USGS 7.5 min Quadrangle Maps or from Experiment Station Maps
5) Roads a) highway b) primary roads c) secondary roads d) 4-wd trails	Digitized from USGS 7.5 min Quadrangle Maps
6) UTM grid	Digitized from USGS 7.5 min Quadrangle Maps
7) Townships and Range	Digitized from USGS 7.5 min Quadrangle Maps
8) Experiment Station Boundaries	Digitized from USGS 7.5 min Quadrangle Maps
9) Pastures	Digitized from Experiment Station Maps
10) Exclosures	Digitized from Experiment Station Maps
11) Vegetation a) tree layer b) shrub layer c) herbaceous layer	Digitized from 1968 Map (Culver and Poulton 1968) (input of attribute files is in progress)
12) Soil Surface Characteristics	Digitized from 1968 Map (Culver and Poulton 1968) (input of attribute files is in progress)
13) Approximate Soil Depth	Digitized from 1968 Map (Culver and Poulton 1968) (input of attribute files is in progress)
14) Soils	Digitized from 1986 Map (Lentz and Simonson 1986) (input of attribute files is in progress)

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Paiute Butte

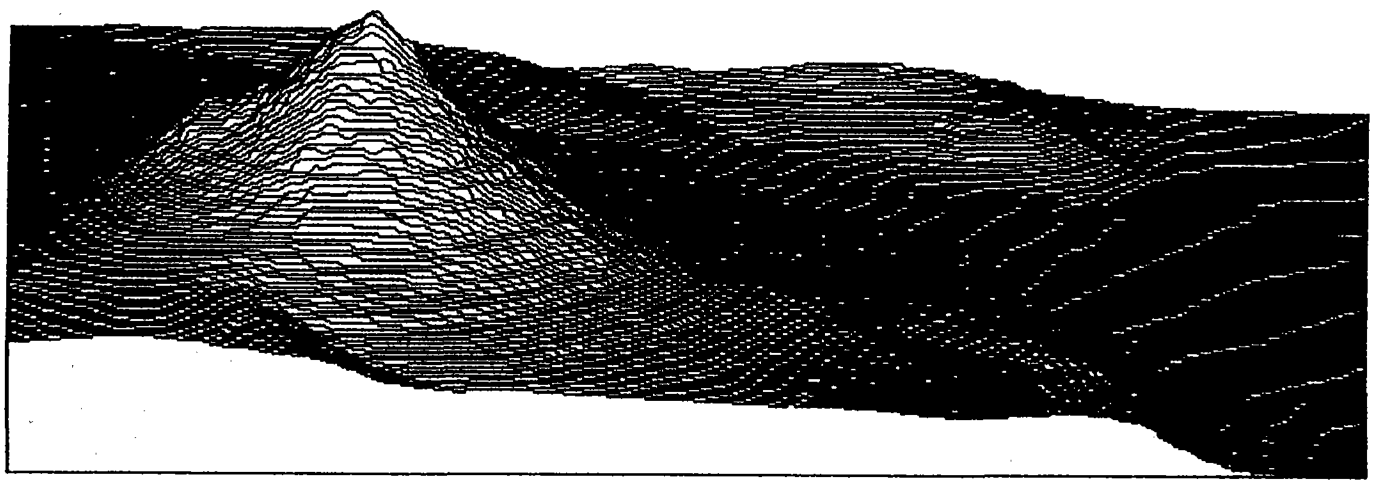

Figure 1. Orthographic projection of our digital elevation model in the immediate vicinity of Paiute Butte, Northern Great Basin Experimental Range. This site is approximately 56 kilometers west of Burns, Oregon.

Understory Plant Succession Following Cutting of Western Juniper (*Juniperus occidentalis*) Woodland on Steens Mountain, Oregon

Jon Bates, Rick Miller, and Tony Svjecar

This report discusses understory plant succession following cutting of a western juniper (*Juniperus occidentalis*) woodland on Steens Mountain in southeastern Oregon. Measurement of the understory response has been part of a larger overall study comparing nitrogen cycling, soil water availability, and litter decomposition between cut and uncut western juniper woodland.

Recent Juniper Expansion

Historically western juniper was largely confined to rockier ridges and rocky low sagebrush flats where fires did not carry due to lack of fine fuels (Miller et al 1993). Most old growth western juniper (> 140 yrs.) will be found on these sites. In the last 100 hundred years western juniper woodlands have been rapidly expanding in range and density particularly in mountain big-sagebrush communities and along drainages (Miller and Rose 1994; Eddleman 1987). This expansion has been a result of several interacting factors which include reduced fire frequencies, improper grazing practices particularly in the late 1800s and early 1900s, and possibly changes in climate (Eddleman 1987; Burkhardt and Tisdale 1969; Kauffman and Sapsis 1989). Once juniper woodlands develop (60-80 yr. woodland) reduced production of understory species may limit fine fuel levels thereby reducing the potential for these areas to burn. Now, fire is being lost as a cost effective tool for managing juniper woodlands.

Fire frequency has declined for a number of reasons. American Indians set many of the fires in the Northwest to improve forage conditions for game animals and promote growth of desired food plants (Miller et al. 1993; Miller and Wigand 1994). The reduction of these peoples population as a result of war and/or disease in the 1800's and eventual confinement to reservations reduced the number of fires set purposefully. More recently, the suppression of wildfires has resulted in reduced numbers and size of fires. Long-term continuous grazing can also reduce the amount of fine fuels which are necessary to carry fires.

An indication that fire frequencies have declined is the condition of many of Oregon's aspen woodlands. Aspen woodlands generally require fires about every 80-100 years to maintain site dominance. Fires kill the older aspen trees but more importantly remove later successional conifers which eventually replace the aspen. After fire, aspen sprouts from roots and reoccupies the site. Without fires (or cutting) that remove or kill the above ground vegetation, aspen stands can be overtopped and shaded out by longer lived trees such as western juniper. At present, many aspen woodlands throughout western North America are being replaced by coniferous forest, a clear indication of reduced fire frequency. On Steens Mountain many of the lower elevation aspen stands are on the way out as a result of succession to western juniper woodland.

Improper grazing may also indirectly contribute to western juniper expansion by setting up conditions essential for its establishment and dispersal. Grazing can shift plant competitive interactions. Heavy season-long grazing of herbaceous plants releases water and nutrients for use by woody plants such as sagebrush and rabbitbrush. Reduced competition from grazed plants can increase the dominance of these shrubs in shrub-steppe plant communities. How does this benefit western juniper? Many juniper seedlings are found beneath sagebrush "nurse" plants which maintain an environment conducive to western juniper seedling establishment (Eddleman 1987). The combination of reduced fire frequency and increased number and longevity of sagebrush safe sites for juniper seedlings may enhance development of juniper woodlands.

The reduction or loss of understory ground cover is also hypothesized to increase dispersal distances of juniper seeds by gravity and overland flow (Burkhardt and Tisdale, 1969). Lack of vegetation to keep juniper seeds from traveling downslope may increase the rate of woodland spread and may also lead to high concentrations of trees at the base of slopes.

The effects of increased density and distribution of western juniper appear to be similar to those documented for pinyon-juniper woodlands throughout the western United States (West 1984). Studies indicate that as these woodlands develop there are reductions in understory plant productivity (Eddleman 1984), changes in nutrient and energy flows through the system (Tiedemann 1987), increased rates of soil erosion (Buckhouse and Mattison 1980; West 1984), and possible losses in plant community and species diversity . Restoration of these sites by fire or mechanical treatments often result in dramatic increases in understory plant productivity (Vaitkus and Eddleman 1987), increased ground cover and reduced soil erosion. Although these changes are often observationally evident there is a lack of quantitative evidence that adequately documents the ecological impacts of western juniper succession into other plant communities and the ecological responses of woodland sites to restoration or wildfires. With regard to understory restoration, quantitative studies in western juniper woodland have been limited to those done in Central Oregon (Vaitkus and Eddleman 1987) and northeastern California (Evans and Young 1985). There is also a general lack of knowledge of how woodland development and restoration of these sites may affect: 1) community level functions and processes such as biological diversity or nutrient cycling, and 2) landscape level processes such as watersheds. There is concern that the lack of a good ecological data base will hamper or misdirect decisions relating to the restoration and use of these lands.

Steens Mountain Juniper Study

We initiated the Steens juniper study to improve our understanding of some ecological processes that maybe influenced by western juniper woodland. The main objectives of this study were to gain and understanding of understory plant succession, nitrogen cycling, soil water availability, and plant litter decomposition after cutting down a western juniper woodland. This paper will focus on measurements regarding understory plant response, comparing cut and uncut juniper woodland.

The study was set up on Steens Mountain 50 miles south of Burns in Harney County, Oregon. The juniper belt on the mountain runs from about 3,800 to 6,800 ft. Much of this area is dominated or rapidly being dominated by western juniper. Of the junipers on the mountain the majority are less than 100 years old (Miller and Rose 1994).

The site selected for our study is dominated by a mature juniper woodland. The site is situated at about 5,000 ft. elevation on a west facing slope. Soils are about 18-20 inches deep, clayey, and fairly rocky beneath the surface. Underlying the soil is an old ash layer that is relatively impenetrable to root growth. This particular site is a worst case scenario. Juniper canopy cover is approximately 20-25 percent and the density of trees about 95 trees/acre. Almost all of the mountain big sagebrush originally present on the site is dead. Understory herbaceous basal cover prior to cutting was less than 3 percent with much of the interspace zones between trees being exposed soil. Plant species composition on the site is primarily made up of native perennial and annual species. Bare ground accounted for nearly 75 percent of the area. Rill erosion was evident throughout the site. Except for unusual conditions (high winds and temperatures, and low humidity) this site will not burn. The only effective treatments would be cutting, other mechanical removal, or herbicides. Cutting is probably the cheapest and most ecologically sound method. Cost sharing would entail an expense of $20-25/acre.

Eight 2-acre blocks were selected in July 1991. Half of each block was cut in August 1991. Cut trees were left on site. Understory measurements were carried out in 1992 and 1993. Measurements included understory plant yield, basal and areal cover, plant density, and species compositions and diversity. Although all species have been measured separately, in this report plants have been grouped into five categories; sandberg's bluegrass, deep-rooted perennial grasses (e.g. Bluebunch wheatgrass, Junegrass etc.), perennial forbs, annual grasses, and annual forbs. Plant measurements were also separated into interspace and tree canopy zones.

The underlying hypothesis of this segment of the study was that understory plant yield, cover, density, and diversity would all significantly increase after cutting down juniper trees. This would be a result of decreased competition for water and soil nutrients.

Results

Study results will mainly focus on information gathered in 1993. As a general rule, all vegetation components measured showed significant increases following cutting of woodland plots in both 1992 and 1993. Climate conditions in 1992 and 1993 were substantially different and are reflected in some of the results. The year 1992 was a drought year and temperatures tended to be higher than normal. Growing season (April - July) precipitation on our site in 1992 was about 4.5 inches (mostly received in June and July) and this was reflected by fairly dry soil conditions especially in woodland plots. In 1993 much of eastern Oregon received record levels of precipitation and temperatures tended to be cooler. Growing season precipitation on the site was about 10 inches.

Yield: In 1992 average total understory yield on the cut plots (40 lbs/acre) was about 2.2 times greater than yield on woodland plots (18 lbs/acre) (Figure 1). In 1993 total understory yield on cut plots averaged 293 lbs/acre and was nearly 9 times greater than yield on the woodland plots (34 lbs/acre) (Figure 2). Perennial plant yield (grasses and forbs) accounted for 97-98 percent of the total yield. Annual plant yields made up a relatively small amount of the total, about 2-3 percent. Soil water availability is the most limiting factor affecting the growth of plants in semi-arid and arid ecosystems. Other studies have demonstrated that by increasing water available for understory plant uptake, understory yields and survival will increase. In this study, measurements of soil water content and plant water stress indicated that soil water was more available over the course of the growing season in the cut plots compared to the woodland plots. This was due to the elimination of juniper competing for soil water on cut plots.

The year effect on understory yield is evident from the results. Woodland understory yield went from 18 lbs/acre in 1992 to only 34 lbs/acre in 1993, about a 90 percent increase but still extremely low given the capabilities of the site. In the woodland plots juniper competition limits the potential response of the understory in a high precipitation year. On the cut plots understory yield went from 41 lbs/acre in 1992 to 293 lbs/acre in 1993, a 700 percent increase, although the increase was not due to the year effect alone. Without competition from juniper, the understory was able to respond in the higher moisture year.

Besides a significant increase in understory yields following cutting there was a shift in the seasonality of understory production. We attribute this shift to both an increase in available soil water later into the growing season and changes in plant species composition from shallow rooted perennial grasses (Sandberg's bluegrass) to deep rooted perennial grasses and forbs. In the woodland plots earlier growing and less productive species, especially sandberg's bluegrass, represented a larger proportion of the total yield than later developing plants (e.g. deeper rooted perennial grasses and forbs). In 1993 sandberg's represented 55 percent and later growing perennials about 44 percent of the total yield (Figure 3). In contrast, on cut plots later growing perennials represented 55 percent of understory yield and sandberg's bluegrass 42 percent.

The resulting increases in understory yield after removing western juniper competition in this study are analogous to results found in studies done in western juniper woodlands of Central Oregon and by others in pinyon-juniper woodlands in the western United States.

Density: Plant density increased significantly following cutting. For example, deep rooted perennial grass density was about .38 plants/ft^2 in both the interspace and old tree canopy zones of cut plots, almost 3 times higher than in the woodland plots (Figure 4). Perennial forb density in the cut plots in the interspace and canopy zones was .28 and .27

plants/ft^2, respectively. In the woodland plots perennial forb density was .15 and .28 plants/ft^2 for interspace and canopy zones respectively. Although perennial forb density in the canopy location is identical between the two treatments, plants on cut plots were much larger and had greater reproductive effort. In general, all plants on the cut plots where larger and produced much greater numbers of reproductive shoots. Because of larger plant size on the cut plots plant cover was also greater.

Cover: Both basal and canopy cover were significantly greater in the cut plots. In 1993 total average basal cover of herbaceous plants on the cut plots was about 5 percent , nearly 3.5 times greater than in the woodland plot (1.4 percent) (Figure 5). Canopy cover of understory plants in cut plots was about 14.5 percent and in woodland plots only about 2.2 percent. Herbaceous cover on the cut plots should continue to increase as open areas are filled in by new plants and the size of existing plants and levels of plant litter increases. Additional protection to the soil surface of cut plots was provided by downed junipers. Canopy cover of downed junipers on cut plots averaged nearly 40 percent. The combined cover of downed trees and understory canopy on cut plots was about 55 percent and would be expected to significantly reduce soil erosion.This was observed following a heavy thunderstorm in July 1992. Downed juniper trees in cut plots tended to trap sediment moving down from adjacent upslope juniper woodland. In the woodlands, overland flow of water and sediment tended to sweep around juniper trees and continue downslope into a sagebrush community. Eddleman (pers. communication) has also observed similar results on larger juniper cuts in the Crooked River area of Oregon.

Species Diversity: Plant species diversity was greater on cut plots both in the interspace and canopy zones as measured by total species numbers. In 1992 the average number of species observed on cut plots (34 species) was over 100 percent greater than the number on woodland plots (16). In 1993 the average number of species found in cut plots was 45 compared to just 27 in the woodland plots (about a 67 percent difference). The differences in the number of species found between 1992 and 1993 also reflect differences between drought (1992) and wet (1993) years. In both years it is evident that plant diversity is significantly greater in the cut plots.

Summary

Cutting western juniper woodland resulted in significantly increasing understory plant yield, density, cover, and total species numbers. Understory response the first year (1992) following treatment didn't appear to be very large. For example, in 1992 understory yield only increased from 18 to 41 lbs/acre. This was partially due to relatively dry conditions in 1992 but it also may take several years before full site potential is reached. By 1993 recovery of the understory was accelerating; the recovery being helped along by the greater than average amount of precipitation received. There is still much unoccupied space in the cut plots and it is expected that the trend of increasing understory yield, cover, and density will continue until most available space is filled. We estimate that plant yield on these sites should average between 400 and 700 lbs/acre depending on the year. Given present vegetation composition, native perennial plants should continue to make up the major component of the system.

Several other points to reiterate or emphasize are: (1) as understory cover improves, soil stability should increase and soil erosion should decrease; (2) cut trees provide several benefits including: a) a source of nutrients to be released into the soil during litter decomposition; b) a source of organic matter which is important in formation of good soil structure; c) protection and establishment sites for plant seedlings; and d) greater ground cover which should also contribute to reducing soil erosion; (3) plant diversity was increased after western juniper was cut, particularly as a result of more perennial and annual forb species. Monitoring of this study and other projects in western juniper woodlands is continuing.

Acknowledgements

The authors thank Fred Otley and his family for use of the land and logistic assistance over the course of the study. Many members of the EOARC staff assisted in the various aspects of the study.

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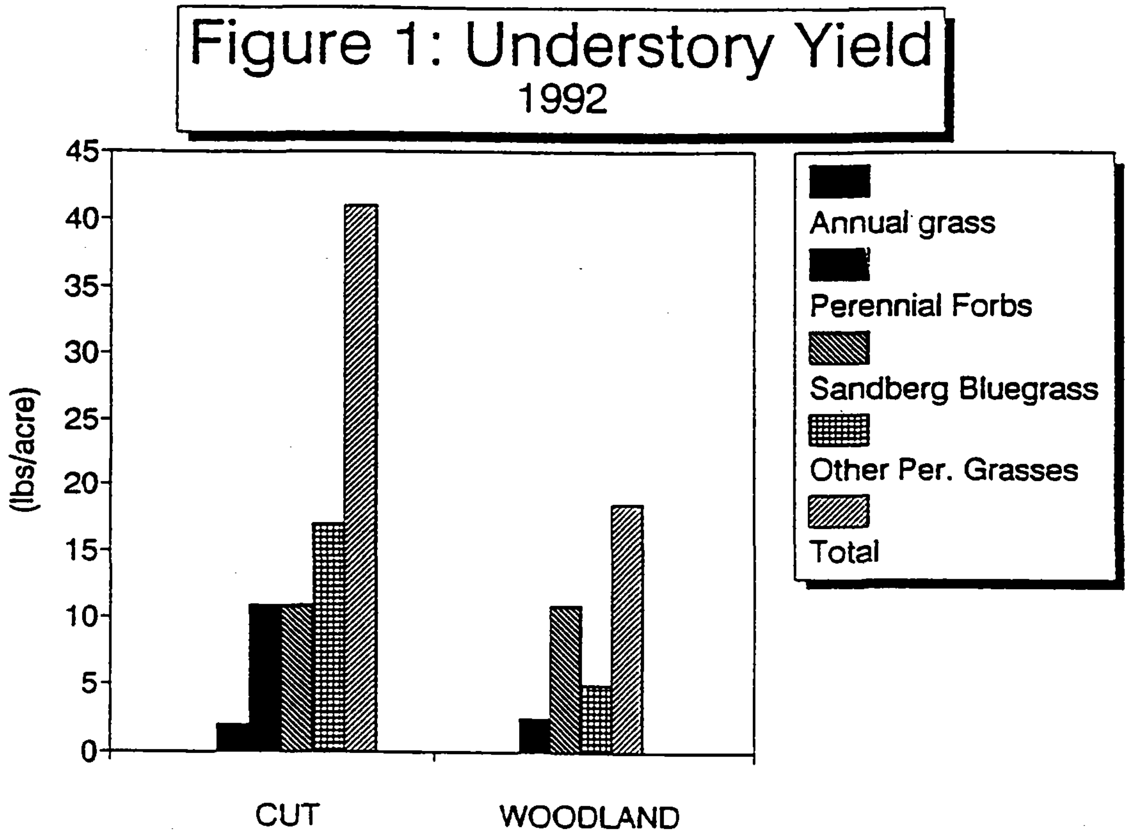
Table 1. Species numbers in cut and uncut western juniper woodland. Steens Mountain, Oregon.

	1992		1993	
Plant Category	Cut	Woodland	Cut	Woodland
perennial grass	8	7	8	7
annual grass	2	1	2	2
perennial forb	9	3	16	7
Annual forb				
- native	10	4	11	7
- non-native	5	1	8	4
TOTAL	34	16	45	27

Steens Mountain, Oregon.



Steens Mountain, Oregon.

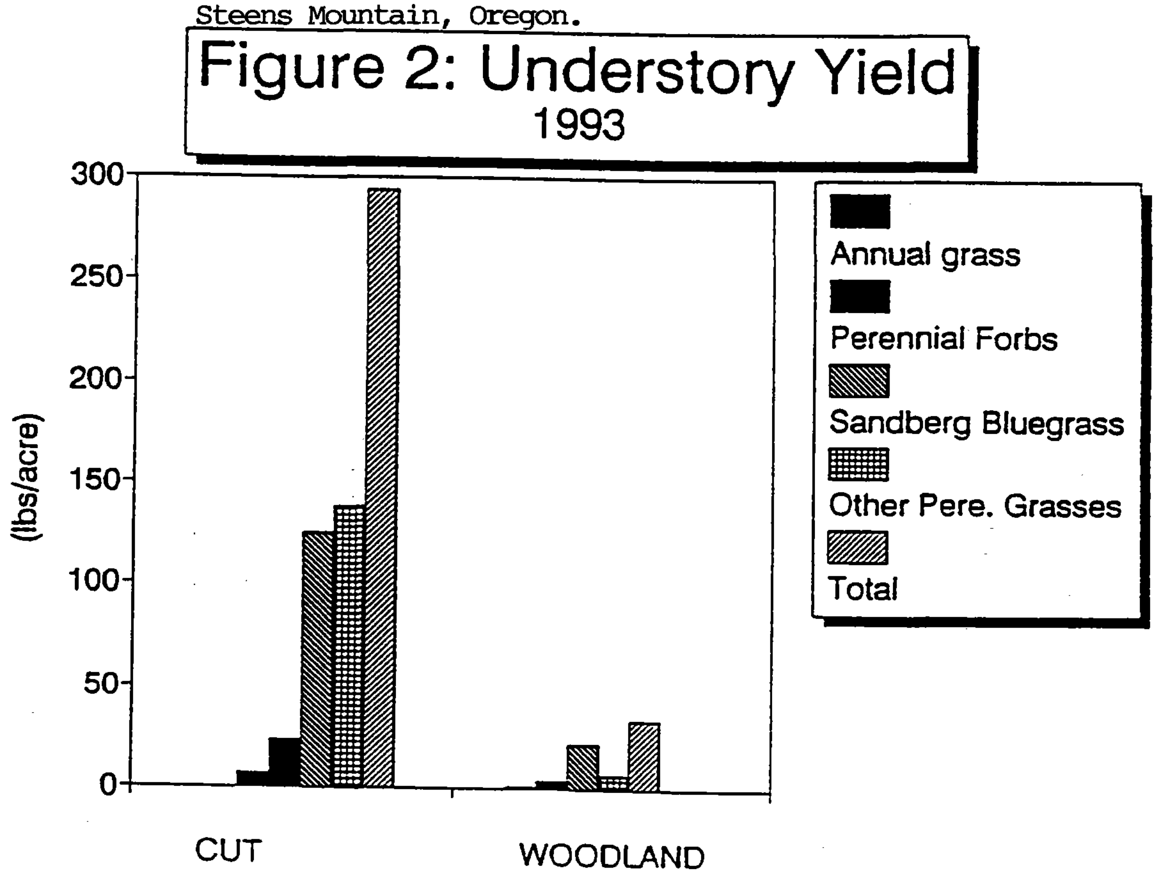
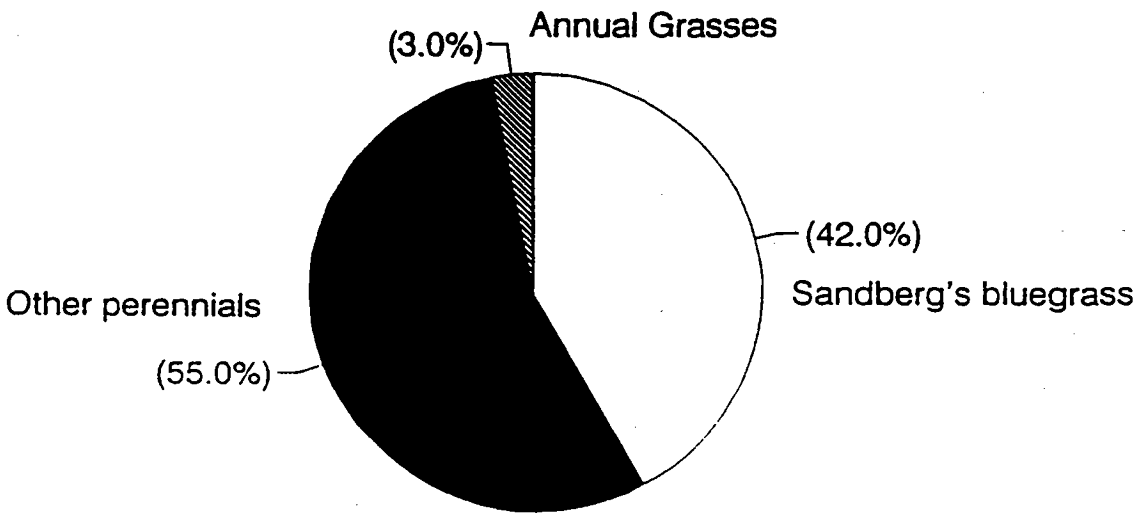
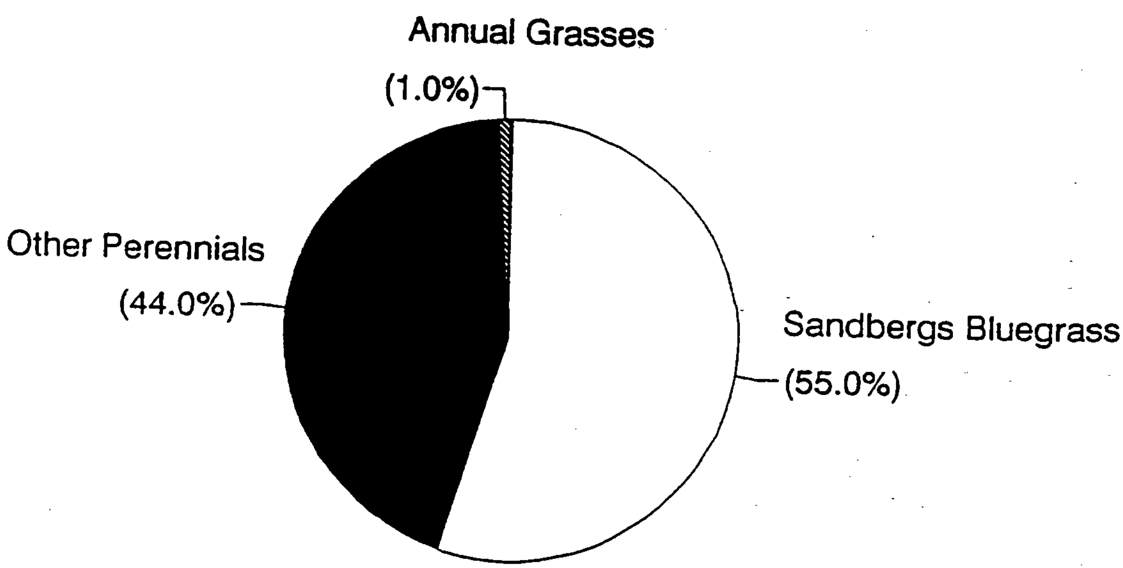


Figure 3: Understory Yield Composition
1993

Steens Mountain, Oregon



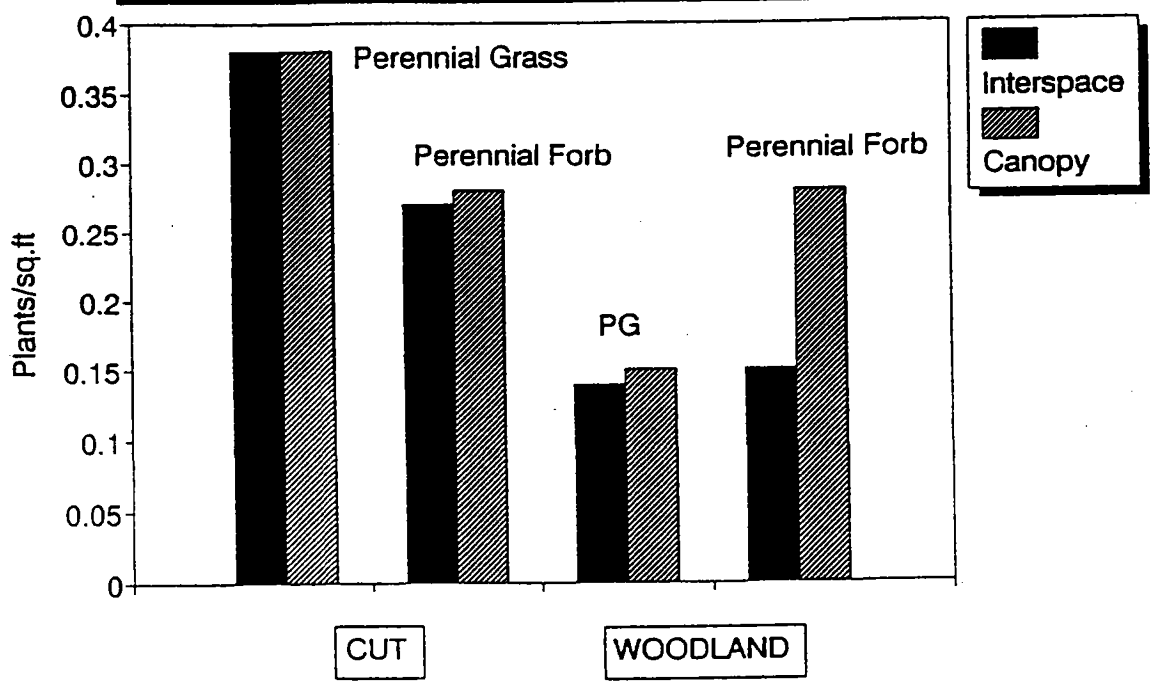
CUT PLOTS



WOODLANDS

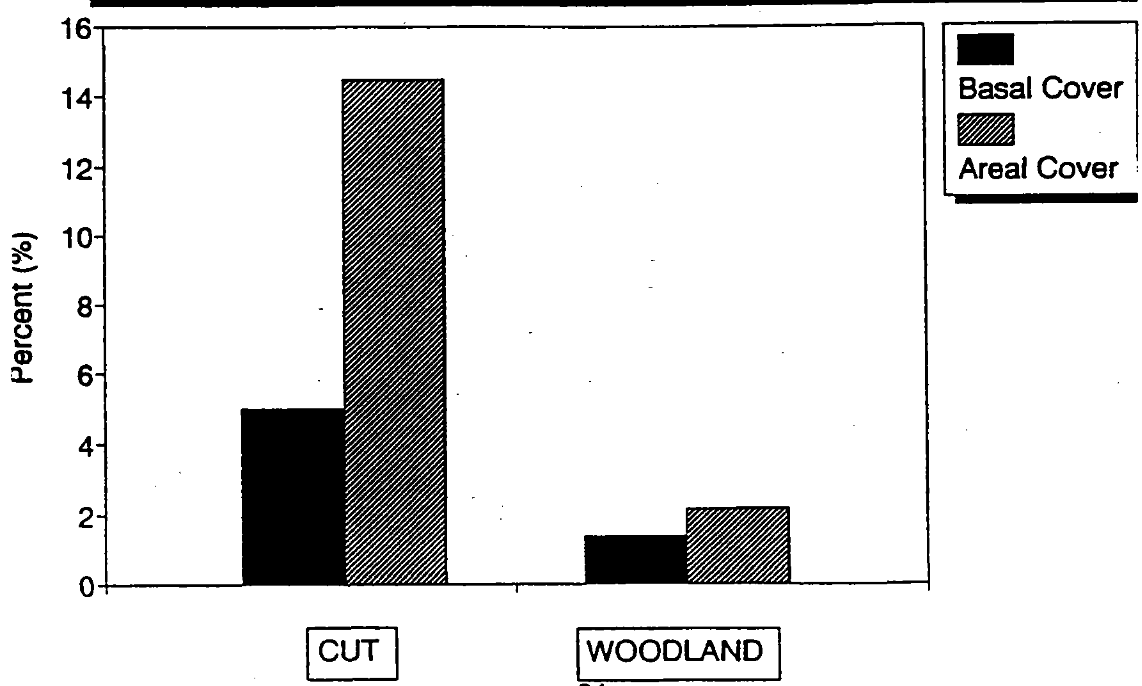
Steens Mountain, Oregon

Figure 4: Understory Plant Density
1993



Steens Mountain, Oregon

Figure 5: Total Understory Plant Cover
1993



Climate Change, Biodiversity, and Native Plant Restoration in the Sagebrush Steppe: The Vegetation Diversity Project

Michael M. Borman

INTRODUCTION

The Vegetation Diversity Project is administered within the Pacific Forest and Basin Rangeland Systems Cooperative Research and Technology Unit at Oregon State University (OSU) in Corvallis. The Cooperative Research Unit was initially established in November 1991 by the Bureau of Land Management's (BLM) Oregon/Washington State Office to address BLM's research needs primarily within Oregon and Washington; however, the Vegetation Diversity Project is a multi-state research effort encompassing the Great Basin and Columbia/Snake River Plateau regions. In November 1993, the Unit was transferred to the newly created National Biological Survey as a part of the Department of Interior's consolidation of all biological research personnel into a single agency.

Management of the majority of public rangeland in the Great Basin and Columbia-Snake River Plateau falls under the authority of the Bureau of Land Management. The flora of this land ranges from highly diverse native plant communities to deteriorated lands dominated by exotic annuals. Approximately nine percent of the BLM's 78 million acres of public land in this region is degraded to such a degree that changes in land management alone will not result in significant improvement. The BLM intends to restore native plant communities on these deteriorated lands, but current revegetation techniques used to establish introduced perennial grasses are often unsuccessful in establishing native plants.

On lands where native communities exist, the BLM desires to maintain and to enhance native plant diversity. Encroachment of highly competitive exotic forbs and annual grasses in native plant communities raises concern among managers over the appropriate management to maintain native communities. Coupled with these concerns are impacts on vegetation of the documented increase in CO_2 and of predicted global climate change.

The BLM therefore recognizes the need for research to understand and solve these problems and for the results of this research to be transferred to land managers. The Vegetation Diversity Project (VDP) has been initiated to address these needs.

Problem Analysis

In February 1993, we completed a problem analysis that includes a literature review and identifies research needs (see last page for citation). Input to the problem analysis was provided by BLM management personnel and university and federal research scientists who are active in or have an interest in restoration of rangeland systems in the Great Basin and Columbia/Snake River Plateau regions. A problem analysis (Pike and Borman 1993) was and sent to BLM State and District Offices, appropriate university and federal research organizations, and other organizations and individuals who indicated an interest.

The Great Basin and Columbia Plateau region consists of two major ecosystems: the sagebrush ecosystem, generally located in the northern half of the region; and the salt-desert shrub ecosystem, located in the southern half. These ecosystems differ greatly in their compositions of plant species and in their climatic and soil conditions. Therefore, techniques developed in one ecosystem may not be directly transferred to the other ecosystem.

In the Problem Analysis, we propose to initially concentrate studies in the Wyoming big sagebrush communities of the sagebrush ecosystem, because: (1) these communities represent a large amount of the BLM lands in Oregon, Idaho, northeastern California, Nevada and Utah; and (2) the low precipitation within these communities limits the success of standard revegetation methods. Shadscale (*Artiplex confertifolia*) communities of the salt-desert shrub ecosystem were given the next priority for study. These communities are a major component in four of the five participating states. Since the shadscale communities differ greatly from sagebrush communities, studies of shadscale communities will be initiated when the project reaches full funding. Similar studies to those proposed for sagebrush communities would be conducted on this new suite of species and environmental conditions. Low sagebrush communities would be given the lowest priority and studies in them are less likely to be initiated.

Research needs fall under five major areas of investigation: (1) long-term monitoring of vegetation diversity; (2) competition and establishment; (3) plant materials and seed technology; (4) maintenance of desired native vegetation; and (5) special status plants. Under each area of investigation a series of high, medium and low priority studies were identified. The priorities are being used as a guide in preparing requests for proposals, and in selecting and funding studies through the duration of the project.

Initial Efforts

The current funding level for the Vegetation Diversity Project is approximately one-third the level projected as necessary to adequately address the research, demonstration, and technology transfer requirements within the proposed ten-year time frame. Funding levels will determine the number and scope of studies conducted. Under the initial funding level, we have been able to initiate nine studies from among the high priority studies identified in the Problem Analysis. Dave Pyke is collaborating with researchers from Utah State University (USU) on a related study funded by the National Science Foundation. Technology transfer has also been budgeted and is funding participation in this field day, a newsletter, and will contribute to other outreach efforts. Oregon State University was awarded a cooperative agreement with the BLM to conduct this research on the basis of a competitive proposal. Research projects have been initiated by Dave Pyke and Mike Borman, from within the Vegetation Diversity Project, and by researchers at or associated with Oregon State University. The following research proposals have been approved and have been, or will soon be, initiated:

(1) TITLE: Establishment and reproduction of medusahead (*Taeniatherum caput-medusae*) on clay and loam soils.

SUMMARY: Medusahead, an exotic annual, was formerly suspected of being a problem plant that was restricted to clay soils, but is now thought to be expanding on loamy soils. This study will compare seedling establishment and reproduction of medusahead on two soil types occupied by a diverse native plant community. Treatments will include severe spring defoliation of the native plants and disturbance of the soil surface. Dave Pyke is the principle investigator and Heather Miller is a M.S. level graduate student conducting the study.

(2) TITLE: Competition between squirreltail (*Sitanion hystrix*) and medusahead (*Taeniatherum caput-medusae*) on clay and clay loam sites.

SUMMARY: The intensity and importance of competition between the native perennial grass, squirreltail, and the exotic annual grass, medusahead, are being evaluated in the sagebrush steppe of eastern Oregon. Population dynamics, growth analysis, and impacts on soil moisture of various densities and proportions of the two species are being assessed. The information is needed to determine if squirreltail may replace medusahead in low input restoration efforts. Mike Borman is the principle investigator and David Clausnitzer is a M.S. level graduate student conducting the study.

(3) TITLE: Comparative demography of three sensitive and morphologically similar species of *Astragalus*.

SUMMARY: The milkvetch genus has many species listed or being considered for listing as threatened or endangered of extinction. The demography of three that occur as endemic species in the northern Great Basin, *A. peckii*, *A. mulfordiae*, and *A. oniciformis*, will be examined. Reproduction, seedling and adult survival will be compared. Responses to wildfires and subsequent revegetation effects will also be compared for *A. mulfordiae* and *A. oniciformis*. Dave Pyke is the principle investigator.

(4) TITLE: Population risks of native perennials and of an exotic annual grass in desired and degraded plant communities: the role of grazing and climate.

SUMMARY: Long-term demographic monitoring plots were established in 1993 to determine the impact of late-winter and of spring grazing and of annual climatic fluctuations on the population of dynamics of native Great Basin shrubs and grasses and of exotic annuals. Seed longevity, seedling establishment and survival, and adult survival and reproduction will be examined at sites in eastern Oregon and southern Idaho. Dave Pyke is the principle investigator and Mark Martinez is a Ph.D. level graduate student conducting the study.

(5) TITLE: Effectiveness of using a strip tiller for reseeding lands dominated by exotic annuals.

SUMMARY: This project will be applied research evaluating use of a strip tiller, with and without an atrazine treatment at 1/2, 3/4, and 1 pound application rates, in conjunction with a standard drill for establishing perennial grasses in cheatgrass monocultures. The project will be a cooperative effort between the VDP and BLM's Intermountain Greenstripping and Rehabilitation Project. Mike Pellant (BLM Idaho State Office) is the

Project Leader and Mike Borman is the principle investigator of the study.

(6) TITLE: Compare the responses of shrubs, forbs, and grasses when nutrients become available in patches or pulses as opposed to uniformly.

SUMMARY: This study addresses the question of why sagebrush becomes the overwhelming dominant on sites in the absence of grazing and fire. It compares the ability of sagebrush, rabbitbrush, thickspike wheatgrass, medusahead and cheatgrass to compete for nutrients as they become available. Work is being conducted in northern Utah. Martyn Caldwell (USU), Dave Pyke (VDP), and John Stark (USU) are the principle investigators. Funding is provided by a grant from the National Science Foundation.

(7) TITLE: Changes in plant community dynamics caused by elevated CO_2 and altered precipitation.

SUMMARY: Studies will examine the response of desirable native plants (such as sagebrush, needlegrass) and undesirable exotic annuals (such as medusahead, cheatgrass) to shifts in precipitation from winter to summer and to increased levels of CO_2. This will be part of the USDI Global Change Research Program. William C. Krueger will be the principle investigator. Four OSU faculty (R.F. Miller, W.E. Winner, L.L. Larson, and G.L. Kiemnec), one USDA-ARS Research Scientist (T. Svejcar), and three graduate students will conduct the study.

(8) TITLE: Quantification of vegetation diversity on intact and deteriorated rangelands: Experiment 1 - Plant diversity on sagebrush steppe rangelands varying in ecological condition.

SUMMARY: This study will initially examine the usefulness of BLM's Ecological Site Index and Soil and Vegetation Inventory and Monitoring (SVIM) data sets for describing vegetation diversity on intact and degraded rangelands. Field studies will also determine the importance of temporal measurements within years and between years for descriptions of the plant diversity on intact and degraded sagebrush ecosystems. W.C. Krueger is the principle investigator. L.E. Eddleman (OSU) is the principle investigator and Pat Dysart is a Ph.D. level graduate student conducting the study.

(9) TITLE: Quantification of vegetation diversity on intact and deteriorated rangelands: Experiment 2 - Below-ground diversity.

SUMMARY: This study will examine the diversity of mycorrhizal fungi associated with intact and degraded sagebrush rangelands. It will examine the importance of mycorrhizal inoculation of perennial grasses during restoration of native plants on degraded lands. This study will also initiate a pilot study on the importance of microphytic crusts (lichens and mosses) for native plant restoration and maintenance on sagebrush rangelands. W.C. Krueger is the principle investigator. D.A. Perry (OSU) and one graduate student will conduct the study.

(10) TITLE: Seed dispersal by large herbivores: Opportunities for vegetation change on rangelands.

SUMMARY: There is a need for effective methods to enhance germination and establishment of desirable species on Wilderness Areas and WSAs, where drill equipment is not allowed and in other areas where drill equipment is not feasible. The use of livestock as a dispersal agent has been suggested in the literature and is being tried in other ecosystems, but not in the Great Basin with Great Basin species. This study will examine the ability of desirable native species and of undesirable species to be ingested, pass through the digestive system of various livestock species and remain viable. W.C. Krueger is the principle investigator. M.L. McInnis and M. Vavra (OSU) are the Principle Investigators and Amaya Lowry is a M.S. level graduate student conducting the study.

Information gathered from these studies and from studies conducted by BLM district personnel will be transferred to land managers using a quarterly update, demonstration sites, field days and field day reports, computer software, and through publications in nontechnical journals such as *Rangelands*, and in peer-reviewed scientific journals.

LITERATURE CITED

Pyke, David A., and Michael M. Borman. 1993. Problem Analysis for the Vegetation Diversity Project. Tech. Note OR-936-01. U.S. Dept. of Interior, Bureau of Land Management, Pacific Forest & Basin Rangeland Systems Cooperative Research & Technology. Unit, Corvallis, OR. 100 p.

The Problem Analysis will be mailed upon request as long as copies are available.

Selective Grazing Among Improved Varieties of Grasses by Beef Cattle, Black-tailed Jackrabbits, and Angora Goats

David Ganskopp and Ruben Cruz

INTRODUCTION

The Soil Conservation Service (SCS) and Agricultural Research Service (ARS) are constantly striving to find or breed improved varieties of forages for use in improved pastures or reclamation of deteriorated rangelands. Criteria considered in the development and release of these varieties include such attributes as seed production, ease of establishment, seasonal moisture requirements, disease resistance, stand persistence, forage production, leaf stem ratios, and nutrient and mineral content. Only within recent years has the acceptability of these forages to livestock and wildlife been an active concern.

At the local level the Soil Conservation Service cooperates with many different landowners to evaluate the success of these varieties under conditions specific to their particular area. These tasks are time consuming, as tested varieties must endure all of the temperature and moisture extremes an area can offer before potentially expensive recommendations to the public can be made with confidence.

In 1990 we established 8 selections of grasses in 9 small pastures on the Northern Great Basin Experimental Range. Our objectives were to evaluate the persistence of these grasses, their seasonal forage production and quality attributes, and their seasonal acceptability to livestock. Selections (and recommended precipitation ranges for planting) were: 2 cultivars of basin wildrye (*Elymus cinereus* (Scribner & Merr.), Magnar (8-25 in) and Trailhead (8-16 in); 1 cultivar of bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), Goldar (8-18 in); 2 cultivars of thick-spiked wheatgrass (*Agropyron dasystachyum* (Hooker) Scribner & J.G. Smith), selection #9021076 (6-16 in) and Secar (8-18 in); the Bozoisky (12-14 in) cultivar of Russian wildrye (*Elymus junceus* Fischer); Nordan crested wheatgrass (*Agropyron desertorum* (Fischer ex Link) Schultes) (8-12 in); and a crested wheatgrass cross called Hycrest II (9+ in), a product of *Agropyron desertorum* and *Agropyron cristatum* (L.) Gaertner). With the exception of Hycrest II, secured from USDA-ARS Logan, UT, seed was acquired from the SCS Pullman Plant Materials Center, WA.

EXPERIMENTAL DESIGN

Pastures and plantings were arranged similar to those in the previous discussion of cattle and native grasses. Seedlings were started in the green house during the 1989-90 winter and transplanted to the field in April 1990. Ninety-eight individual plants of each of the 8 selections were established in each of the 9 pastures for a total of 784 plants per pasture. Again each plant was randomly positioned so animals could not focus on a specific row or area to graze from a single selection. Because plants were kept free of competing weeds they grew to roughly baseball diameter during April, May, and June. In June 1990, black-tailed jackrabbits appeared in abundance and began foraging heavily on the plots. On 10 July, 1990 the pasture were fenced with chicken wire to exclude rabbits, and each plant was checked for presence and severity of grazing.

In 1991 Angora goats were on the station to evaluate their potential for sagebrush control. These animals were used in 2 sets of trials during the late-boot (seed stalks nearly emerged) and dormant (cured forage) stages of growth to evaluate their preferences for these forages. Three pastures were grazed in early June and 3 pastures in late August. During each session 6 mature goats were released progressively into a pasture and followed by a researcher with a portable computer to keep track of bites and time spent grazing on each plant. Because some of these varieties could not be identified from casual observations two other observers noted the positions of plants as the goats grazed for later determination of variety. Each goat was observed until it had foraged on 50 separate plants with a total of 250 observations gathered in each pasture.

Similar trials were conducted in 1992 with cattle at the same stages of plant growth. In these instances 3 steers were used with each animal being observed until it had consumed 84 plants for a total of 252 plants grazed in each pasture. While a vast amount of data are available from these trials, the following discussions will focus on the numbers of plants of each variety that were grazed as an expression of forage selection.

RESULTS

Cattle

Cattle exhibited slightly different patterns of selection between the 2 two stages of plant growth, so results from each period are presented separately. When forages were green and growing (late-boot stage) cattle appeared to place the forages into two categories. These were basically acceptable and avoided. Hycrest II, Goldar, Nordan, Thick-spiked, and Secar were all acceptable with between 40 and 31 percent of the plants of each variety being grazed (Figure 1-A). Indeed, had the steers not been selective grazers and simply foraged at random, roughly 31 to 32 percent of each of the cultivars would be grazed. This was almost the case with the acceptable forages, and observations are close enough that we can not really isolate a clear favorite from among the top five. Avoided selections included the 2 basin wildrye selections, Magnar and Trailhead, and the Bozoisky cultivar of Russian wildrye.

When forages were dormant, roughly three levels of selection occurred. Preferred forages were the Hycrest II and Nordan crested wheatgrasses (Figure 1-B). The cattle grazed four selections at roughly expected rates, which we will classify under the indifferent heading. These were thick-spiked wheatgrass, Secar Snake River wheatgrass, Bozoisky Russian

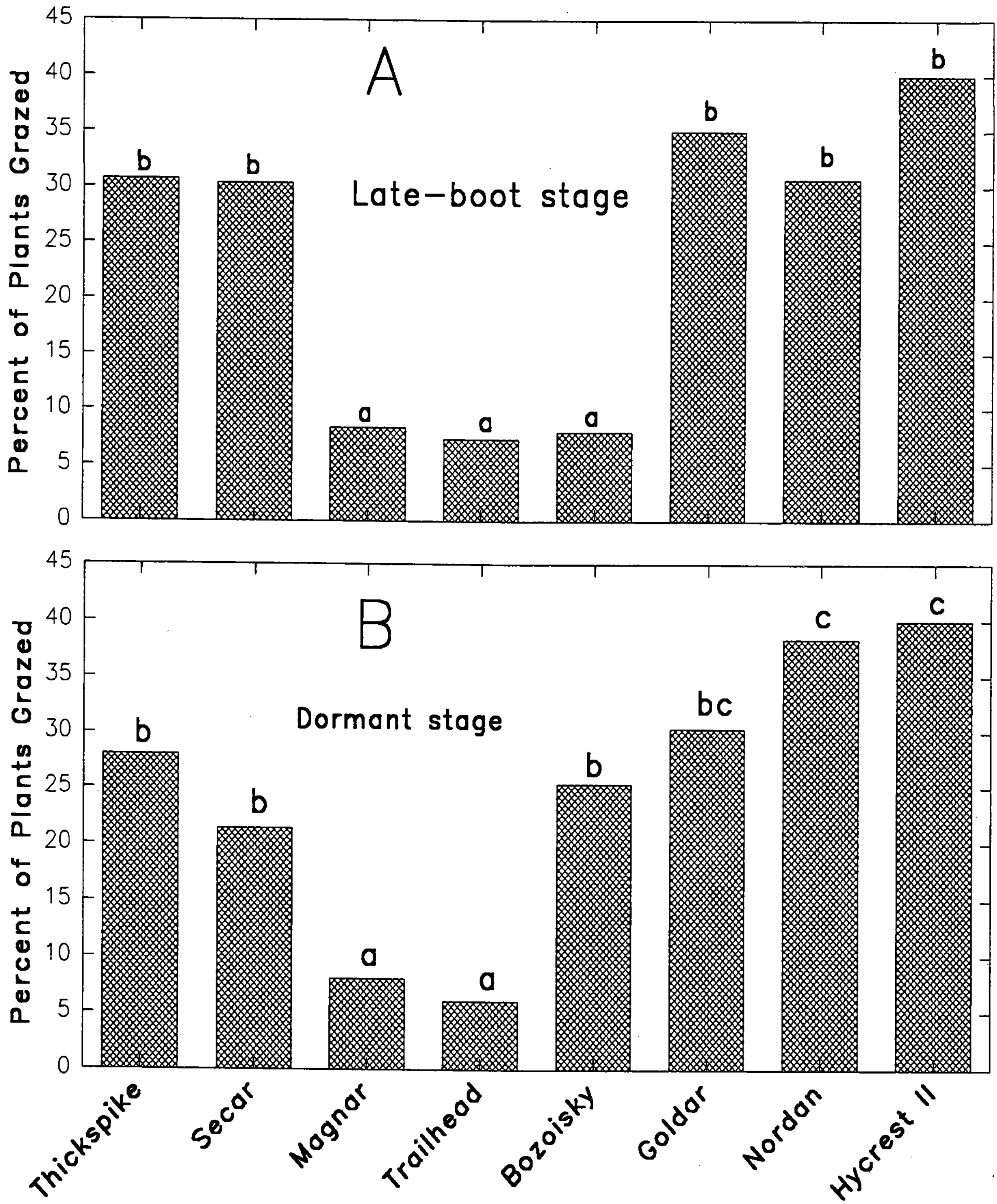


Figure 1. Selective patterns of steers grazing 8 cultivars of grasses during the late-boot (graph A) and dormant (Graph B) stages of growth. Columns sharing a common letter do not differ significantly (P>0.05). 1992. Northern Great Basin Experimental Range.

wildrye, and Goldar bluebunch wheatgrass which could be placed in either preferred or indifferent categories. Avoided selections included only the two basin wildryes, Magnar and Trailhead. The only real shift in ranking between the late- oot and dormant stages of phenology was the transition of Bozoisky Russian wildrye from avoided to acceptable. In general we had 5 selections viewed as acceptable at the late-boot stage and 6 selections ranked as acceptable or better during dormancy. This slightly lower level of selective grazing after forages have cured appears typical of large herbivores in most environments. No significant separations occurred among the closely related pairs of cultivars (thick-spiked and Secar, Magnar and Trailhead, and Nordan and Hycrest II).

Angora Goats

Goats exhibited the same patterns of selection among cultivars at both stages of growth, so data from the 2 periods were combined (Figure 2-A). The two crested wheatgrass selections (Hycrest II and Nordan) were clearly ranked as preferred forages. Between the two they accounted for roughly 80+ percent of the grazing activity. During the late-boot stage of growth the goats removed individual leaves from these plants and they focused solely on the seedheads after the forage matured.

The two basin wildryes (Magnar and Trailhead), Bozoisky Russian wildrye and Goldar bluebunch wheatgrass were classified as acceptable forages. The thick-spiked and Secar Snake River wheatgrasses were ranked as avoided, since the goats visited only 3 or 4 plants during each grazing session.

Black-tailed jackrabbits

Research in other areas indicates jackrabbits focus on grasses in spring and early summer, switch to broad leaf plants in late summer and fall, and endure the winters by foraging on shrubs. Jackrabbits were at exceptionally high densities in 1990 and 1991 on the station, and in many of our pastures they were the primary consumers of forage. Among selections jackrabbits were most fond of the two crested wheatgrasses (Hycrest II and Nordan) with roughly 70 percent of the plants grazed on, many almost to the point of death (See Figure 2-B). The 30 to 40 percent level of use on thick-spiked, Secar, and Goldar are about what we would expect from random foraging patterns, so we would judge these acceptable to the rabbits. The two basin wildryes (Magnar and Trailhead) and Bozoisky Russian wildrye were foraged on at low levels (about 4 to 18 percent) by the rabbits, and classified as avoided.

DISCUSSION

For cattle it appears that thick-spiked wheatgrass, Secar Snake River wheatgrass, Bozoisky Russian wildrye, Goldar bluebunch wheatgrass, and Nordan and Hycrest II crested wheatgrasses were all at least acceptable or preferred forages. The Bozoisky Russian wildrye, however, appeared more palatable when cured than when it was green. The avoided rankings

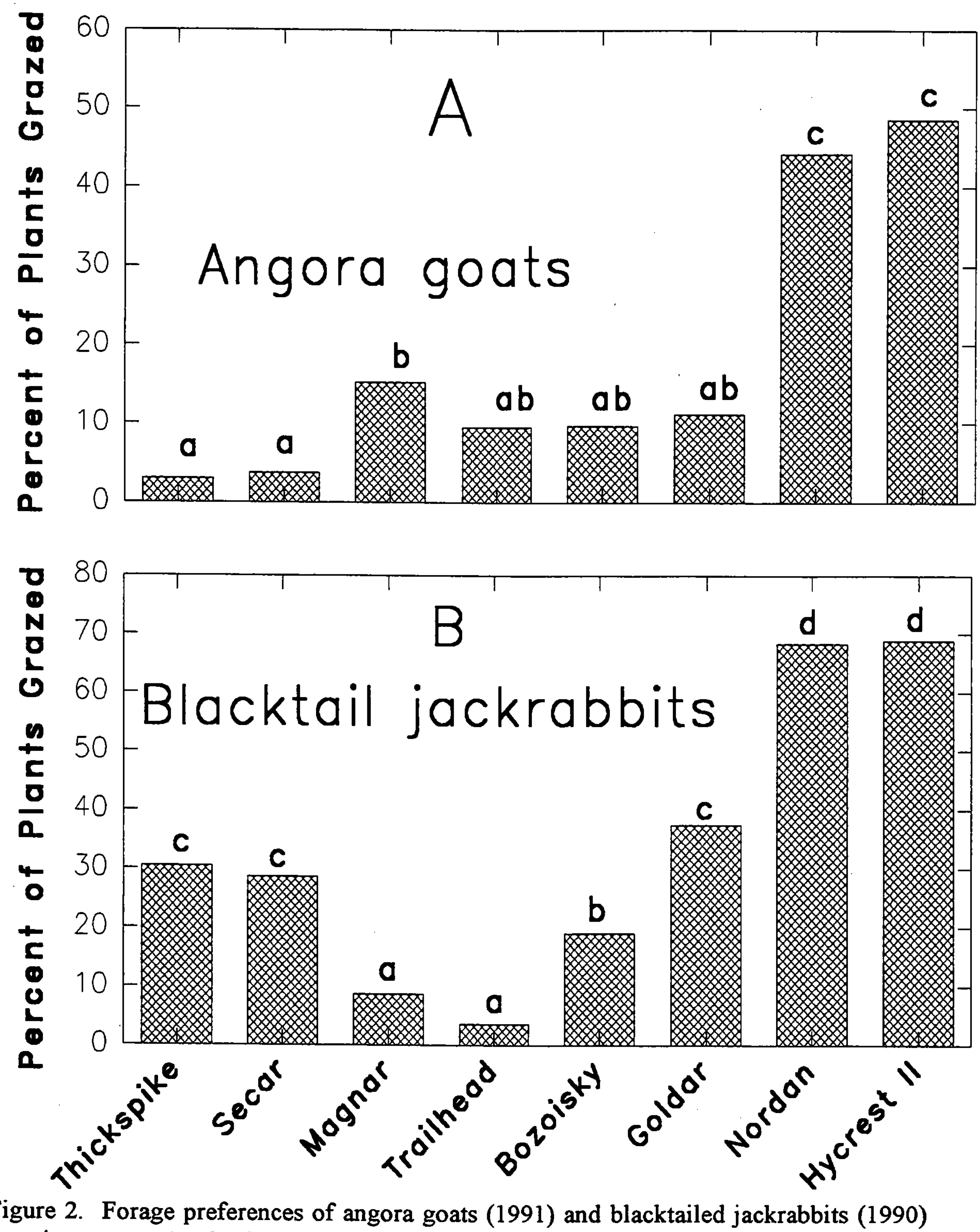


Figure 2. Forage preferences of angora goats (1991) and blacktailed jackrabbits (1990) foraging among 8 selections of grasses available for reclamation of Northern Great Basin Rangelands on the Northern Great Basin Experimental Range. Columns sharing a common letter do not differ significantly ($P \leq 0.05$).

of the 2 basin wildryes (Magnar and Trailhead) appear somewhat contrary to results obtained with our native grasses where our local basin wildrye ranked second in popularity. We have no sound explanations for this phenomena.

Among angora goats only the thick-spiked and Secar Snake River wheatgrass were avoided. In its early stages of release, Secar was initially classified as a bluebunch wheat grass. Recently, however, scientists discovered it was indeed a bunchgrass form of thick-spiked wheatgrass. It appears we should have consulted the goats, as they had no problems placing the two within the same category. Of the remaining varieties, all seemed acceptable forage for goats with the two crested wheatgrasses ranking the highest.

With their spring-summer reliance on grasses, jackrabbits are making use of grasses when they are most susceptible to heavy defoliation. It follows then that high numbers of these animals can possibly have an adverse impact on the health of range grasses. Among the jackrabbits only the two basin wildrye selections (Magnar and Trailhead) were avoided, the two crested wheatgrasses were relished, and the remaining selections judged acceptable. Of particular interest is the close similarity in the patterns of selection of cattle and jackrabbits. Indeed, both species appeared to favor and avoid the same selections.

Of particular note in these trials and the previous study is the popularity of crested wheatgrass, at least among the animals studied. For cattle and goats on improved pastures this would appear to be an excellent choice, as crested wheatgrass is a well-adapted and one of the most grazing tolerant grasses in our region. Unfortunately, the black-tailed jackrabbits also seem to be especially attracted to crested seedings. Therefore, in some low basins especially prone to jackrabbit outbreaks, one may consider planting a variety somewhat less appealing to the rabbits to avoid competition for forage with livestock. We might also consider other varieties along our roadways and other right of ways to avoid attracting livestock or wildlife to areas where their long term well being could be severely threatened.

In closing we would like to again point out that these trials are simply expressions of the animals' preferences. Livestock can and do perform acceptably on forages they do not particularly care for when selective opportunities are not available. In mixed stands, however, some extremely selective behavior can be exhibited. If grazing pressure is light, ungrazed plants or species will have a competitive advantage, so identification of key species may be important if stand integrity is a concern. High intensity grazing systems are designed to eliminate much of this selective behavior by placing great demands on the forage base. This elimination of selective behavior, however, typically results in a poorer quality diet for the animals in question. Finally, our animals were most selective when forages are green and growing, so efforts to uniformly graze down or clean up a pasture would be most successful after forages have cured. Grasses will be of poor quality at this time, however, and protein supplements may be necessary to maintain performance if extended use of the pasture is contemplated.

Broadcast Seeding as a Means of Restoring Depleted Western Juniper Woodland

L. E. Eddleman

In central Oregon there is a general lack of understory vegetation in western juniper (*Juniperus occidentalis* ssp. *occidentalis*) woodlands. In many areas ground cover other than that of juniper is essentially absent. Restoration of understory vegetation cover appears difficult to accomplish and may require innovative and perhaps costly approaches to be successful. Broadcast seeding may need to be used as a means of introducing new plant propagules into the system.

Changing resource values require methodologies which are low impact and conserve on-site plant and soil resources. As a first step,a study was initiated to evaluate the effectiveness of broadcast seeding without soil surface treatment but with retention of juniper boles and branches. Wood debris were retained to ameliorate the near-ground environment and to allow cycling of their nutrients back into the ecosystem.

METHODS

The study was located on Comb's Flat, 5.5 miles southeast of Prineville, Oregon, at an elevation of 3,740 feet on land under ownership of L S Ranches. Topography is gentle with a NNW facing aspect. Soils are moderately deep, averaging 24 inches, with a sandy loam surface grading into clay loam and finally into a loamy clay to clay just above fractured basalt bedrock. Long-term precipitation at Prineville, 2,850 feet elevation, is 10 inches but are approximately 11 inches at Comb's Flat.

During the last week in February 1988 and 1989, each of nine grass varieties were broadcast seeded on a set of five 807 ft^2 plots. Following seeding trees were cut and limbs were lopped and scattered. One set of plots was not seeded and one additional set was neither seeded nor slash covered.

Seeding rates were an adjusted estimate for each grass variety based on seed vigor (germination value) and seed size, and on suggested seeding rates which were further adjusted for to allow for no site preparation. Rates were high, ranging from 9 to 21 pounds per acre. At least minimal establishment was desired for each variety.

Vegetation was sampled by density counts and by cover estimates using twenty 2.15 ft^2 sample plots in each seeded plot and five sets of 20 plots each in the woodland. Broadcast seeded plots were sampled for establishment at 2 and 3 years after planting. Periodic soil moisture samples were taken in 1988, 1989, and 1990.

Vegetation was dominated by a 20 percent western juniper canopy cover. Shrubs were a well scattered mixture of Basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) and mountain big sagebrush (*A. t.* ssp. *vaseyana*). Primary perennial grasses were Bluebunch wheatgrass (*Agropyron spicatum*) Thurbers needlegrass (*Stipa thuberiana*), squirreltail (*Sitanion hystrix*), junegrass (*Koeleria pyramidata*) and native bluegrass (*Poa sandbergii*).

Characteristics of the ground surface cover were as follows for 1988 and 1989 respectively: bare soil 65 and 70 percent, total plant cover 11.8 and 7.4 percent, perennial bunchgrasses 4.6 and 5.4 percent of which native bluegrass made up 61 percent and 59 percent of the bunchgrass total, and annual grasses 0.7 percent and 0.9 percent. In 1988 annual lupine (*Lupinus microcarpus*) contributed 4.8 percent cover but only 0.6 percent in 1989.

RESULTS

Non-seeded plots — Plots in which no seeding took place were measured for plant cover in 1992. Bare ground in the woodlands had not changed and remained high (Table 1). In treated plots total understory plant cover had increased particularly on those plots with scattered juniper slash. Both perennial bunchgrass cover and annual grass, primarily cheatgrass (*Bromus tectorum*) appear to be increasing following treatment.

Table 1. 1992 ground cover percent in woodlands, open plots and slash covered plots. Comb's Flat, 5.5 miles southeast of Prineville, Oregon.

	JUNIPER WOODLAND	NO SEEDING NO SLASH		NO SEEDING SLASH COVERED	
Year treated	No	1988	1989	1988	1989
Bare ground	65	56	46	37	20
Juniper slash				30	48
Understory	11	18	13	23	28
All Bunchgrass	6	10	5	9	8
Native bluegrass	[3]	[2]	[2]	[2]	[2]
Annual grass	< 1	5	3	10	6

Response in plant cover was undoubtedly influenced by the general low input of precipitation amounts in 1987-88 and in the intervening period through 1992. Potentially effective moisture was considered to be precipitation received from October through September. Using an 11 inch average for Comb's Flat precipitation inputs were as a percent of average; 1987-88 (70 percent), 1988-89 (104 percent), 1989-90 (59 percent), 1990-91 (76 percent), 1991-92 (82 percent).

Seeded plots — Broadcast seeded grass varieties did manage to successfully establish some plants (Table 2). With the exception of GOLDAR (bluebunch wheatgrass) and NORDAN (crested wheatgrass), overall establishment rates were roughly double or more than double for the 1989 seeding as compared to the 1988 seeding.

As noted above potential effective moisture was 70 percent and 104 percent of average in 1987-88 and 1988-89 respectively. Precipitation was below average for the May through September period in both years. However during the growth initiation period of March through April, precipitation was less than 2 inches in 1988 and nearly 5 inches in 1989. Inputs of moisture during the 1988 growth initiation period more closely approximate the long-term average for the area.

Table 2. Seeding rates and plant establishment in each of two consecutive late winter seedings, 1988 and 1989. Comb's Flat, 5.5 miles southeast of Prineville, Oregon.

GRASS VARIETY	SEEDING RATE lb/ac	SEED PLANTED [a] #/m²	ESTABLISHED PLANTS #/m² 1988	#/m² 1989	% of seed 1988	% of seed 1989
GOLDAR[b]	21	513	7	12	1.8	3.2
SECAR	14	822	1	4	0.1	0.5
NORDAN	20	972	6	6	0.6	0.6
EPHRAIM	19	925	5	12	0.5	1.3
RUSH	17	168	5	24	3.0	14.3
TEGMAR	9	212	3	18	1.4	8.5
ROSANA	16	477	6	15	1.3	3.1
CRITANA	14	471	7	23	1.5	4.9
SHERMAN	14	2929	7	13	0.2	0.4

[a] Divide by 10.76 for number per square foot.

[b] Grass varieties are: GOLDAR bluebunch wheatgrass, SECAR bluebunch wheatgrass, NORDAN crested wheatgrass, EPHRAIM crested wheatgrass, RUSH intermediate wheatgrass, TEGMAR intermediate wheatgrass, ROSANA western wheatgrass, CRITANA thickspike wheatgrass, SHERMAN big bluegrass.

Observations on plant growth, including seeded species, in the treated plots indicated that soil moisture conditions were suitable for continued plant growth through September for two growing seasons post treatment. In general plant available soil moisture was found at 4 inches and below as of August 1 the first and second year post treatment. Herbaceous plant growth and development had ceased in the woodlands by mid-June 1988 and by late June 1989.

CONCLUSIONS

The apparent release of soil moisture and nutrients due to tree cutting and amelioration of the near-ground environment allowed significant increase in the existing understory vegetation suggesting that seeding may not have been necessary even with the low levels of existing understory plants. Reduced bare ground and greater vegetation response favor slash retention and dispersal.

Establishment of plants from the 1988 seeding is likely closer to reality than that of the 1989 seeding. Although some of these grass varieties can be established by broadcast seeding in stressful environments using juniper slash as the only seedbed modifier, the seeding rate is too costly for practical purposes.

If broadcast seeding is to be usable on degraded woodland areas, minimal seedbed preparation is needed to reduce the seeding rate. Seedbed preparation could be accomplished with a 4-wheel off-road vehicle with mounted whirlwind broadcast seeder and towing a drag or soil pitter at a time when soils are moist. Such a project is underway in Jefferson County.

Yellow Starthistle Invasion and Management

Larry Larson, Michael McInnis, and Gary Kiemnec

INVASION

Yellow starthistle (*Centaurea solstitialis*) is a winter annual (a plant that germinates from seed in the fall and over-winters as a rosette) that has invaded rangelands throughout the western United States. In the Pacific Northwest, the most susceptible rangelands are those with loamy soils, south facing slopes, receiving 12-25 inches (winter/spring peak) of precipitation. Yellow starthistle favors sites originally dominated by perennial grasses; primarily bluebunch wheatgrass (*Agropyron spicatum*, Idaho fescue(*Festuca idahoensis)*, and Sandberg's bluegrass (*Poa sandbergii*). This weed does not appear to compete well with sagebrush, but readily invades areas of soil and/or vegetation disturbance within sagebrush communities.

The competitive success of yellow starthistle is directly related to its rapid growth and resource capture (Sheley et al. 1993, Sheley and Larson 1994a). However, yellow starthistle seedlings and rosettes are sensitive to resource stress (competition for light, water, nutrients, and space) and are subject to high mortality when stress conditions prevail. In general, yellow starthistle seedlings grow more rapidly than most perennial grass seedlings. This characteristic leads to poor grass stand establishment when new grass seedings are infested with yellow starthistle. Once established, vigorous stands of perennial grass have been shown to limit re-invasion by yellow starthistle (Larson and McInnis 1989a, Larson and McInnis 1989b). Perennial grasses that initiate growth in the fall, maintain some growth through the winter months, and continue growth into mid-summer have the best success in competing with yellow starthistle.

In annual-dominated rangelands (i.e. cheatgrass [*Bromus tectorum*]) with deep soil, the rapid and deep penetrating roots of yellow starthistle tend to avoid direct competition with the fibrous root systems of annual grasses (Sheley and Larson 1994b). In areas where cheatgrass is widely dispersed, yellow starthistle root and shoot growth rates can be several times faster than cheatgrass. This growth attribute results in deep soil penetration by starthistle roots, continued growth well into the later part of the growing season, and increased starthistle seed production. In such circumstances, yellow starthistle can dominate the site. However, yellow starthistle growth rates tend to decline as plant density increases (cheatgrass and yellow starthistle) and/or soils become shallow (Sheley and Larson 1994b). This shift in competitive ability means that yellow starthistle will take on the role of a secondary rather than a dominant species when these conditions prevail.

PREVENTION

Prevention techniques are the least expensive and most effective method of limiting yellow starthistle invasion on productive rangelands. Proper grazing management is an essential element in this strategy and, although additional research needs to be conducted, there are several key grazing elements that can be identified at this time. An effective grazing prescription should include moderate grazing (typically 30-50 percent utilization of annual production), altering the season of grazing, rotating livestock to allow plants to recover before being regrazed, and promoting litter accumulation. Grazing in this fashion will limit yellow starthistle germination and promote mortality of seedlings and rosettes through the maintenance of desirable vegetation cover and vigorous grass growth.

Yellow starthistle prevention cannot be achieved through grazing management and plant competition alone. Disturbance (soil and plant community disturbance) is a natural component of all plant communities and is an essential part of plant community development and maintenance. Unfortunately, yellow starthistle is well adapted to take advantage of most grassland disturbances. Therefore prevention programs need to include a rangeland monitoring component so that isolated patches and individuals of yellow starthistle can be identified, flagged, and treated for control. In most cases isolated infestations should be flagged for several years so that treatment effectiveness can be followed through time.

CHEMICAL CONTROL

An effective control program requires disruption of the annual cycle of yellow starthistle invasion and the closure of the plant community to rapid re-invasion. Yellow starthistle control involves using combinations of treatments, including herbicide applications (with follow-ups), cultivation and seeding desired grasses. A number of herbicides are available to initiate the process of yellow starthistle control. Specific herbicides and application recommendations should be developed through consultation with extension and weed control agents. Herbicide application should be done by qualified individuals according to label instructions.

Following initial control, a perennial grass cover should be established on the site to interrupt the cycle of re-invasion. Grass stand establishment will increase the level of resource stress faced by starthistle seedlings and rossettes, limiting their survival and the rate of re-invasion. Our demonstration and research plots using Oahe intermediate wheatgrass (*Agropyron intermedium*), Tualitin tall oatgrass (*Arrhenatherum elatius*), Paiute orchardgrass (*Dactylis glomerata*), Covar sheep fescue (*Festuca ovina*), Critana thickspike wheatgrass (*Agropyron dasystachyum*), and Sherman big bluegrass (*Poa ampla*) have successfully controlled or reduced the rate of starthistle re-invasion (Larson and McInnis 1989a, Larson and McInnis 1989b). The degree of success or failure of any seeding will depend on the selection of a grass species suited to the site, the density of the established stand of grass and the land manager's ability to maintain grass vigor. Yellow starthistle growth rates and seed viability (at least 15 years) require a long-term commitment to starthistle control programs. This commitment will likely include an initial control and vegetation establishment program followed by a program of vegetation management and monitoring with periodic chemical application to control localized infestations. We recommend that land managers refrain from fertilizing new grass seedings that are infested with yellow starthistle because that practice has been shown to increase starthistle production (Larson and McInnis 1989a).

BIOLOGICAL CONTROL

Three weevil species (*Bangasternus orientialis, Estenopus villosus, Larinus curtis*) and two flies (*Urophora sirunaseva, Chaetorellia australis*) have been released in California and the Pacific Northwest during the past 8 years for yellow starthistle control. All of these agents attack the flowerhead. The goal of these control agents is to either reduce seed production and reduce colonization or establishment of this species. The effectiveness of insect control on yellow starthistle is currently under investigation and it is to early to determine their long-term impact on yellow starthistle populations.

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Vegetation and Livestock Exclusion in the Sagebrush Steppe

Jeffrey A. Rose, Richard F. Miller and Tony Svejcar

INTRODUCTION

Removal of domestic livestock has been suggested as a method to improve the ecologic condition of rangelands. This recommendation is based on the hypothesis that domestic livestock grazing does not irreversibly alter the plant communities' natural character and ecologic processes. Many livestock exclosures have been established across the western United States to test this hypothesis. With the establishment of the Northern Great Basin Experimental Range in 1936, 13 long-term livestock exclosures were established to monitor plant community response to removal of grazing pressure.

When the exclosures were established in 1936, range condition was poor over much of the experimental range. Plant communities had been subjected to season long continuous grazing since the introduction of cattle and sheep in the late 1800s. Sandberg's bluegrass and big sagebrush were the dominants in most of the plant communities. Periodic sampling of the exclosures since 1937 has found increases in plant density and cover on the experimental range, both inside and outside the exclosures (Rose *et. al.* 1993, Sneva *et. al.* 1984,Tueller 1962).

The current study is a more extensive examination of the plant community response to livestock exclusion in the Wyoming big sagebrush zone of the experimental range. In this study we further test the hypothesis that removal of domestic livestock will improve the ecological condition of native rangelands. We will test this hypothesis using plant density, cover, and standing crop.

Study Site

The study was conducted at the Northern Great Basin Experimental Range (NGBER) in Harney County, Oregon approximately 36 miles west of Burns. The experimental range is jointly operated by the USDA-ARS and Oregon State University Agricultural Experiment Station. The vegetation is representative of the northern Great Basin sagebrush steppe. Elevation of the NGBER ranges from 4200 ft to over 5500 ft above sea level. Climate for the is semi-arid, with cold and wet winters and hot and dry summers. Precipitation averages 11.3 inches per year, with over 80 percent of that falling between September and June. Mean January temperatures is 27° F and mean July temperature is 67°F.

Vegetation on the experimental range is dominated by western juniper (*Juniperus occidentallis* Hook.), low sagebrush (*Artemisia arbuscula* Nutt.) and big sagebrush (*Artemisia tridentata* Nutt.). Bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), Idaho fescue (*Festuca idahoensis* Elmer), Thurber's needlegrass (*Stipa thruberiana* Piper) and

Sandberg's bluegrass (*Poa sandbergii* Vasey) are the principal bunchgrasses. There are a wide variety of forbs present. Prairie lupine (*Lupinus lepidus* Doug.), speckle-pod locoweed (*Astragalus luntiginosus* Doug. ex Hook.), western hawksbeard (*Crepis occidentalis* Nutt.), bigseed lomatium (*Lomatium macrocarpum* (Nutt.) Coult. and Rose) and Menzie's larkspur (*Delphinium menziesii* DC.) are common perennial forbs throughout the experimental range. Annual forbs present include autumn willowweed (*Eppilobium paniculatum* Nutt. ex T. & G.), littleflower collinsia (*Collinsia parviflora* Lindl.), Microsteris (*Microsteris gracilis* (Hook.) Greene), and desert alyssum (*Alyssum desertorum* Stapf.).

Soils are of volcanic origin and are classified as mollisols or aridisols. Depth to bedrock varies from 2 to 4 feet, and a cemented horizon can usually be found to about 2.5 feet.

The experimental plots were established in three of the six, 160 ac pastures (ranges 8, 9, 10) near the center of the experimental range . These 160 ac pastures are the most uniform exclosures in the Wyoming big sagebrush type (*Artemisia tridentata* ssp. *wyomingensis* Beetle) in terms of vegetation and soils. In 1990, an additional exclosure was added adjacent to each of the 1936 exclosures in the 1960 ac pastures.

METHODS

Within each pasture, plant cover, density and standing crop were sampled inside and outside of the 1936 exclosures. Sampling was conducted in Late April thru mid June of 1992 and 1993. Plant cover was determined using the line intercept method using six, 98 ft (30 m) transects. Shrub density was determined using a 646 m^2 (6.6 ft x 98 ft) plot. Plant density and cover were determined by placing 10, 2.2 ft^2 (0.2 m^2) plots along the cover transect (one every 9.8 ft (3 m). Cryptogamic soil crust cover was estimated visually from within the 2.2 ft^2 (0.2 m^2) density plots. Every other density plot was clipped to determine net above ground primary production.

Plots were arranged in a randomized complete block design, with two grazed and ungrazed treatments in each of the three blocks. Data were analyzed using PROC ANOVA in the SAS statistical package (SAS 1986).

RESULTS AND DISCUSSION

The two years of the study were dramatically different in annual precipitation. Annual precipitation was 9.6 inches in 1992 and 21.1 inches in 1993. Precipitation in 1993 was a record for the over 50 years of data at the experimental range and nearly double the long-term average of 11.3 inches. As a result, where the year effect is significant cover, and density were always greater in 1993 than in 1992.

Plant Cover

Total plant and shrub cover were significantly higher inside of the exclosures than outside in 1992 and 1993 (Table 1). Wyoming big sagebrush cover was greater inside the exclosures than outside, but the cover of green rabbitbrush was greater outside of the exclosures. Shrub cover results from early studies, including all of the exclosures (Rose *et. al.* 1993, Sneva *et. al.* 1984, Tueller 1962), showed no significant difference in total and total shrub cover.

Total grass cover inside the exclosures was significantly greater than outside during both years of the study (Table 1). Sandberg's bluegrass was the only grass species in which we found treatment differences, and only in 1992. There was no difference in Sandberg's bluegrass cover in 1993. Cover values for the grazed plots were slightly greater than the excluded plots. This low-growing perennial grass has often been found to increase with grazing. Better growing conditions in 1993 may have reduced the differences between the grazed and excluded plots.

Total forb cover was significantly higher outside of the exclosure in 1992, but significantly higher inside of the exclosures in 1993. No single forb species showed significant response to position (Table 1). Western hawksbeard, larkspur, big seed lomatium, and longleaf phlox all tended to have greater cover outside the exclosure than inside.

Soil cryptogamic cover was greatest inside the exclosure in both years of the study (Table 1). These findings are consistent with other studies from across the west (Anderson *et. al.* 1982, Archer and Smeins 1991) These small lichens, fungi, algae and mosses occupy the upper two inches and are thought to play some role in nutrient cycling of semi arid ecosystems (Rychert *et. al.* 1978). Their location close to the soil surface makes them very susceptible to physical disturbance.

Plant Density

Total shrub, Wyoming big sagebrush and green rabbitbrush density was not significantly different inside and outside the exclosures (Table 2). Density of granite gilia was greater in the exclosures than in the grazed areas. In a study from Utah (West *et. al.* 1984) and earlier studies from the Northern Great Basin Experimental Range (Rose *et. al.* 1993, Sneva *et. al.* 1984, Tueller 1962), granite gilia decreased under grazing pressure. This small shrub from the phlox family is a minor component of the plant community both inside and outside of the exclosures. Granite gilia is relatively palatable and not very resistant to grazing. There was a trend for more Wyoming big sagebrush outside of the exclosures than inside, but the data was not significant.

Total grass, perennial grass, and cheatgrass (the only annual grass found during the study) density was similar in and out of the exclosures (Table 2). Prairie junegrass was the only species to exhibit significant differences between exclosure location. In 1993, prairie junegrass density was greatest in the grazed areas. This grass is often considered sensitive to grazing, therefore these results were surprising. Sandberg's bluegrass, Idaho fescue, and bottlebrush squirreltail also had greater density outside of the exclosures compared to inside, but the data was not statistically significant. Although Sandberg's bluegrass is a small stature plant, its density was 46 percent to 55 percent of the total grass density and 25 percent to 45 percent of the total grass cover. This plant is often considered a lower seral plant, common in moderate to heavily disturbed areas of the sagebrush steppe. The abundance of it across the Northern Great Basin Experimental Range may be attributed to the past grazing history of the station.

Cheatgrass was the only annual grass encountered in the exclosure study (Table 2). Its density was 4 percent to 5 percent of the total in 1992 and 7 percent to 9 percent or the total in 1993. The increased precipitation probably helped increase its density. Continued monitoring in 1994 will help to determine if this increase is is correlated with the high precipitation in 1993. Past work has found cheatgrass to be only a minor component at the NGBER (EOARC file data).

Perennial forb density, comprised mainly of specklepod locoweed, Menzie's larkspur, western hawksbeard, and bigseed lomatium, was greatest outside the exclosures in 1992, but not different between treatments in 1993 (Table 2). Bigseed lomatium density was greater outside than inside the exclosures in both years of the study. Specklepod locoweed density was greater outside the exclosures than inside in 1993, but in 1992 there was no difference between the two locations. Western hawksbeard was the only perennial forb to have significantly greater density inside than outside the exclosure during both years of the study. Menzies larkspur also had significantly greater density inside than outside the exclosures, but only in 1992. Cover and density of western hawksbeard density has also been found to be greatest inside the exclosures across the experimental range (Rose *et. al.* 1993), possibly indicating sensitivity to grazing. However, Menzie's larkspur, a poisonous plant, also had greater densities inside compared to outside of the exclosures. A possible answer is that the livestock are not consuming clinical quantities of the plant, but are consuming enough to reduce its density. The actual numbers of plants consumed may be low.

Annual forbs constitute the majority of plants found in the density plots (Table 2). Their total density was greatest outside of the exclosure. Little flower collinsia, microsteris, and desert alyssum were the three most prominent annual forbs. Microsteris and desert alyssum density was greater outside than inside of the exclosures in 1992 and 1993. Little flower collinsia density was greatest inside the exclosures only in 1993. Density was greater in 1993 than in 1992 for all species of annual forbs. The increase in density in 1993 was probably attributed to the 200 percent increase in precipitation. Density of cryptogamic crusts patches was significantly greater inside the exclosures compared to the grazed areas (Table 2).

Standing Crop

There was no significant difference in standing crop between the two locations

(Table 3). standing crop was significantly greater in 1993 than in 1992. Once again the increased rain fall from 1992 to 1993 had a significant impact on productivity and thus standing biomass standing crop. Litter levels were greater inside of the exclosures than outside, but litter mass was not significantly different from 1992 to 1993.

Species Richness and Diversity

The effect of climate on species composition can be readily seen in the actual abundance data. In 1992 the exclosures and grazed areas had 35 and 36 species respectively (Table 4). In 1993, there was an increase in actual number of species. A 12 species increase occurred in the exclosures and a 7-species increase in the grazed areas. In the vegetation in 1993, there were 11 annual forbs and 3 perennial forbs not found in 1992, but there was 1 annual forb and 1 fungi present in 1992 not found in 1993. This resulted in a net change of 12 species. However actual abundance data can be misleading. The "new" species found in 1993 may have been there in 1992, but unfavorable conditions did not permit them to express themselves.

Species richness indices show that there is little difference between grazed and ungrazed locations and that the sites are fairly rich in species (Table 4). The Margalef and Menhinick indices increased for both treatments from 1992 to 1993. Richness indices take into account the number of species present and the sample size, but do not take into account how the species relate to each other in the community.

Pielou's Index and the modified Hill ratio are a measure of evenness or how species abundance is distributed among the species in a community. As the indices approach 1, then a single species would become very abundant and the density of the rest of the species would decline. For example, in a simple plant community with 10 plant species (A thru J) and a random sample of 100 plants the evenness value would be close to 0 if 91 of the samples were from species A and the remaining 9 samples were species B thru J. The evenness values would be close to 1 if all 10 species were represented by 10 samples each. Peilou values for all locations and years are above 0.84, indicating that the communities are fairly even. The modified Hill ratio also indicates that the communities are fairly even, with values between 0.70 and 0.87. Both indexes showed a reduction in evenness from 1992 to 1993. This reduction is related to the increase in annual plant density in 1993 due the increased precipitation. Annual forb density increased 40 percent outside and 130 percent inside the exclosures. Year seemed to have a more dramatic affect on the evenness of the communities than treatment.

Diversity measures incorporate species richness and evenness into a single index. Species diversity measures indicated little difference between the grazed and excluded sites and from year to year (Table 4). Simpson's Index indicates that the grazed plots were a slightly more diverse, but Shannon's Index showed the opposite trend. Simple communities have Simpson's Indices approaching 1 and Shannon's Indices approaching 0.

SUMMARY

This study reports the results of 57 years of livestock exclusion for Wyoming bigsagebrush communities in the northern Great Basin. When exclosures were established in 1936, the rangeland was dominated by Wyoming big sagebrush and Sandberg's bluegrass, and was considered to be in poor condition. The vegetation had changed dramatically from the time the exclosures were established. Today high seral perennial grasses are a major component of the current communities. Although there are subtle differences between exclosures and grazed areas, the diversity, herbaceous plant biomass, cover and density were not dramatically different. Averaged over the two years of the study, cover of grasses was 6 percent higher inside the exclosure and density was 5 percent higher outside of the exclosure. In general, our results indicate that cover is higher inside the exclosures and density is slightly higher in the grazed areas.

Cryptogamic soil crusts appeared to fare better inside the exclosures. Their fragile nature may not hold up to the physical disturbance. These organisms are active during the short time of the year when soil surfaces are moist. Negative impacts to these organisms may be reduced by grazing areas with extensive soil crusts after the soil surface is dry.

Removal of livestock grazing does not appear to have drastic effects on the Wyoming big sagebrush communities of the NGBER. Most studies examining livestock exclusion and adjacent grazed areas compare excluded areas with heavily grazed areas. The NGBER has had moderate grazing regime since its establishment. This moderate use may not be heavy enough to produce significant differences.

The below-normal in 1992, and near-twice normal precipitation in 1993 are two dramatically different years. Yet under these conditions, the general trends in the data remained consistent over the two years. Chambers and Norton (1993) found the negative affects of grazing during a drought occurred primarily under heavy grazing (Chambers and Norton 1993). As stated previously, the grazing has been moderate since the establishment of the station. This level of use has allowed the vegetation to improve from the original 1936 conditions. Complete protection from livestock grazing may be relatively ineffective in the reduction of sagebrush and increase in herbaceous biomass because of the long life and competitive nature of sagebrush (Daddy *et. al.* 1988).

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Table 1. Percent plant cover of major vegetation groups and selected species for 1992 and 1993. Northern Great Basin Experimental Range.

	1992		1993	
	Outside	Inside	Outside	Inside
	%	%	%	%
Total Vegetation	22.0Aa*	25.3Ba	26.9Ab	30.9Bb
Total Shrub	12.7Aa	16.8B	15.8Ab	17.1B
Wyoming Big Sagebrush	9.6A	14.8B	12.3A	8.3B
Green Rabbitbrush	2.9A	1.8B	3.2A	1.5B
Granite Gilia	0.01A	0.2B	0.01A	0.2B
Total Grass	6.4Aa	6.6Ba	7.6Ab	8.3Bb
Bluebunch Wheatgrass	1.0	1.0	1.1	1.0
Idaho Fescue	0.8	0.5	0.8	1.0
Prairie Junegrass	0.3	0.1	0.4	0.5
Sandberg's Bluegrass	2.4A	1.6B	3.2	3.1
Bottlebrush Squirreltail	0.7	0.6	0.8	0.4
Thurber's Needlegrass	1.2	2.7	1.1	2.4
Total Forbs	1.84a	2.87a	1.51b	3.21b
Western Hawksbeard	0.23	0.49	0.80	0.90
Menzie's Larkspur	0.22	0.31	0.35	0.87
Bigseed Lomatium	0.65	0.26	0.49	0.73
Longleaf Phlox	0.45	0.19	0.60	0.36

*Upper case letters indicate significant differences between exclosure locations within year and lower case letters indicate significant differences between years within exclosure location.

Table 2. Plant density (# / 10 ft^2) of major vegetation groups and selected species for 1992 and 1993. Northern Great Basin Experimental Range.

	1992		1993	
	Outside	Inside	Outside	Inside
	# / 10 ft^2	# / 10 ft^2	# / 10 ft^2	# / 10 ft^2
Total Shrub	0.95	0.84	0.94	0.83
Wyoming Big Sagebrush	0.68	0.52	0.68	0.53
Green Rabbitbrush	0.21	0.20	0.21	0.18
Granite Gilia	0.04A	0.10B	0.04	0.11
Total Grasses	25.99	23.03	23.38	24.12
Perennial Grasses	24.62	21.00	21.26	22.99
Bluebunch Wheatgrass	2.07	1.01	0.88	1.13
Idaho Fescue	1.13	0.75	0.75	0.93
Prairie Junegrass	0.63a	0.40	1.33Ab	0.35B
Sandberg's Bluegrass	12.75	12.70	11.16	11.97
Bottlebrush Squirreltail	2.424	1.540	1.313	1.742
Thurber's Needlegrass	5.606	5.556	4.343	5.758
Perennial Forbs	22.172A	15.051B	17.551	16.641
Specklepod Locoweed	1.212a	1.263	3.081Ab	0.981B
Menzie's Larkspur	1.49A	2.65B	1.38	2.02
Bigseed Lomatium	2.57Aa	1.91Ba	2.24Ab	1.03Bb
Western Hawksbeard	1.41Aa	2.02Ba	0.63Ab	1.33Bb
Annual Forbs	97.50Aa	53.76Ba	136.59Ab	122.04Bb
Desert Alyssum	44.06Aa	12.42Ba	68.01Ab	31.79Ba
Littleflower Collinsia	35.91a	29.67a	27.50Ab	55.76Ab
Microsteris	9.44Aa	5.78Ba	27.25Ab	19.54Bb
Cryptogamic Crusts	3.33Aa	16.54Ba	7.10Ab	13.79Bb

*Upper case letters indicate significant differences between exclosure locations within year and lower case letters indicate significant differences between years within exclosure location.

Table 3. Standing biomass of major vegetation groups for 1992 and 1993. Northern Great Basin Experimental Range.

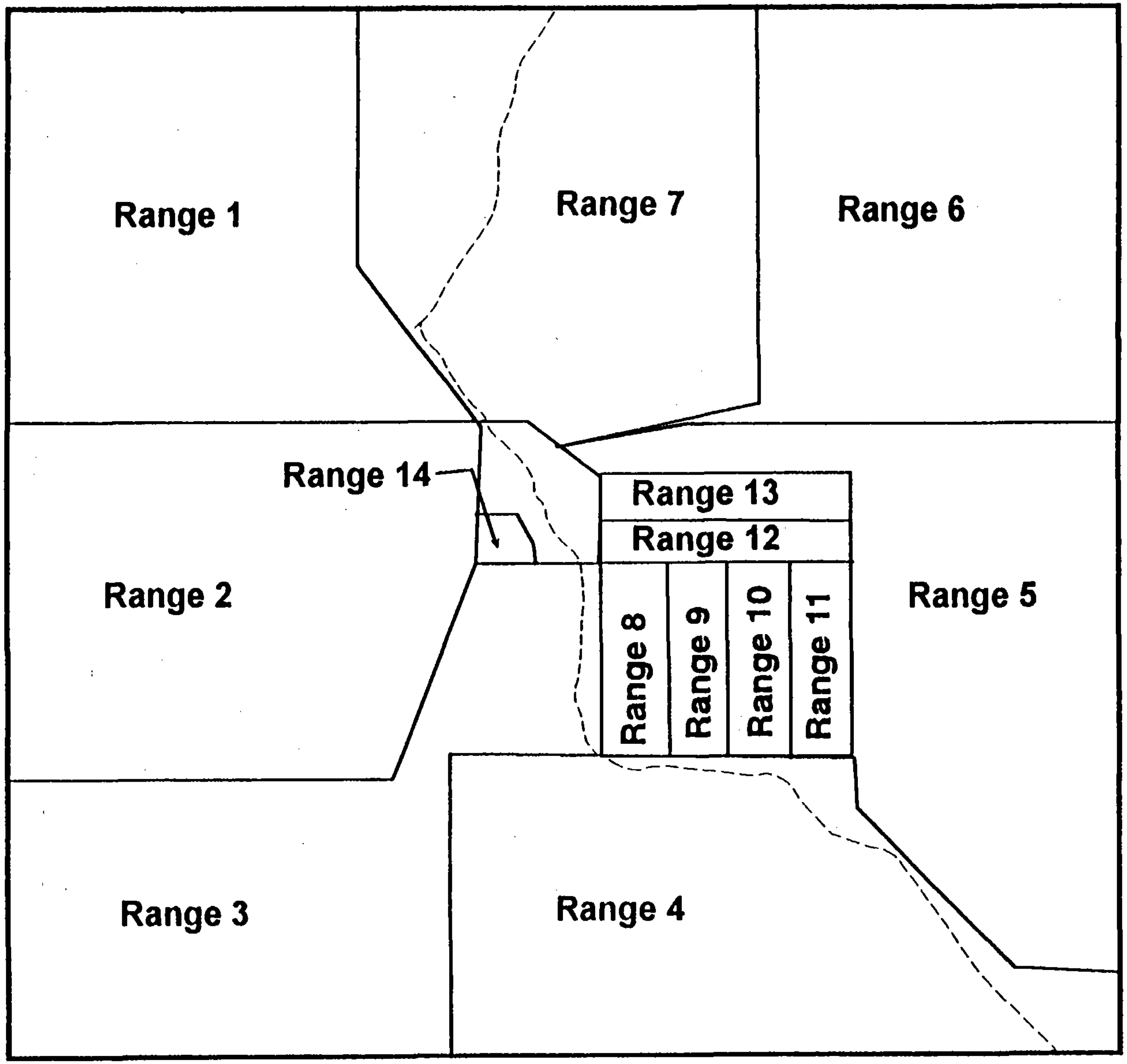
	1992		1993	
	Outside	Inside	Outside	Inside
Total	203.5a	231.1a	495.0b	468.6b
Total Grasses	148.5a	137.5a	335.1b	311.1b
Perennial Grasses	145.6a	135.2a	325.0b	300.9b
Cheatgrass	2.9a	2.3a	10.1b	10.2b
Total Forbs	55.0a	93.6a	159.9b	157.5b
Perennial Forbs	37.4	47.8	60.4	68.7
Annual Forbs	17.6a	45.8a	99.5b	88.8b
Litter	122.7A	249.6B	131.3A	252.5B

*Upper case letters indicate significant differences between exclosure locations within year and lower case letters indicate significant differences between years within exclosure location.

Table 4. Plant species richness, diversity and evenness for plant communities inside and outside the exclosures. Northern Great Basin Experimental Range.

	1992		1993	
	Outside	Inside	Outside	Inside
Actual Abundance	36	35	43	48
Species Richness				
Margelef - R_1	7.645	7.872	9.338	9.972
Menhinick - R_2	3.649	4.039	4.537	4.668
Species Diversity				
Simpson's - λ	0. 051	0.050	0.058	0.042
Shannon's - H'	3.155	3.136	3.192	3.363
Species Evenness				
Pielou - J'	0.881	0.882	0.874	0.849
Modified Hill Ratio	0.864	0.833	0.813	0.702

Figure 1. Map of original pastures at the Northern Great Basin Experimental Range



Beef Cattle Forage Preferences: Native Grasses and Crested Wheatgrass

Ruben Cruz and David Ganskopp

INTRODUCTION

Recent work in the northern Great Basin established that free ranging beef cattle derive most of their nutritional benefit from the grass component of the vegetation. Near Burns Junction, OR roughly 85 to 91 percent of the year-round diet of cattle consisted of grasses (McInnis and Vavra, 1987). In the same research, forbs (broad-leaf plants) contributed from 1 to 14 percent, and palatable shrubs, primarily saltbush (*Atriplex spp.*) and winterfat (*Ceratoides lanata*) made up roughly 1 to 7 percent of the total annual diet. Other efforts on the Northern Great Basin Experimental Range near Burns found forbs made up 26 to 50 percent of total cattle diets in May, June, and July, however, grasses still dominated the diet in the remaining months and made up 78 to 99 percent of the total forage consumed (Angell et al., 1991). With some localized exceptions (Welch and Wagstaff, 1992), the volatile-oils in sagebrush and juniper are effective deterrents to browsing, and these woody plants typically make up less than 1 percent of the total annual diet of cattle.

Because selective grazing by wild or domestic animals can affect the character or composition of vegetation, information about the seasonal preferences of grazers is quite valuable. Those benefitting from such information include pasture managers concerned about the persistence or establishment of forages, livestock, or wildlife managers striving to meet the nutritional needs of their herds, and other land managers seeking to either encourage or discourage use of their ground cover. The objective of this research was to establish the relative preferences of beef cattle for seven of our most prominent native grasses and crested wheatgrass (*Agropyron desertorum*) at three different stages of growth. This was accomplished in cafeteria style grazing trials in pastures supporting equal numbers of plants of each selection.

EXPERIMENTAL DESIGN

The native grasses evaluated in this project included: bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), Idaho fescue (*Festuca idahoensis* Elmer), bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) Smith), Thurber's needlegrass (*Stipa thurberiana* Piper), needle-and-thread grass (*Stipa comata* Trin. & Rupr.), Sandberg's bluegrass (*Poa sandbergii* Vasey), and basin wildrye (*Elymus cinereus* Scribn. & Merr.). Nordan crested wheatgrass, a well adapted and long used introduction to the region, was also included. Nine small pastures were established on the Northern Great Basin Experimental Range beginning in 1990. Each pasture supported 100 plants of each selection (for a total of

800 plants in each pasture) established either from transplants on or adjacent to the station or seedlings started in a greenhouse. Each plant was randomly positioned in the pastures, so foraging animals could not simply search out a favorite area or row for continuous grazing. When a plant was consumed they were forced to make new decisions about their next choice. Three pastures were grazed early when plants were green and leafy, three grazed after seed stalks were up and bluebunch wheatgrass was flowering, and three grazed when the grasses had cured and turned brown.

During each sampling session three steers were successively released in a pasture. Steers were allowed to graze until each had consumed 84 plants, so a total of 252 individual selections were made by the animals in each pasture. Two technicians kept track of the plants visited by the steers and a third technician, equipped with a portable computer, monitored the number of bites and amount of time spent at each plant. From this information several different expressions of grazing behavior were derived for each grass. Some of these were: total bites, bites per visit, total time, time per visit, bites per minute, number of plants grazed, number of plants regrazed, and distance traveled by cattle to reach each plant. This discussion will focus on the number of plants grazed and number of plants regrazed by the steers.

RESULTS

The steers were very selective in their foraging and results were different at each stage of growth. When grasses were in the vegetative stage of growth (green and leafy with no seed stalks visible), Nordan crested wheatgrass was the favored forage with over 70 percent of the plants being grazed (See Figure 1-A). The second and third most preferred species were basin wildrye at 32 percent and bluebunch wheat grass at about 25 percent. These two scored close enough that one can not be ranked above the other with much confidence. The same can be said when comparing bluebunch wheatgrass with the number-4 ranked Thurber's needlegrass (about 20 percent) and the 5 ranked squirreltail (about 18 percent). Closely clustered in 6th, 7th, and 8th places were Idaho fescue (7 percent), needle-and-thread grass (6 percent), and Sandberg's bluegrass (4 percent), respectively.

Results were somewhat similar when the grasses were flowering. Crested wheatgrass was still ranked in first place with again nearly 70 percent of the plants in the pastures being grazed (see Figure 1-B). Clustered closely in second, third, and fourth place were basin wildrye (17 percent), bluebunch wheatgrass (11 percent), and squirreltail (10 percent). No statistical separations were possible among the remaining Sandberg's bluegrass, Thurber's needlegrass, Idaho fescue, and needle-and-thread grass. We attempted to get more information on the lower ranking grasses by clipping off all the crested wheatgrass, so the steers would be forced to select from among the remaining grasses. The result was that the cattle shifted nearly 50 percent of their grazing effort to basin wildrye. The balance of their foraging (22 percent) came from Thurber's needlegrass, which we would confidently rank in the number 3 position. The remaining 23 percent was split among bluebunch wheatgrass (12 percent), squirreltail (7 percent), with Sandberg's bluegrass, Idaho fescue, and needle-and-

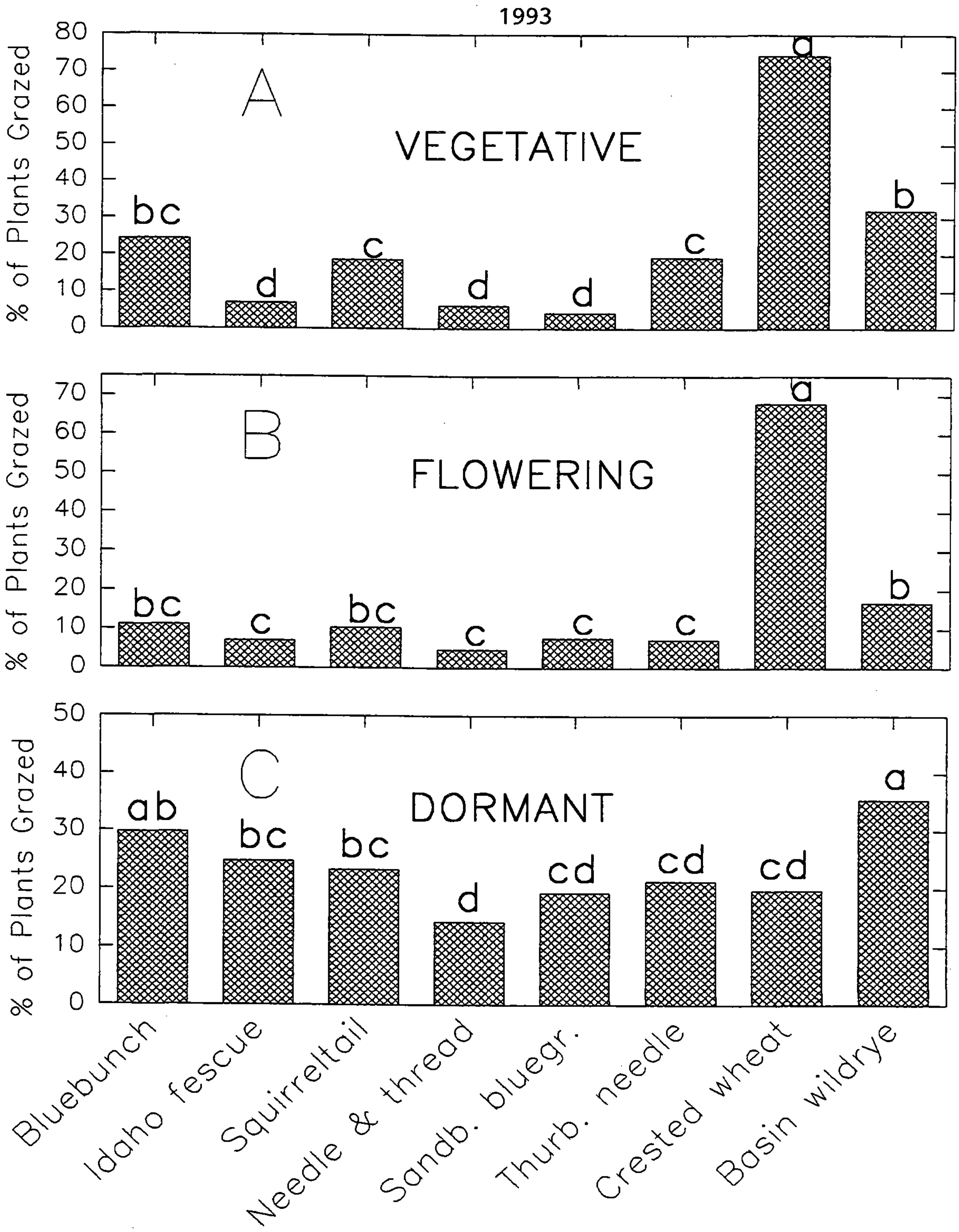


Figure 1. Percent or number of plants grazed from each of 7 native grasses and crested wheatgrass in forage selection trials during 3 stages of growth on the Northern Great Basin Experimental Range. Columns sharing a common letter do not differ significantly (P>0.05).

thread grass totaling only a few percentage points altogether. We can not confidently separate the rankings of these last five species. significantly (P>0.05). After the forages had cured, the cattle were much less selective (Figure 1-C). Among the selections, the percent of plants grazed ranged from 14 to 35, is a much narrower range than the 4 to 74 percent that occurred during the earlier stages of growth. Of note is that basin wildrye and bluebunch wheatgrass became the more preferred forages with very little separation possible among the remaining grasses.

Also of interest is the percent of grazed plants that were revisited by the steers and foraged on for a second or third time in the same day (Figure 2). Interpretations of preferred and less preferred forages are roughly the same as those derived from Figure 1, with the exception that some of the less preferred forages were not targets of any regrazing during the vegetative (Figure 2-A) or flowering (Figure 2-B) stages of growth. The greater frequency of regrazing across all species during the dormant stage of phenology (Figure 2-C) again suggested a lower level of selectivity by cattle after forages have cured. Of note, however, is that a substantial amount of regrazing of individual plants occurred even though the forage supply of individual species was not depleted. This suggested that cattle were attempting a more complete harvest of their favorite grasses before moving on to the less desirable choices. This observation was reinforced during the flowering stage of growth when removal of crested wheatgrass from a pasture simply resulted in a shift in focus to basin wildrye.

DISCUSSION

Several aspects of this study did not conform with our expectations. In particular was the very strong selection for crested wheatgrass over the native species when forages were green and growing (vegetative and flowering). We have previously separated crested wheatgrass seedings and native ranges with thoughts of preventing selective and excessive use of the native grasses by livestock. In contrast our results suggest that when grasses are green and growing cattle would probably deplete the crested wheatgrass in a mixed pasture before aggressively grazing the native grasses. Although probably not acceptable on public rangelands, the interseeding of crested wheatgrass into native pastures might lower the grazing demands previously made on the native species or lure cattle away from sensitive or critical areas. As these hypotheses have not been tested yet, they should be viewed with some skepticism. In such instances, however, crested wheatgrass could become a key species, and careful watch on season of use and utilization levels would be warranted to maintain its presence in the pasture.

The high ranking of basin wildrye was also a surprise (second in rank when green and first when cured). This large stature grass is most prevalent on our deeper and somewhat more alkaline soils, often in association with sagebrush and greasewood (*Sarcobatus vermiculatus*). The steers foraged somewhat differently on this grass than the other species after its seedstalks had emerged. They avoided the very tough seed stalks by stripping off individual leaves. This left the stems standing, and gave the false impression that the plants

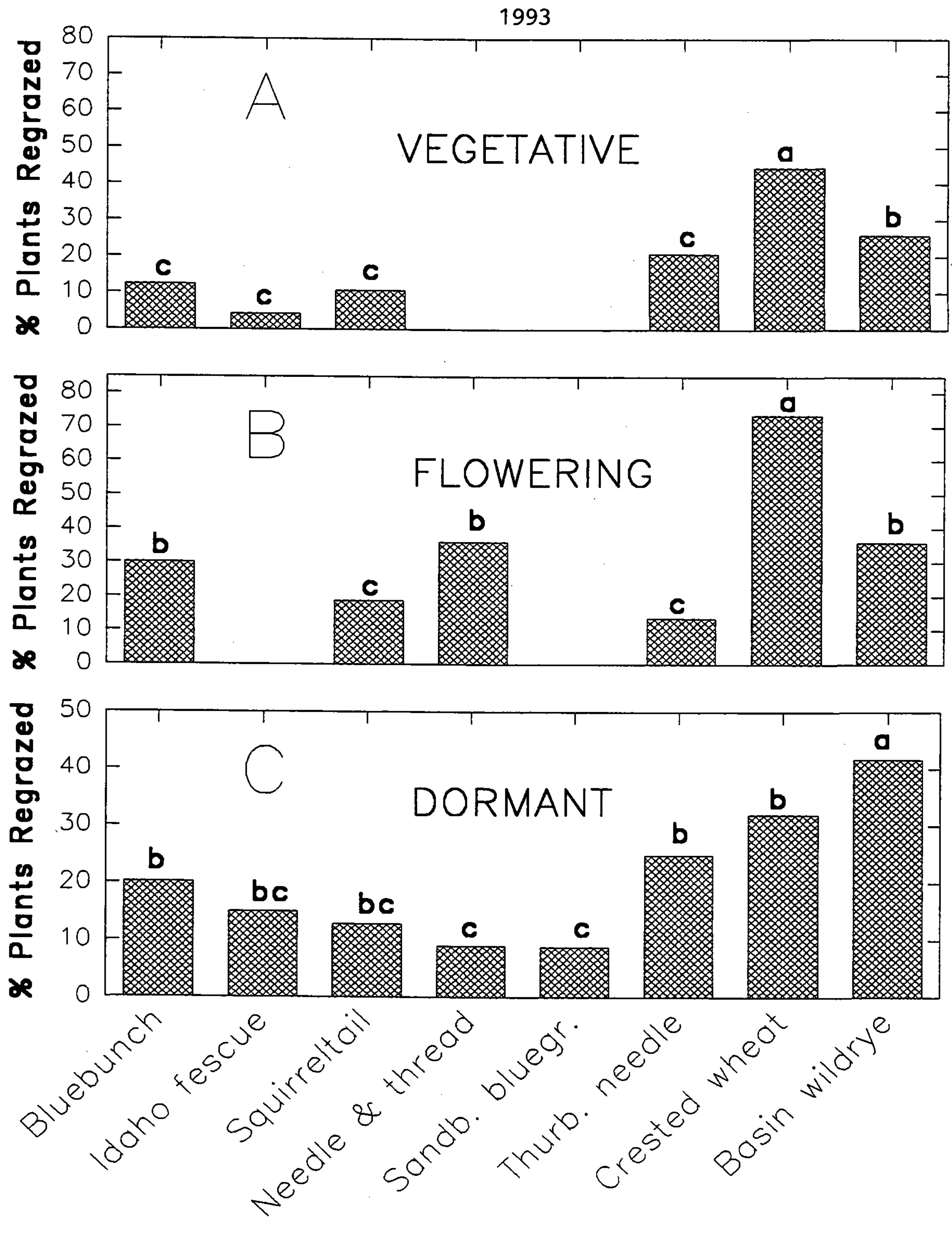


Figure 2. Percent of grazed plants from each of 7 native grasses and crested wheatgrass that were regrazed in selection trials during 3 stages of growth on the Northern Great Basin Experimental Range. Columns sharing a common letter do not differ significantly (P>0.05).

had received little utilization. As seed sources are available for several selections of basin wildrye and it seemed acceptable to cattle, it might be given more scrutiny for reclamation efforts on our sites with deeper (24+ inches) soils.

Also unexpected was the low ranking received by Idaho fescue (fifth to eighth place). As this grass typically occurs on our cooler north and east aspects, supports green growth well into our summer grazing season, we expected a higher level of use by the cattle. Chemical analyses of these forages revealed that Idaho fescue was lower than average in forage quality. To date, conventional forage chemistry has been a poor predictor of livestock selection or intake. Other lesser known chemicals in many of our problem shrubs and weeds induce aversive reactions in animals, however, chemical components that are strongly and positively associated with livestock forage selection.

In conclusion we have ranked the acceptance of these forages by cattle under green and growing conditions and for cured growth (Table 1). These rankings may be of some assistance in selecting one or more key species for monitoring pasture health or in predicting beef cattle grazing patterns over a diverse landscape. Because there is considerable genetic variation in our grasses across the region, these rankings should not be rigidly interpreted. Given the extremely selective behavior of cattle, however, managers can probably quickly derive their own list of rankings by observing their animals for a brief period when the full array of forages are available.

Table 1. 1993. Rankings of relative acceptability to cattle (highest = 1 and lowest = 8) of prominent Northern Great Basin grasses during green and cured stages of growth.

	Stage of growth	
Species	Green and growing	Cured forage
Nordan crested wheatgrass	1	2
Basin wildrye	2	1
Bluebunch wheatgrass	3	3
Bottlebrush squirreltail	4	6
Thurber's needlegrass	5	4
Needle-and-thread grass	6	8
Sandberg's bluegrass	7	7
Idaho fescue	8	5

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Winter Grazing as a Grazing Management Program for Northern Great Basin Rangelands

Steve Brandyberry, Tim DelCurto, and Raymond Angell

Reasons for grazing native range during winter

The cattle industry in the western U.S. originally existed as continuous, year-round grazing operations with cattle being free to roam, needing minimal management input. The severe winters of 1886-87 and 1889-90 killed thousands of free roaming cattle, and effectively marked the end of the open-range period of the western livestock industry. From this time on, winter feed was made available to livestock. The main costs incurred by livestock operators are those associated with the putting up and feeding of winter hay. These costs include labor, machinery, and fuel. Some of the most productive meadow ground is tied up in the production of hay. A return to winter grazing instead of winter hay feeding could free up these productive pieces of land for other purposes, thereby increasing management flexibility and options. Previous research at the Northern Great Basin Experimental Range (NGBER; formerly Squaw Butte Experiment Station) has shown that winter grazing offers economic advantages when compared to traditional hay feeding systems, primarily by reducing costs associated with putting up hay during summer and feeding hay during winter months. Common management practices in this area involves cattle grazing native range from spring through mid to late fall. At this time, cattle are moved down to native meadows, where they are fed hay through the winter before returning to the range, following spring calving. Winter grazing differs from this program in that cattle are moved off range and allowed to graze native meadow forage in the fall, before returning to rangeland for the winter grazing period.

Grazing cool-season forages during the winter should have little impact on plants' ability to initiate spring growth and produce forage the following year. In this respect, winter grazing should not adversely affect the range forage resource. In fact, this program may actually be beneficial to range condition and productivity. Removing dormant plant material may have little impact on plant productivity, and may improve forage quality. Grazing distribution and overall range utilization may be improved. Since all forage is in a state of dormancy, differences in forage quality are small; animals therefore have less incentive to concentrate use on certain species or areas. Water requirements are lower during winter, enabling animals to graze further from water sources and return to these sources less often. Canadian research has shown that cattle can utilize snow as a source of water. This could improve distribution, since a source of water would be present in many areas of the range. This could also alleviate some of the problems associated with maintaining open sources of water during winter, such as chopping ice, heating water tanks, and preventing water lines from freezing. The class of livestock used on winter grazing programs is also important. Dry, pregnant, mature beef cows have lower nutritional requirements, will graze further from water and return to water less frequently. They will also utilize steep slopes and other less accessible areas of the range more readily than other classes of livestock, including young, growing animals or cows with calves at their sides.

Winter grazing is also compatible with multiple-use management objectives currently employed in the management of public lands. Cattle are utilizing the range resource at a time when other demands for its use are at a minimum. Recreational use of public lands during winter is rare. The potential exists for conflict between livestock and big game if forage is limited and cattle are grazing range that is also traditional big game winter range. This would need to be considered in the planning stages. The impact on riparian areas should be minimal, since similarities of forage quality and other factors enhancing grazing distribution (including use of snow as a water source) will be pulling animals away from the riparian zones. Because of the enormous potential for winter grazing as a management alternative, research was instigated at the NGBER to investigate the efficacy of wintering beef cattle in the Northern Great Basin and possible managerial options to improve animal performance on winter range.

Supplementation of Winter Grazing Beef Cows

Cattle consuming low-quality roughages, such as winter range forage, are often given protein supplements. The addition of protein increases intake and utilization of these forages. Traditional protein supplements, such as soybean and cottonseed meal, are not readily available (and thus are quite expensive) in most areas of the Pacific Northwest. Alfalfa is commonly fed as a supplement in the Northern Great Basin because it is more available and economical to feed than traditional protein meal supplements. A two-year study was initiated in the winter of 1989-90, to further investigate alfalfa as a winter range supplement. In year one (1989-90), 48 mature gestating Hereford x Angus cows were stratified by age and body condition, and randomly allotted within stratification to one of the following treatments: (1) control (no supplement); (2) 3.31 lbs. of alfalfa pellets; (3) 6.61 lbs. of alfalfa pellets; and (4) 9.92 lbs of supplemental pellets. The study was repeated in 1990-91 (year 2), except that 72 cows were used in year 2. For both years, cows were gathered daily at 0900 to 1200 hours and individually fed their supplements. Chemical composition of the alfalfa supplement and grazed range forage is listed in Tables 1 and 2. Individual feeding of the cows began in early November and ended on February 21 (year 1) and January 15 (year 2). The trial was terminated at an earlier date in year 2, due to lack of available forage and concern over the health of the unsupplemented cows. A trace-mineralized salt mix containing vitamin A was provided free choice.

Measurements included cow body weight and body condition score (taken every 28 days), forage and total intake and digestibility, distance traveled, and grazing time. Esophageally fistulated steers were used to obtain estimates of diet quality.

Table 1. Quality of diet selected by esophageal steers in year 1 (1989-90). Northern Great Basin Experimental Range, Oregon.

	Sampling Period			
Item	Dec.	Jan.	Feb.	SE[a]
Organic matter, %	73.9	77.7	77.5	1.15
ADIN[b], %	48.9	50.5	55.3	2.70
	% of organic matter			
Crude protein	6.82	6.26	5.43	.24
ADF	72.2	67.1	70.5	.95
NDF	81.5	79.1	79.0	.84
ADL	6.33	6.14	7.61	.14

[a]Standard error of the mean.
[b]ADIN = acid detergent insoluble nitrogen. Expressed as a % of total N.

Table 2. Quality of diet selected by grazing steers in year 2 (1990-91). Northern Great Basin Experimental Range, Oregon.

	Sampling period			
Item	Dec.	Jan.	SE[a]	P-value
Organic matter, %	84.2	83.6	.50	.56
ADIN[b], %	53.3	53.1	1.36	.92
	% of organic matter			
Crude protein	4.78	5.42	.18	.03
ADF	67.9	67.6	.97	.85
NDF	80.8	83.1	.80	.03
ADL	6.22	6.90	.19	.04

[a]Standard error of the mean
[b]ADIN = acid detergent insoluble nitrogen. Expressed as a % of total N.

Diet quality declined throughout the winter grazing period, due to reductions in forage availability caused by forage removal, and(or) increases in plant maturity and nutrient leaching. Providing supplemental alfalfa improved cow body weight and body condition status in both years (Figures 1 thru 4). The largest improvements were noticed in cows receiving 3.31 lbs of alfalfa, relative to nonsupplemented control cows. Higher levels of supplementation provided smaller benefits relative to body weight and condition changes. Intake data show that at higher levels of supplementation, alfalfa substituted for forage, reducing the quantity of forage consumed. Forage intake and digestion, in addition to performance, was optimized by providing the first level (3.31 lbs) of alfalfa supplement.

Animal performance for all treatment groups was much lower in year 2 (1990-91) than in year 1 (1989-90). This difference may be due to a number of factors. First, more forage was available in the first winter, since a substantial amount of fall regrowth had occurred prior to the winter grazing period. Therefore, the forage may have been more readily available and of higher nutritional quality in year 1. Intake differences verify this hypothesis. In addition, the winter grazing period of 1989-90 was unseasonably mild, with little or no measurable precipitation. In contrast, 1990-91 was marked by extremely cold temperatures, especially in December. This reduced grazing activity and forage intake, which led to decreases in animal performance.

In summary, this two-year study showed that supplemental feeding of alfalfa is important in maintaining beef cattle weight and body condition, as well as improving forage intake and utilization during the winter grazing period. Supplementing 3.31 lbs of alfalfa pellets appeared to be the most effective supplementation strategy to optimize animal performance and forage utilization. Feeding higher levels of supplemental alfalfa resulted in smaller increases in animal performance and substitution of supplement for forage. In addition, this study clearly demonstrated the influence of the environment on forage quality and availability, as well as beef cattle nutritional physiology, in a winter grazing program.

This first study showed that alfalfa supplementation is beneficial to beef cows on winter range. However, pelleting alfalfa is expensive and could be justified only if animal performance is improved by pelleting the alfalfa hay. Another way of reducing costs associated with providing supplement would be to provide supplemental feed on an alternate-day basis. While this practice has been shown to be as effective as daily feeding, and to offer such economic advantages as reducing labor and travel costs, previous work has focused on protein meals or concentrates, not on alfalfa. Therefore, a winter grazing trial was initiated to compare the following: 1) physical form (pelleted vs. long-stem hay) of alfalfa supplements, and 2) frequency (daily vs. every other day) of alfalfa supplementation on beef cattle winter grazing Northern Great Basin rangelands.

This study was conducted during the winter of 1991-92 on the NGBER. Two, 1,000 acre pastures were used in the 70-day study, which ran from early November to mid-January. Original designs had the study ending in mid-February; however, low amounts of available forage (the result of six consecutive dry years) and snow cover, which reduced forage availability even further, caused the trial to be terminated early. In early October, 60 mature, pregnant Hereford x Angus cows were grouped by age, condition score, and fetal age. They were randomly assigned within groups to one of the four following treatments: (1) 4.4 lbs/day of alfalfa pellets, (2) 4.4 lbs/day alfalfa hay, (3) 8.8 lbs alfalfa pellets every other day (same as 4.4 lbs/day), and (4) 8.8 lbs/every other day of alfalfa hay (same as 4.4 lbs/day). Animals were gathered daily at 0800, sorted into individual pens, and fed their supplement. On days when only two groups received alfalfa supplement, the remaining two groups were returned to graze. Cows were moved to the second pasture on day 28. Cow weights and body condition (1-9 scale) were obtained on days 0, 28, 56, and 70. Two sampling periods (early December [Period 1] and mid-January [Period 2]) were conducted to obtain estimates of forage intake, digestibility, grazing behavior, and diet quality. Diet quality estimates was obtained by using esophageally fistulated steers.

Diet quality was lower in period 2 (Table 3) due to reductions in forage availability caused by the grazing animals' removal of forage, and by excessive snow cover. Neither physical form nor frequency of alfalfa supplementation had any effect on cow body weight, body condition, forage, NDF or total intake and digestibility, grazing time, or distance travelled. However, the effect of period was significant (Tables 4 &5). Cows lost weight over the first 28 days of the study, but showed weight gains at subsequent weigh periods. This change may have been caused by changes in forage quantity. Cows were moved on day 28 from a pasture where forage availability was limited to one with more available forage.

Cows lost more condition the last 14 days of the study than in either of the previous 28 day periods. Reductions in forage availability and rapidly increasing fetal growth may have prompted increased mobilization of tissue reserves to meet the increased demands of the fetus. Cows spent less time grazing in mid-January (period 2); colder temperatures and snow cover may have contributed to reducing grazing time as animals tried to reduce energy expenditures to conserve energy for heat production. Intake and digestibility of grazed forage was lower during this time, as well. Diet quality was reduced in period 2; this lower quality diet could have reduced forage intake. Cows were observed grazing bare sagebrush twigs during period 2. Subsequent cow and calf performance was not affected by supplementation treatment. Results from this study indicate that feeding alfalfa pellets or hay on a daily or alternate day basis has no affect on performance, intake, digestion, or grazing behavior of winter grazing beef cows. Alternate day feeding of alfalfa hay does not negatively impact animal performance and may offer the benefits of reducing labor and feed processing costs. Weather conditions and forage supply can influence winter grazing animals and should be considered when planning winter grazing programs.

Table 3. Chemical composition[a] of alfalfa supplements and forage selected by esophageal steers winter grazing northern Great Basin rangelands. 1991-92.

	Alfalfa		Forage		
Item	Pellets	Hay	Early December	Early January	SE[b]
OM	88.50	90.06	72.48[c]	87.29[d]	1.43
ADF	36.41	35.08	77.32[c]	66.70[d]	1.68
NDF	43.85	49.46	83.90[c]	72.61[d]	1.40
IADF	20.06	27.60	24.43[c]	46.92[d]	1.10
CP	18.08	19.86	5.09[c]	5.86[d]	.26
ADIN[e]	20.37	20.53	23.88[c]	50.62[d]	.97
in vitro OMD	67.25	63.62	58.44[c]	34.36[d]	1.13
ADL	8.32	9.10	9.79[c]	20.67[d]	.36

[b]Standard error of the mean.
[c,d]Means with different superscripts differ (P<.10).
[e]ADIN = acid detergent insoluble nitrogen. Expressed as a % of total N.

Table 4. Influence of physical form and frequency of alfalfa supplementation on weight gain and condition score of beef cattle winter grazing northern Great Basin rangeland. 1991-92.

	Treatment[a]					Period[b]		
Item	1	2	3	4	SE[c]	1	2	3
Wt. gain, lb.	3.10	-5.11	5.68	7.00	10.76	-81.85	80.77	10.66
Condition change, units	-1.20	-1.49	-1.30	-1.40	.10	-.40[d]	-.32[d]	-.63[e]

[a]Treatments: 1 = 4.4 lbs. alfalfa pellets fed daily; 2 = 4.4 lbs. alfalfa hay fed daily; 3 = 8.8 lbs. alfalfa pellets every other day; 4 = 8.8 lbs. alfalfa hay every other day.
[b]Periods: 1 = day 0 to day 28; 2 = day 29 to day 56; 3 = day 57 to day 70.
[c]Standard error of the mean.
[d,e]Period means with different superscripts differ (P<.01).

Table 5. Influence of physical form and frequency of alfalfa supplementation on intake, digestibility and grazing behavior of beef cattle winter grazing northern Great Basin rangelands. 1991-92.

	Treatment[a]					Period[b]		
Item	1	2	3	4	SE[c]	1	2	SE
OM intake, lb.								
NDF	16.36	16.52	16.76	16.78	.52	20.13[d]	13.10[e]	.30
Forage	18.17	18.22	18.63	18.41	.64	21.52[d]	15.20[e]	.36
Total	22.58	22.62	23.04	22.82	.64	25.92[d]	19.60[e]	.36
OM intake, % BW								
NDF	1.59	1.60	1.71	1.68	.18	2.00[d]	1.29[e]	.07
Forage	1.77	1.76	1.90	1.84	.21	2.14[d]	1.50[e]	.08
Total	2.20	2.19	2.34	2.28	.23	2.57[d]	1.93[e]	.08
OM digestibility, %								
NDF	44.74	44.56	44.20	44.14	.60	56.46[d]	32.36[e]	.38
Forage	46.40	46.40	46.43	46.39	.05	58.46[d]	34.34[e]	.02
Total	51.03	50.01	51.04	50.22	.21	59.68[d]	41.47[e]	.14
Grazing time, hr/d	5.96	6.17	5.63	6.00	.30	6.69[d]	5.19[e]	.18
Distance travelled, miles	3.80	3.86	3.89	3.68	.36	3.71	3.91	.22

[a]Treatments: 1 = 4.4 lb. alfalfa pellets daily; 2 = 4.4 lb. alfalfa hay daily; 3 = 8.8 lb. alfalfa hay every other day; 4 = 8.8 lb. alfalfa hay every other day.
[b]Periods: 1 = day 0 to day 28; 2 = day 29 to day 56; 3 = day 57 to day 70.
[c]Standard error of the mean.
[d,e]Period means with different superscripts differ ($P<.01$).

Year-Round Management of Rangelands Used for Winter Grazing

Potentially limiting factors in winter grazing programs include environmental conditions, forage quality, and the quantity of forage available for grazing. While we have no control over the weather, the potential may exist to improve range forage conditions. Traditionally, pastures utilized in winter grazing programs are not grazed during the rest of the year. Grazing these ranges early in spring ("preconditioning") may improve the quality of winter forage by delaying plant development; at the time of dormancy, nutrients would be retained in aboveground forage instead of in the roots. However, this practice may negatively impact forage availability, especially in arid climates; these changes may have a greater impact on forage conditions than changes in diet quality. Therefore, a two-year study was initiated to determine the effects of preconditioning on the quality and quantity of winter forage.

In early to mid-March of 1992, five 100 x 165 ft (30 x 50 m) sites were selected in a 1,000 acre, native range pasture, and excluded from grazing by electric fencing. Cow-calf pairs grazed this range from mid-March to mid-April of both 1992 and 1993, removing 75 AUMs and 125 AUMs of forage, respectively. Plots were sampled in late October to early November, following a hard freeze to ensure plant dormancy. Total forage production was estimated by clipping 20 randomly selected m^2 (3.3 sq. ft.) plots on both the inside (ungrazed), and outside (grazed), of each site. Immediately following clipping, five esophageally fistulated steers grazed the inside, then the outside of each site to obtain estimates of diet quality.

Growing season precipitation totals for 1991-92, 1992-93, and the 40-year average are shown in Figure 5. The growing season runs from September to August of the following year. Values for effects of treatment and year on forage production and chemical composition are shown on Tables 6, 7, and 8. Spring grazing reduced total forage available in the fall by over 100 lbs/acre. Spring grazing did not affect the quality of the diet selected by grazing animals. Standing forage quality, however, appeared to be enhanced by spring grazing. The increased amount of forage available on ungrazed sites provided animals with a greater opportunity to select a high-quality diet; this cancelled out the improved standing forage quality in the grazed sites. Forage production was higher in 1993 than 1992, but forage quality was much higher in 1992 than 1993. The crop year of 1992-93 was the wettest on record. Favorable growing conditions will increase forage production at the cost of reducing forage quality. Plants have higher concentrations of cell wall and reproductive tissue, which are harder for animals to digest. These increases in plant fiber reduce the availability of proteins and other nutrients. While the amount of forage is increased, the overall quality is reduced in years of abundant moisture.

Preconditioning did not appear to enhance the quality of diets selected by grazing animals. While forage quality of the standing crop appeared to be slightly improved by spring grazing, no spring grazing dramatically increased forage production and offered animals an increased opportunity to selectively graze. Major changes in forage quality and

Table 6. Effect of grazing treatment on forage production and chemical composition[a] of winter forage following deferred or spring grazing on northern Great Basin rangelands. 1992-93.

	Clipped samples				Esophageal samples			
Item	Ungrazed[b]	Grazed	SE[c]	P-value	Ungrazed	Grazed	SE	P-value
Total forage (lb./acre)	238.0	167.4.0	13.45	< .01				
NDF, %	77.17	75.21	.70	.07	78.00	77.94	.33	.90
ADF	56.61	54.63	.84	.12	60.40	59.81	.47	.37
AD[d]	6.35	6.21	.24	.69				
OMD					62.86	62.38	.49	.49
DMD	46.88	48.74	1.16	.28				

[a]Chemical composition expressed on a % OM basis.
[b]Ungrazed = grazing deferred until winter. Grazed = early spring grazing.
[c]Standard error of the mean.
[d]A significant (P<.05) treatment x year interaction was evident for ADL concentrations in esophageal samples.

Table 7. Effect of year on forage production and chemical composition[a] of winter forage following deferred or spring grazing on northern Great Basin rangelands. 1992-93.

	Clipped samples				Esophageal samples			
Item	1992	1993	SE[b]	P-value	1992	1993	SE	P-value
Total forage (lb./acre)	105.0	282.0	13.45	< .01				
NDF	69.21	83.17	.70	< .01	70.45	85.50	.33	< .01
ADF	52.85	58.39	.84	< .01	55.30	64.91	.47	< .01
ADL[c]	5.56	6.99	.24	< .01				
OMD					65.86	59.38	.48	< .01
DMD	50.26	45.37	1.16	.01				

[a]Chemical composition expressed on a percent OM basis.
[b]Standard error of the mean.
[c]A significant (P<.05) treatment x year interaction was evident for ADL concentrations in esophageal samples.

Table 8. Influence of grazing treatment and year on chemical composition[a] of winter forage following deferred or spring grazing on northern Great Basin rangelands[b].

	1992				1993			
Item	Ungrazed	Grazed	SE[c]	P-value	Ungrazed	Grazed	SE	P-value
Clipped samples:								
CP	7.48	9.48	.54	.05	2.08	2.12	.11	.81
Esophageal samples:								
CP	7.64	8.43	.20	< .01	3.23	3.15	.10	.59
ADL	6.03	6.96	.26	.01	7.83	7.70	.21	.68

[a]Chemical composition expressed on a % OM basis.
[b]A significant (P<.05) treatment x year interaction was evident for these variables.
[c]Ungrazed = grazing deferred until winter. Grazed = spring grazing.

quantity between 1992 and 1993 were likely caused by environmental differences, especially precipitation. In arid range environments, regrowth following grazing is not an automatic occurrence. In these environments, our research suggests little, if any, benefits to preconditioning of winter range forage.

Effects of Environment on Winter Grazing Beef Cattle

Cold temperatures can increase the energy requirements of cattle by over 100 percent, as animals increase their heat production in order to maintain a constant body temperature. Other environmental stressors (such as wind, precipitation, and mud) can raise energy requirements even higher. In feedlot or confinement situations, animals will increase their feed intake to try and meet these demands. Digestive activity is also increased, which speeds up the rate of digesta passage, but reduces diet digestibility. Other physiological changes also occur in response to colder weather. Grazing animals often reduce grazing activity and subsequent forage intake during adverse winter weather, apparently attempting to conserve energy for use in heat production by reducing grazing activity, which is very expensive in terms of energy use. These reductions in intake, coupled with the observed decreases in digestibility, result in body weight and condition losses prior to calving. This, in turn, can negatively affect postpartum reproductive performance. However, the exact mechanisms involved in this process are not yet clear. For one thing, animals can adapt to winter conditions, these animals are far better off during cold winter weather than other animals. The mechanisms involved in this adaptation are complicated and not completely understood.

We conducted a study during the winter of 1992-93, to investigate the effects that environmental variables had on grazing beef cattle, nutrition, performance, behavior, and physiology. Estimates of these effects were made on a day-to-day basis. We also hoped to get some insight on how animals respond to various environmental stressors.

The study was initiated on November 11, 1992. Twenty-four mature, pregnant Hereford x Angus cows, and seven bifistulated steers grazed a 1,000 acre, native range pasture, and were supplemented once daily with a corn-cottonseed meal mix (24% CP; 4.4 lb.•day). We began this sampling period on November 23. Cow body weight and condition, forage and total intake and digestion, time spent grazing, distance traveled, thyroid hormone and blood urea N levels, and digesta kinetics were animal responses that were measured. We decided to attempt daily estimations of grazed forage intake, a relatively new and untested procedure. Environmental variables measured at a nearby weather station included temperature, wind speed and direction, humidity, precipitation, snow depth, solar radiation and black body temperature (an estimate of total heat load derived from wind, temperature, and solar energy).

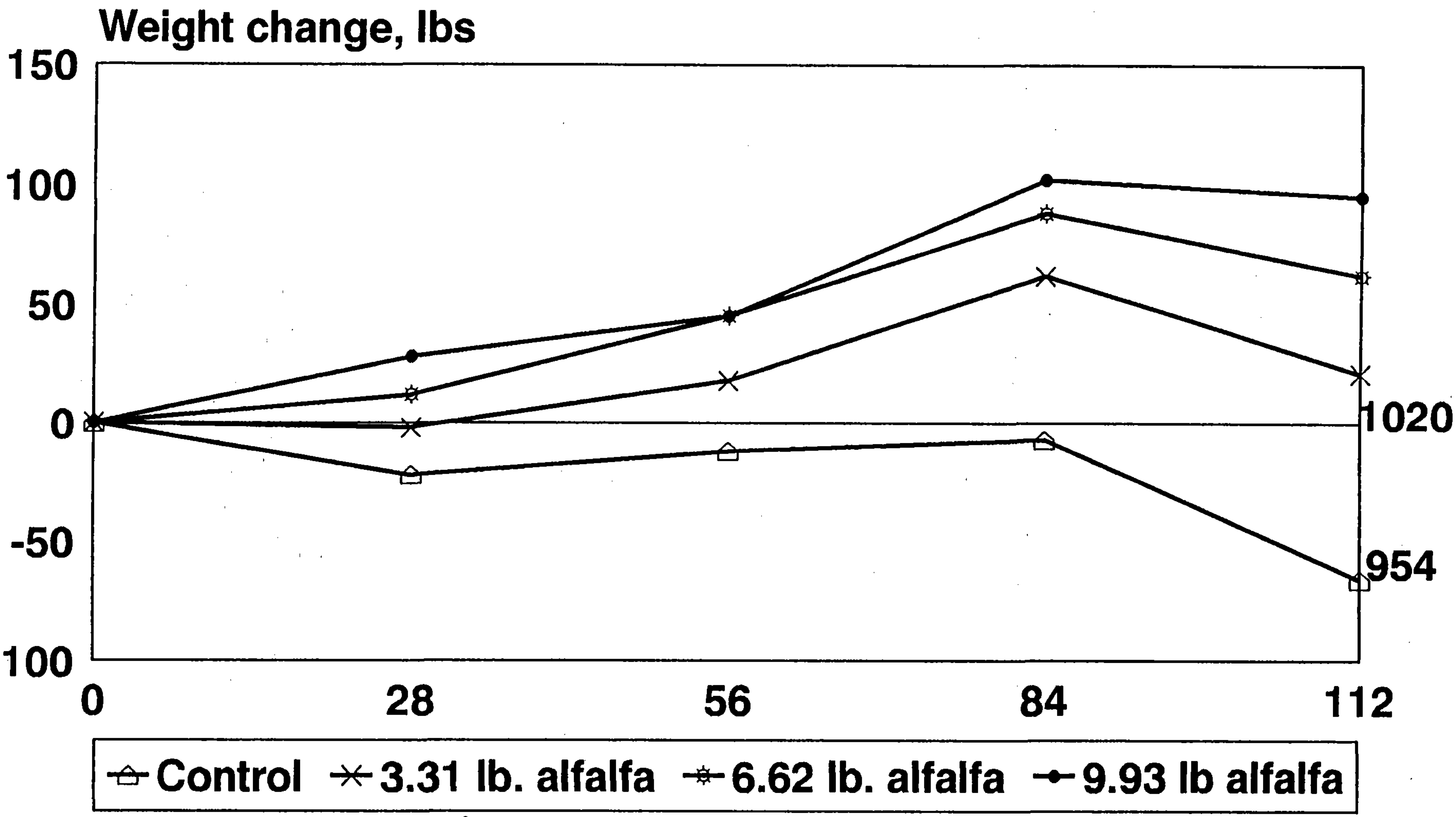
The grazing period ended on December 9, as 10-12 inches of snow covered all plants except sagebrush. We decided to push on and began feeding a low-quality hay at this time. By trials end, the snow was nearly 3 ft. deep on the range site. The original termination date was March 1, 1993; but by February 22, the road into the study pasture was impassable, so we terminated the study at that time.

While final results and conclusions have not been drawn, preliminary indications are that in this case, winter environment had no real significant impact on animal performance. Only snow depth had consistent affects on any animal responses. However, several interesting pieces of information was obtained from the study. The first involved snow consumption by cattle. Cows on this study did not travel to the lone source of open water in the pasture from early December until trial termination in late February; however, no adverse effects were noted, which agrees with several Canadian studies in this area. Visual observations showed cows consumed snow immediately after eating in the morning; however, no snow was eaten until all feeding had ceased. Cows also dramatically increased their feed intake and subsequent body weight and condition once hay feeding began. After a few days, intakes declined, but the levels remained slightly higher than those seen during grazing. Once hay feeding began, cows tended to congregate in the feeding ground and remained all day, of course heavy snow cover may have influenced this behavior. Our technique for daily estimation of forage intake under grazing situations appeared to work satisfactorily. And finally, we concluded that winter grazing is not a feasible management plan in years with severe winters, or in areas where such winters are common. Conclusions drawn in this study should be extrapolated to actual grazing situations only with great care, as this turned out to be not a grazing study, but more of a winter hay-feeding study.

Conclusions Regarding Winter Grazing

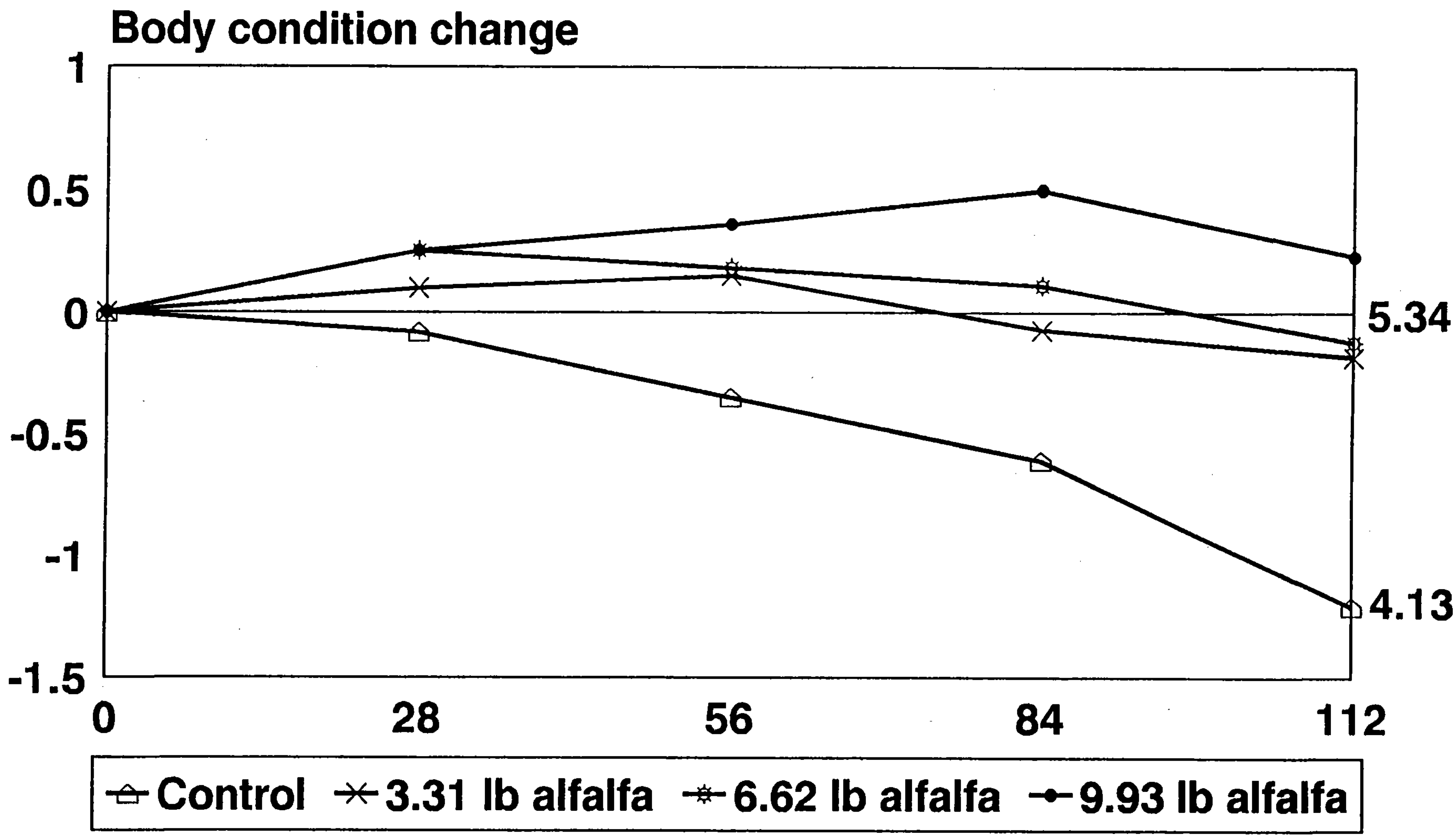
Results from the NGBER indicate that winter grazing can be a viable alternative grazing management program in this area. Feeding low levels of supplemental alfalfa in either pelleted or hay form daily, or on alternate days, can improve animal performance and maximize forge utilization without substituting for it. Forage quality of arid rangelands used for winter grazing may not benefit from spring grazing, as reductions in forage quantity appear to overshadow any potential enhancements in quality. Spring grazing reduces the amount of forage available for winter use; this could be especially detrimental to winter grazing in dry years. When designing and implementing winter grazing programs, the number one consideration should be, what is the chance that adverse winter weather (especially heavy snows) will occur?

Other criteria that should be met or addressed include the proximity of the winter range to the producer's base operation. Producers must be able to get to the range to supplement and check on animals, and to quickly get them out if the situation necessitates. A reliable water source is necessary, since snow will not always be present as an alternative water source. Winter ranges should have areas where animals can seek shelter, such as: a draw or pockets, or maybe some trees. Areas where forage is available in all but the heaviest snows, such as south slopes and wind swept ridges, is also a good idea. Use older, pregnant cows, preferably ones with winter grazing experience, or who are adapted to winter weather. Their requirements are lower and they will do better on the mature forage resource. Winter grazing programs will work in the proper situation or environment if certain considerations have been met.



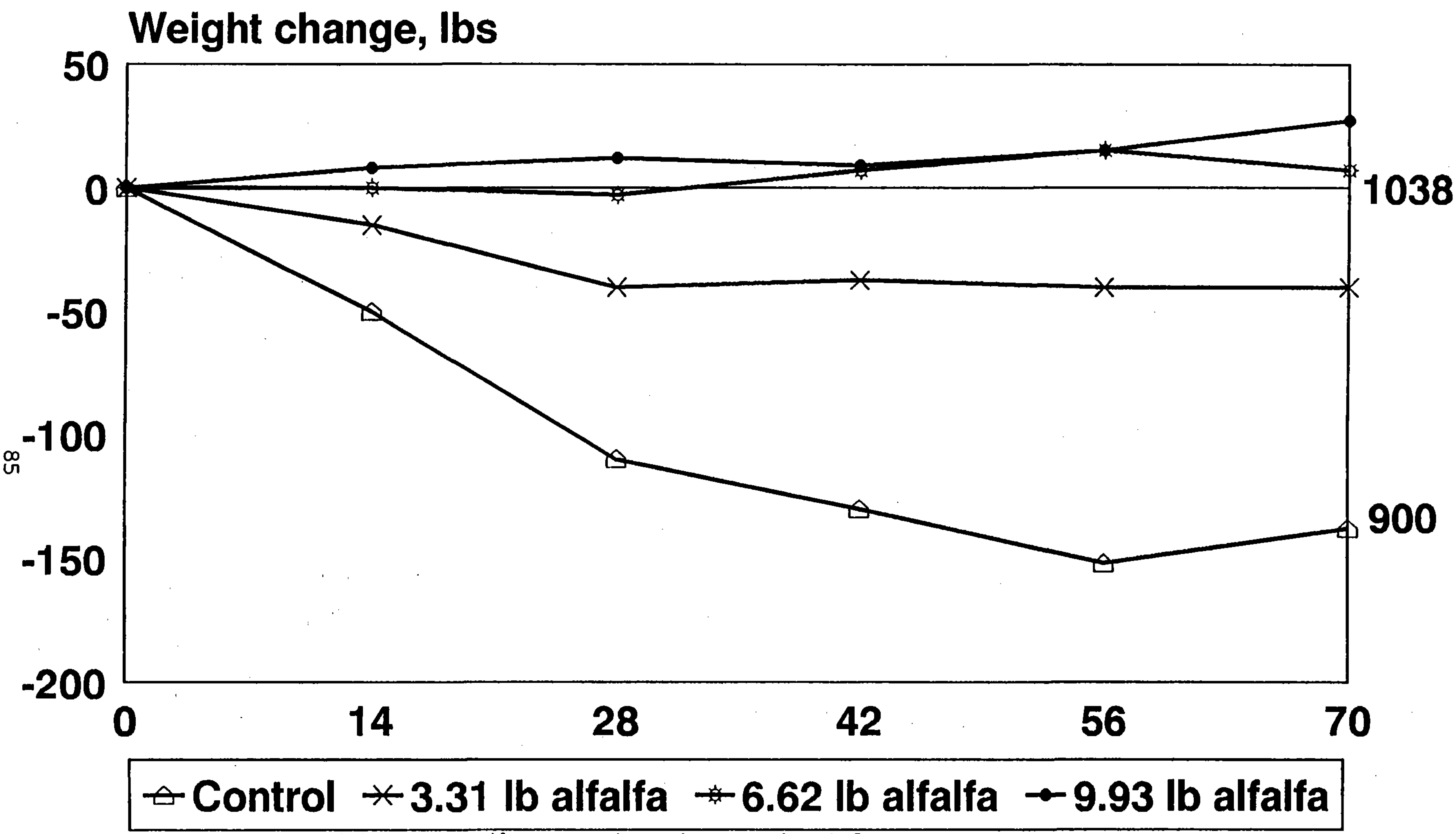
Northern Great Basin Experimental Range, Oregon.

Figure 1. Effects of alfalfa supplementation on cow body weight changes in year 1 (1989-90).



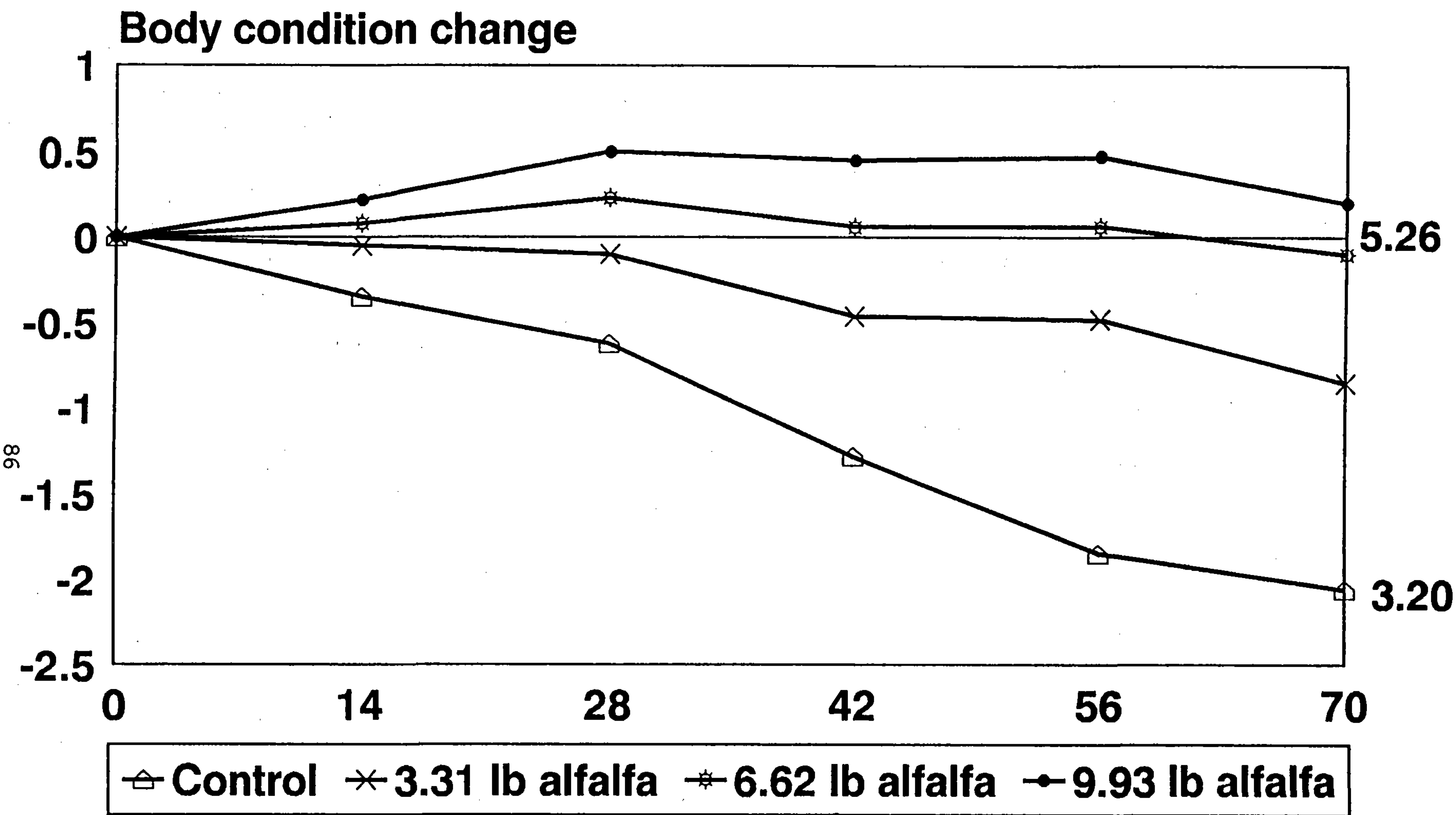
Northern Great Basin Experimental Range, Oregon.

Figure 2. Effects of alfalfa supplementation on cow body condition change in year 1 (1989-90).



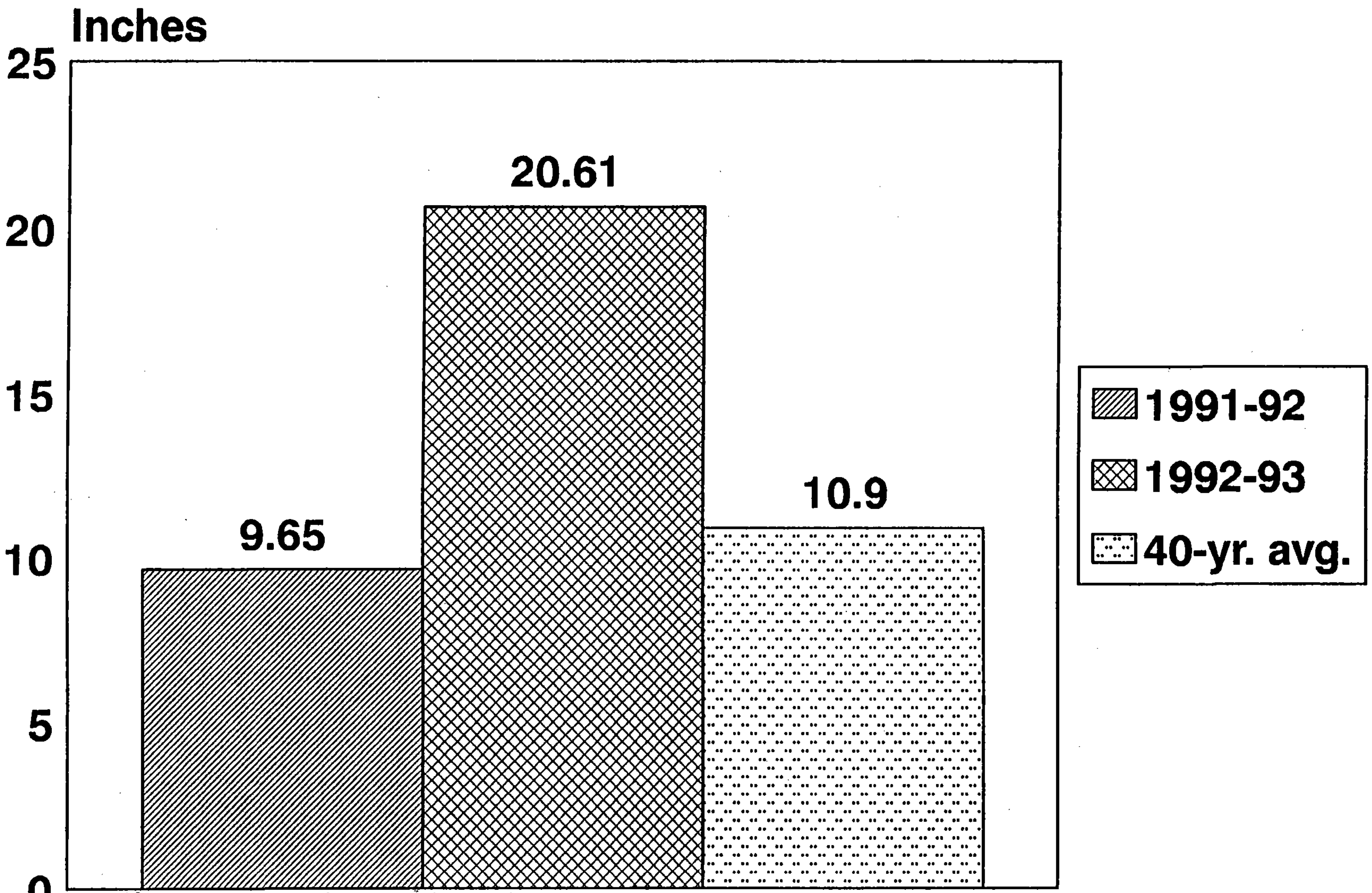
Northern Great Basin Experimental Range, Oregon.

Figure 3. Effects of alfalfa supplementation on cow body weight change in year 2 (1990-91).



Norther Great Basin Experimental Range, Oregon.

Figure 4. Effects of alfalfa supplementation on cow body condition in year 2 (1990-91).



Northern Great Basin Experimental Range, Oregon.

Figure 5. Total precipitation received during 1991-92, 1992-93, and the 40-year average.

Land use and Nonpoint Source Phosphorus Pollution in the Dairy-McKay Hydrologic Unit Area of the Tualatin River Basin, Oregon[1]

Donald W. Wolf and John C. Buckhouse

Water quality is of increasing concern to society. Supplies of water are for all practical purposes static, while the demand for high quality water for industry, agriculture, population and recreation steadily increases. Currently, Oregon's Tualatin River is the center of a controversy relating to this concern for water that is clean and usable for a variety of purposes.

The Tualatin River originates in the Oregon Coast Range and runs east 40 miles to join the Willamette River. Along its way, it meanders through roughly 86 miles of channel and drains 711 square miles of land with varied topography and use (Carter, 1975). For most of its last 40 miles, the channel has little drop in elevation, giving it a slow-moving, almost lake-like character during the summer low flow period. During the summer, this stretch may experience periods of eutrophication when, to put it simply, the river "stinks" (Castle, 1991).

Although the quality of water in the Tualatin River has been of concern to some for a long time, concern was focused in 1986 when the Northwest Environmental Defense Center filed suit against the Environmental Protection Agency (EPA) (Castle, 1991; Cleland, 1991). The suit sought to force the adoption and enforcement of pollutant limits for Oregon streams in general and the Tualatin specifically. It was decided that these limits, called total maximum daily load or TMDL, should have more local input than the Federal government could provide, so the task was passed to the Oregon Department of Environmental Quality (DEQ) (Castle, 1991).

In 1987, DEQ conducted a statewide assessment of nonpoint source (NPS) pollution problems. As a result of this assessment, the Tualatin River Basin became the DEQ's priority surface water concern. The Tualatin was defined as "water quality limited," a designation that has specific meaning in relating to practices required to reduce pollutants (Cleland, 1991: Soil Conservation Service, 1990). For the Tualatin, studies showed that both ammonia and phosphorus (P) were factors limiting water quality, but P was considered to be the key limiting factor and a stringent TMDL, 0.07 mg/l (70 ug/l) of total P was set for the Tualatin River Basin. It is estimated that of the total P contributed to the Tualatin on a yearly basis, 85 percent is from point sources such as sewage treatment plants and 15 percent is from nonpoint sources (Castle, 1991). As a water quality-limited basin, all sources that contribute to the problem are responsible for bringing the problem under control.

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Of the subbasins comprising the Tualatin drainage, the Dairy-McKay subbasin (or hydrologic unit) was identified as a major contributor to the water quality problems of the Tualatin River. Termed a hydrologic unit area (HUA) by USDA, this subbasin contains only about one-third of the total area (256 square miles) of the Tualatin Basin, but about half of the forested land and half of the agricultural land. These land uses contribute sediments and sediment-related nutrients to surface waters, with about 60 percent of agricultural lands

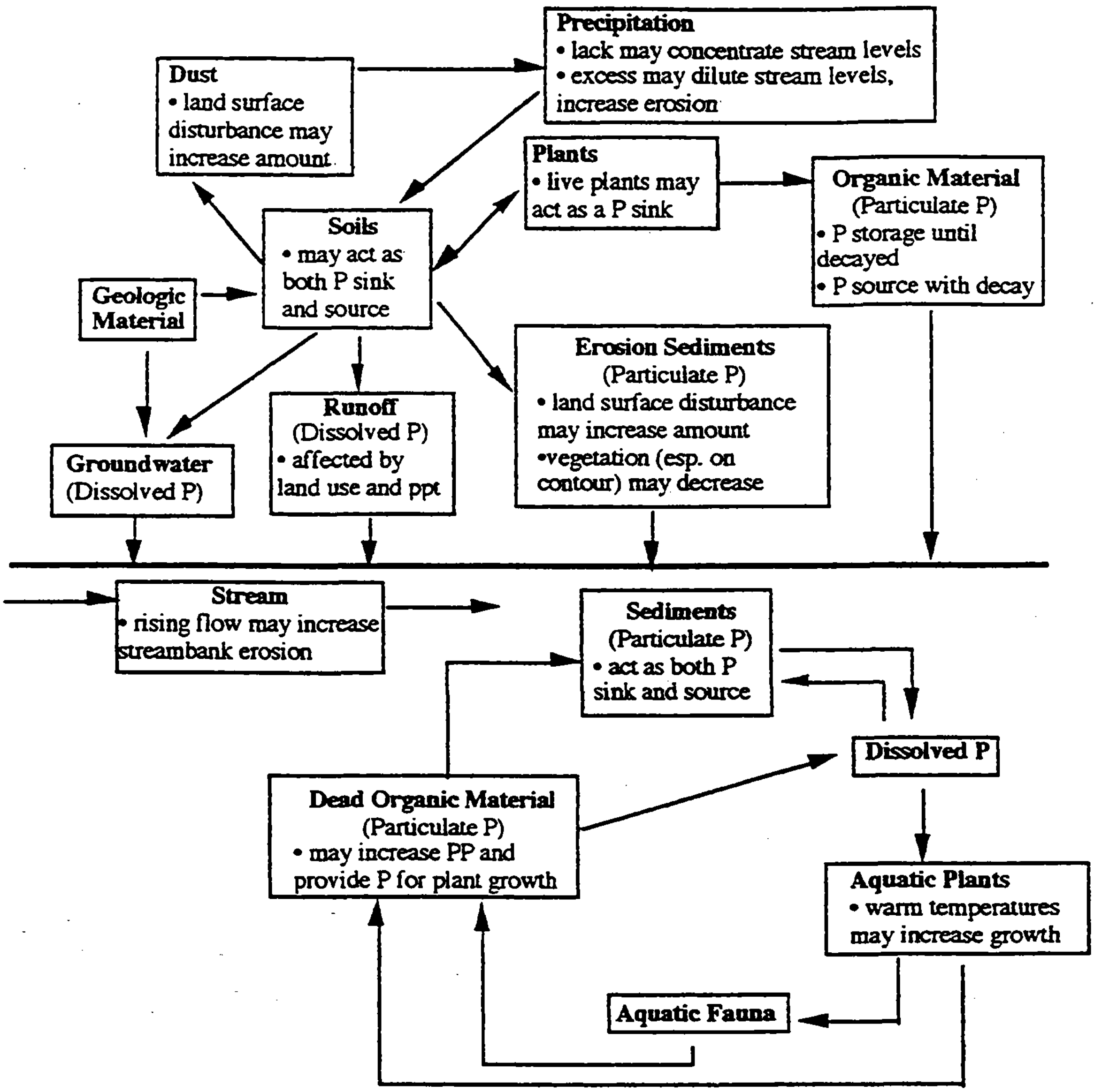

Figure 1. Landscape Level P Interactions
Tualatin Drainage (Wolf, 1993).

eroding at three times the rate considered acceptable by the Soil Conservation Service (Soil Conservation Service, 1990). On Dairy and McKay Creeks, the TMDL for P is frequently exceeded upstream of any known point sources, indicating that a portion of the problem is from nonpoint sources (Soil Conservation Service, 1990). Non-point pollution problems have focused attention on all land management activities in the basin.

The levels of P in a stream are influenced by a variety of influences that occur across the landscape (Figure 1). The data presented on the influence of particulate P to the total P concentrations in the Dairy-McKay HUA supports the contention that a land use is one major factor determining the P content of streams. It is apparent, and not unexpected, that the influence of particulate P on total P is much greater at downstream sites than at upstream sites. If the mouth of a stream is considered as the mouth of a funnel, collecting and concentrating materials gathered from upstream, it is logical that the downstream reaches would have much greater levels of particulates. The materials from all such streams enter the river and become the contributions to a much larger funnel. In this way, whatever land use takes place near the upstream reaches of Dairy Creek eventually influence the P concentrations at Lake Oswego, the mouth of the Tualatin River, the Willamette River, and eventually the Columbia River.

Considering a number of indicators -- the soils of the bottomlands, the greater likelihood of sediments being transported from areas adjacent to streams, and the trends from linear forecasting indicating that both temperature and sediments are very influential in determining P concentrations -- it is apparent that the management of areas near streams is likely to have the greatest effect on the P content of streams. The establishment of riparian buffers for both sediment filtering and to provide shade to help maintain cooler streamwater temperatures would appear to be one practice with particular merit.

The transport and movement of P is a complex process involving a variety of interactions. No single factor or theory satisfactorily accounts for and predicts its movements. Managing a watershed containing a waterway of concern in a manner that reduces nonpoint source P inputs, especially particulate forms, will be more assured of success than management with an instream focus.

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Stand Establishment From Seeded Native Grasses

Tony Svejcar, Dave Pacioretty, Kara Paintner, Steve Beverlin, and Dave Ganskopp

INTRODUCTION

Interest in reseeding of degraded rangelands with native species has increased dramatically in recent years. The availability and cost of native seed can limit the acreage considered for native reseeding. In addition, limited knowledge of seeding rates, dormancy characteristics and population patterns for native species can make management decisions difficult. Seeding rates are often based on experience with introduced species with similar seed characteristics, and stands have traditionally been evaluated the first year after seeding. If a species had high germination rates, then the first year evaluation was appropriate. However, if seed dormancy is part of a specie's adaptation to a fluctuating climate, then several years or more may be necessary to fully evaluate the success of seeding. The goal of this study was to evaluate the effect of seeding rate with four species of native grasses over a two-year period.

METHODS

The study site was located near Horse Mountain and BRIM well in Lake County about ten miles southwest of Wagontire, Oregon. The site was dominated by Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis* (Beetle & A. Young) Welsh) that had been burned in the fall of 1990. Four species common to the area were chosen; Basin wildrye (*Elymus cinereus* Scribn. & Merr.), bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) Smith), and Indian ricegrass (*Oryzopsis hymenoides* (R. & S.) Ricker). Each species was seeded with a rangeland drill in replicate five acre plots at a high and low seeding rate (Figure 1). A total of twenty plots or eighty acres was seeded and fenced to exclude livestock and rabbits in the fall of 1991. The high seeding rate for Basin wildrye, bluebunch wheatgrass, and bottlebrush squirreltail was 10 pounds of seed per acre, the low rate was 5 lbs/acre. Indian ricegrass seeding rates were 6 lbs/acre and 3 lbs/acre, respectively. Within each five acre block we established four permanent 1.2 yard^2 (1m^2) plots. Within each we counted seedlings in two drill rows. Sampling was conducted three times in 1992 and 1993. Precipitation and temperature were triangulated from weather stations at Squaw Butte, Alkali Lake, and The Poplars (Figure 2).

RESULTS AND DISCUSSION

The highest seeding rate resulted in higher seedling numbers for Basin wildrye, bluebunch wheatgrass, and squirreltail in April 1992 (Figure 3). We also measured the highest number of Indian ricegrass seedlings in April 1992, but at the low seedling rate. The winter following the seeding was very dry for most of eastern Oregon. However, the study site received 0.8 inches of precipitation in March and temperatures were fairly warm (Figure 2), which may account for the relatively high seedling densities in April 1992. Seedling densities declined over the course of the 1992 sampling period for all species (Figure 3).

In 1993, average seedling density was similar across sampling dates for both seeding rates (Figure 4). The exceptions were Basin wildrye on June 30 and July 27, and Indian ricegrass on July 27 (Figure 3). In several cases the seedling density at the end of 1993 was higher than at the end of 1992, which showed that there may have been carry-over of dormant seed. Both Indian ricegrass and Basin wildrye had higher seedling densities at the higher seeding rates. But, the average for all species shows no difference between seeding rates (Figure 4).

We conclude that the higher seeding rate may be desirable for some species, but when averaged there was no benefit. Such a result has economic implications because twice as many acres could be seeded using the low rate. In general, seedling numbers increased slightly the second year. We intend to follow seedling numbers again during the spring and summer of 1994, and conduct another seeding in the fall of 1994.

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BRIM NATIVE SEEDLING PROJECT

Indian Ricegrass 6 lb/ac Nezpar Seeded 11/22/91	Bluebunch Wheatgrass 10 lb/as Secar Seeded 11/26/91	Indian Ricegrass 3 lb/ac Nezpar Seeded 11/20/91	Basin Wildrye 10 lb/ac Magnar Seeded 12/4/91
Bottlebrush Squirreltail 5 lb/ac Seeded 12/10 91	Basin Wilddrye 5 lb/ac Magnar 12/4/91	Bluebunch Wheatgrass 10 lb/ac Secar 11/26/91	Basin Wildrye 5 lb/ac Magnar 12/3/91
Bluebunch Wheatgrass 5 lb/ac Secar Seeded 11/25/91	Indian Ricegrass 3 lb/ac Nezpar Seeded 11/19/91	Indian Ricegrass 6 lb/ac Nezpar Seeded 11/20/91	Bottlebrush Squirreltail 10 lb/ac Seeded 12/11/91
Basin Wildrye 10 lb/ac Magnar Seeded 12/5/91	Bottlebrush Squirreltail 10 lb/ac Seeded 12/12/91	Bluebunch Wheatgrass 5 lb/ac Secar Seeded 11/25/91	Bottlebrush Squirreltail 5 lb/ac Seeded 11/10/91

Figure 1. Plot layout from the BRIM native seeding project. Each plot is five acres in size with a total project acreage of 80 acres. Within each plot the grass species seeded, pounds of seed per acre, variety name, and date seeded are listed.

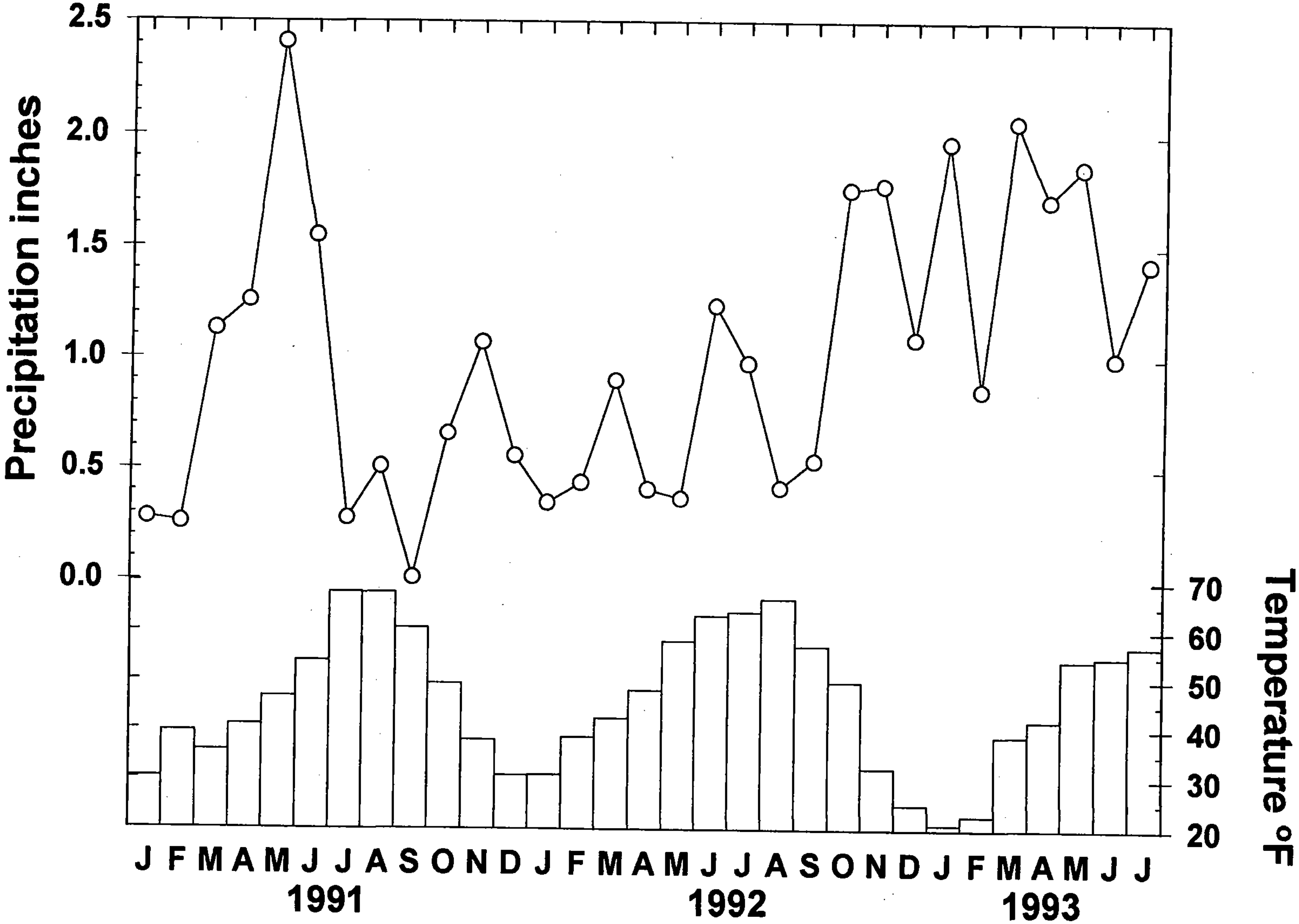

Figure 2. Average precipitation and temperature by month triangulated from Squaw Butte, Alkali Lake, and The Poplars for 1991-1993.

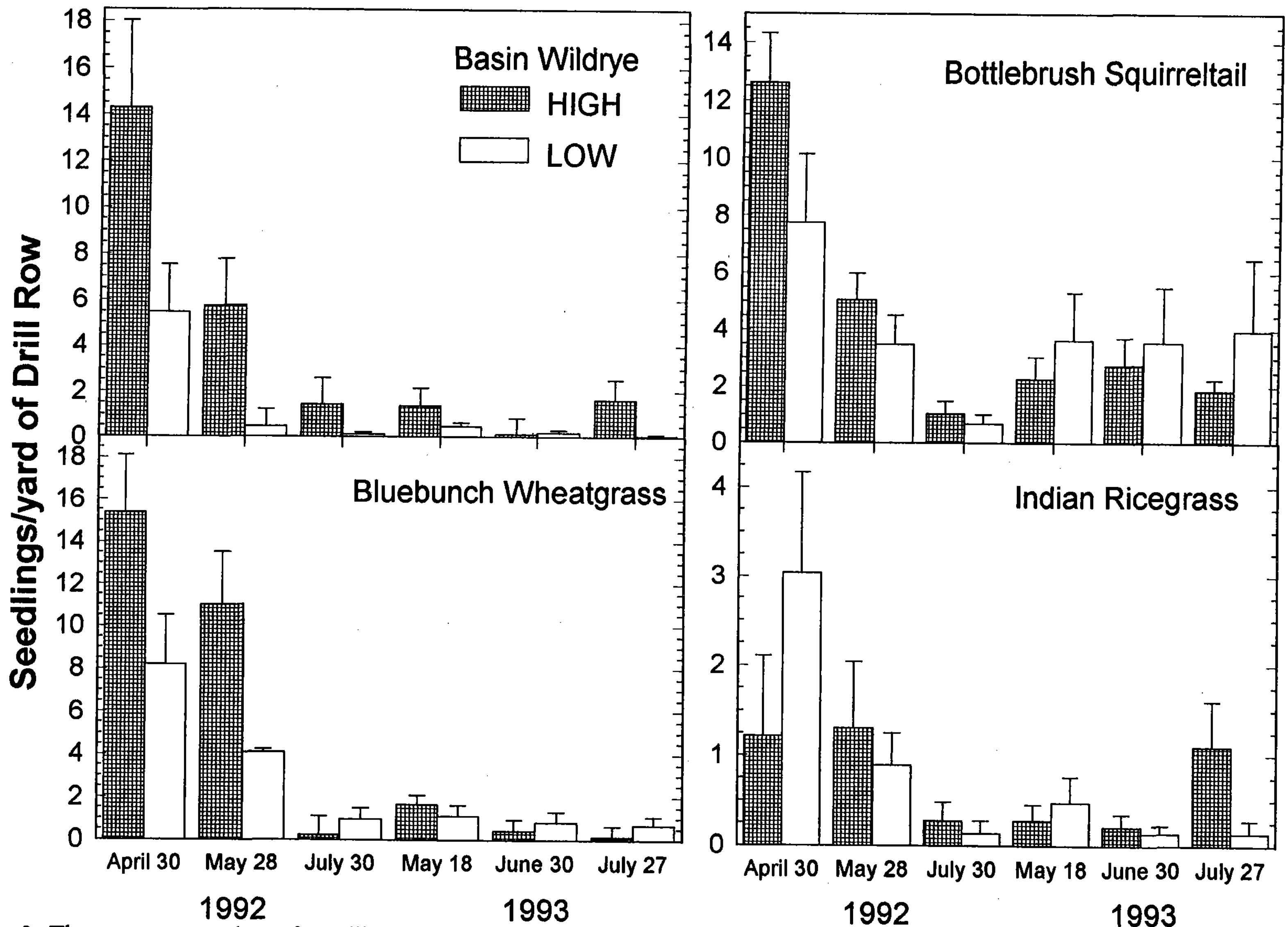

Figure 3. The average number of seedlings per yard of drill row at high and low seeding rates for Basin wildrye, bluebunch wheatgrass, bottlebrush squirreltail, and Indian ricegrass in 1992 and 1993 at the BRIM seedling site.

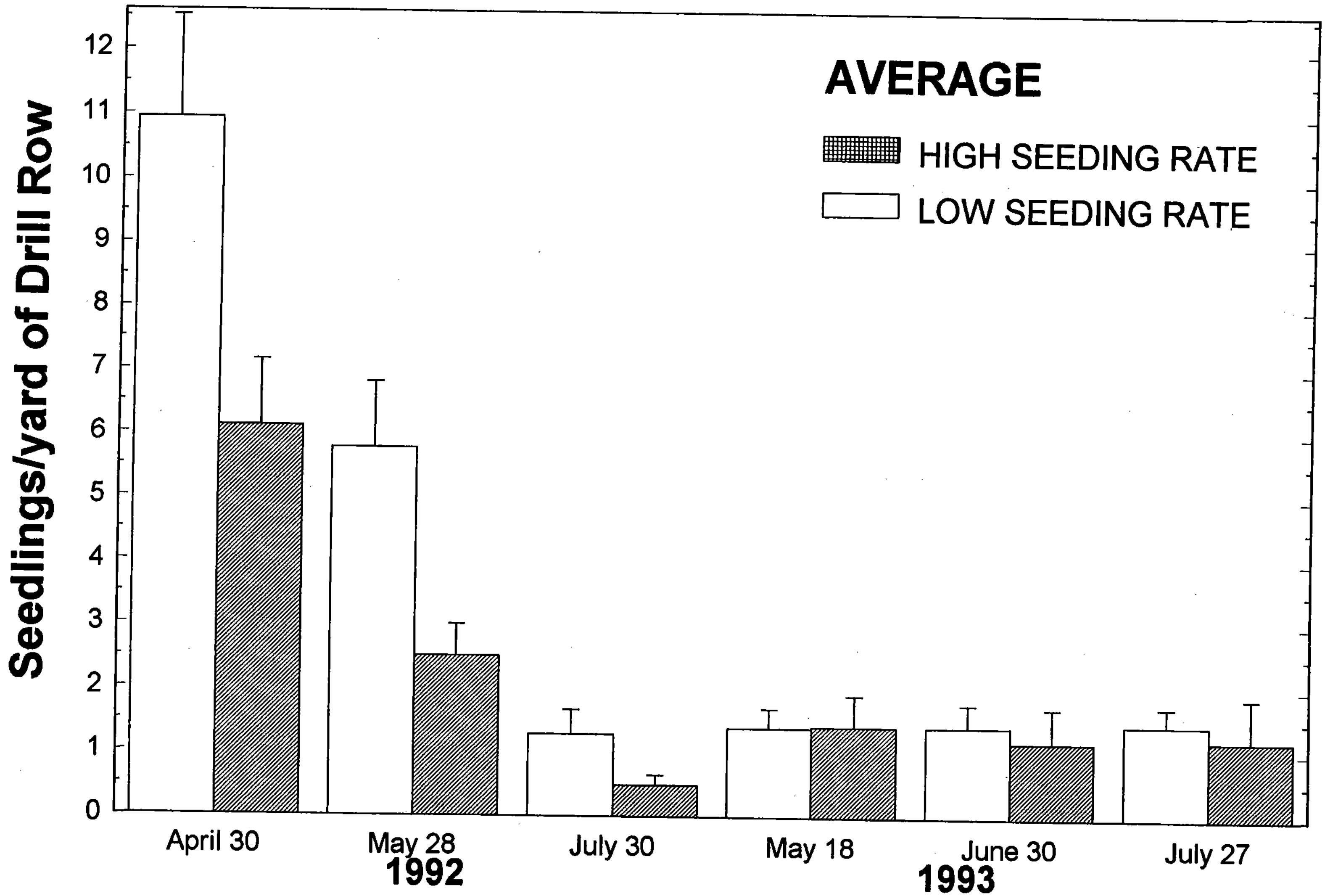

Figure 4. The average total number across species of seedlings per yard of drill row at high and low seeding rates for in 1992 and 1993 at the BRIM seedling site.

Range 14 - Vegetation Change

Jeffrey A. Rose and Richard F. Miller

INTRODUCTION

Increases in sagebrush density and cover are continuous problems faced by land managers. As density and cover of sagebrush increases, associated herbaceous vegetation cover and density declines. This process is inevitable and if not checked will result in a near monoculture of woody plants. Prior to European settlement fire was the mechanism that reduced the sagebrush and permitted understory vegetation to reassert itself. Since the settlement of the sagebrush steppe, aggressive fire suppression for the protection of natural resources and man-made structures has altered the historic fire regime. Introduction of domestic livestock grazing has also helped to alter the fire regime through removal of fine fuels that help carry fire once it is ignited.

With the removal of fire, other means of sagebrush control had to be implemented. Mechanical and chemical control methods were developed to remove sagebrush from rangelands, but control is only temporary. Sagebrush will immediately begin to encroach after a control method is implemented. This establishment and increase in density of sagebrush occurs regardless of the land management strategy in the absence of natural wildfire (Sneva *et. al.* 1984, West *et. al.* 1984). This poses an interesting question. What conditions favor sagebrush establishment? In the desert southwest plant establishment occurs in pulses, often following rainfall events (El-Ghonemy *et. al.* 1979). Establishment of sagebrush has also been suggested to occur in pulses, but the results have been inconclusive (Romney *et. al.* 1980, West *et. al.* 1979).

The objective of this research was to determine the conditions that favor big sagebrush establishment and identify pulses of establishment based on climatic and plant community conditions over a 38-year period. We hypothesized that sagebrush establishment of sagebrush occurs in pulses and these pulses are related to climatic conditions.

Study Site

The study was conducted at the Northern Great Basin Experimental Range, 36 miles west of Burns, Oregon. The NGBER is jointly operated by the USDA-ARS and Oregon State University. Vegetation is typical of the northern Great Basin sagebrush steppe. Elevation of the experimental range varies from 4200' to 5500' in elevation at the top of the dormant Pleistocene volcano, the distinguishing feature of the NGBER.

Climate is semiarid with mean annual precipitation of 11.3 inches. Eighty percent of the annual precipitation falls as rain and snow between September and June. Mean January and July temperatures are 27°F and 67°F, respectively.

Big sagebrush, low sagebrush, and western juniper are the dominant woody plants across the experimental range. Bluebunch wheatgrass, Idaho fescue, Thurber's needlegrass and Sandberg's bluegrass are the most common grasses. A variety of perennial forbs can be found, including Prairie lupine, specklepod locoweed, western hawksbeard, bigseed lomatium, and Menzie's larkspur.

Soils are of volcanic origin and are classified as mollisols of aridisols. Depth to bedrock varies from 4 feet to less than 2 feet.

The study was located in Range 14 of the NGBER. Range 14 is a 40 acre pasture in the center of the Northern Great Basin Experimental Range. This pasture has a history of long-term monitoring following big sagebrush removal. When the Experimental Range was established in 1936, Range 14 was hand-cleared of all sagebrush. Then in 1952, other study investigators sprayed 2,4-D for sagebrush control. Since 1952, there has been no large-scale sagebrush removal from Range 14. The pasture has been periodically grazed, but the majority of the use has been in the summer when most of the grasses are dormant.

Past Information

Annual soil moisture information has been collected from Range 14 since 1965 (Table 1). A long-term NOAH weather station is located less than a mile from Range 14. At this station, daily maximum and minimum temperature and precipitation are recorded. Records go back to the 1940s. Periodically from 1959, sagebrush cover and density have been recorded. Herbaceous plant production has also been periodically measured. In the years that herbaceous plant production was not sampled, production was estimated using forage forecasting models developed for the experimental range.

Current Study

All Wyoming big sagebrush were harvested from five, 300 ft^2 plots located randomly throughout the pasture. Larger Wyoming big sagebrush plants were cut slightly below ground level and the ground level marked. Smaller plants were removed by shovel, roots clipped and canopies removed with clippers. Canopies were removed from the main stem. Stems were numbered and returned to the lab where they were re-cut using a carbide tip circular saw. This type of saw provided a clean, smooth surface for ring counts and measurements. Samples that were too small to cut with the circular saw were cut at the ground level mark with pruning shears. Once in the lab, sections to be measured were polished with emery cloth. Rings were counted using a binocular dissecting microscope. An in-line Vernier scale was used to measure the ring widths. Ring widths from two radii were measured and then averaged to account for the irregular shape of the stem. A ring width index was then calculated to isolate the effects of climate on growth from other factors such as, plant size, age, site productivity and density (Frauds 1976; Monserud 1986). Age was determined by counting the number of rings from the center out to the current year's growth on each radii. Date of establishment for each sagebrush was decided to be the date, (1990) minus the age of the individual. Density for each year was calculated by adding the number of plants established within a given year from the plot.

Because a large percentage of the precipitation to the experimental range falls between September and June, the climatic data was based on a crop year, September through August.

Data Analysis

All sagebrush, plant community variables, and climatic data were run through a correlation analysis (PROC CORR in SAS 1986) to find significant relationships between variables. Correlation coefficients, a measure of the relationship of variables, rarely exceeded 0.30, although many were highly significant ($p < 0.001$). These numbers indicated that there was a weak, but significant relationship between sage establishment and some climatic and plant community variables.

We then used a canonical correlation analysis (PROC CANCORR in SAS 1986). A canonical correlation is a technique to test the relationship between two sets of variables. This type of analysis is useful because many environmental variables may work together, or interact, to cause a response in the organism being studied. Most of these factors could be controlled if the study was conducted in the laboratory, but this is impossible in the field. The canonical correlation analysis will find variables within the groups that respond similarly and combine them into one variable. These new variables may contain one or many of the original variables. Once the new variables are formed they are then correlated with the new variables for the other group. We group average maximum and minimum daily temperature, monthly precipitation, total precipitation, soil moisture and herbaceous plant biomass into an environmental set of variables. The ring index, total big sagebrush density, big sagebrush seedling density and big sagebrush basal area were group into the other set of variables for canonical correlation.

Results and Discussion

Ages of sagebrush found ranged from 4 to 38 years old. The age of the oldest plant, 38 years, corresponds to the date of the last herbicide treatment. This individual may have established following the herbicide treatment. We found no plants younger than 4 years. Germination of sagebrush probably did occur in the years 1987-1990, but conditions following germination may not have been conducive to survival.

We did find two peaks in establishment (Figure 1). The first peak occurred from 1966 thru 1971. The second peak occurred from 1976 thru 1981, with a dip in establishment in 1979. Pulses in establishment are common in desert communities of the southwestern U.S. (El-Ghonemy *et.al.* 1980 Romney *et. al.* 1988, Wallace and Romney 1980). Romney and associates (1980) suggested that big sagebrush established in pulses at the Nevada Test Site. However, a study at the U. S. Sheep Experiment Station near Dubois, Idaho, found that establishment of threetip sagebrush (*Artemisia tripartita* Rydb.) did not occur in pulses (West *et. al.* 1979). They concluded that the pattern of winter precipitation common in the northern sagebrush steppe provides a more reliable source of soil moisture than the summer thunderstorm pattern in the southwest.

Results of the canonical correlation analysis indicated that 89 percent of the variation in the data could be accounted for in the first two plant community and environmental variables. The first plant community variable was represented by the calculated ring index and the second community variable was a combination of new sagebrush density and to a lesser degree actual ring width (Table 1). The greater the "r" value the stronger the relationship between the variables. Environmental variable 1 was a combination of soil moisture and maximum daily temperatures for October and April (Table 1). An increase in environmental variable 1 was caused by a increase in soil moisture and a decrease in maximum daily temperatures in October and April.

Environmental variable 2 was a combination of herbaceous plant biomass, January precipitation, November maximum daily temperature, and minimum daily temperatures for March and April (Table 1). When herbaceous plant biomass, January precipitation, and November decreased and March and April minimum daily temperatures increase, environmental variable 2 increases.

Correlation of the first community and environmental variables found that community variable 1 (dominated by ring index) was positively correlated with environmental variable 1 ($r = 0.74$)(Figure 2). The relationship between sagebrush and environmental variable 1 indicate that ring growth of sagebrush will be greatest in years of high soil moisture in the surface 0-8 inches and when October and April have below average daily maximum temperatures. Big sagebrush has some active leaves on its stems throughout the year. This enables it to grow very early and late in the season when the other plants have become dormant. Years with higher soil moisture and cooler October to April temperatures may enable sagebrush to use less soil moisture in the fall before plants become dormant. The cooler April conditions may also save moisture for the warmer weather in May and June.

Community variable 2 (dominated by new sagebrush density) and environmental variable 2 were also positively correlated ($r = 0.68$)(Figure 3). Establishment of new plants was high in years when herbaceous plant biomass and daily minimum temperatures in March and April were high. Warm spring nights and low levels of competition from herbaceous plants were obvious factors that could favor sagebrush seedling establishment. November maximum daily temperatures and January precipitation had a negative affect on establishment of new sagebrush. Cold November temperatures and greater than average January precipitation tended to reduce establishment of sagebrush. Sagebrush flowers in mid-to late summer and seeds mature on the flowering stem through the fall. Low November temperatures may damage the seeds while they are on the flowering stems thus reducing the seeds available to germinate the following spring. Greater than average precipitation is often a benefit to plants, but the majority of precipitation in January comes as snow. A study in Colorado found that mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* (Rydb.)Beetle) seedlings under the snow were killed by a snow mold (Sturges and Nelson 1984). Looking back at Figure 1, the two periods of high sagebrush establishment occurred during periods when herbaceous plant biomass, November maximum daily temperatures and January precipitation were 1.5°F below average.

SUMMARY

Growth and establishment of big sagebrush is affected by many interacting environmental factors. Optimum conditions of any one of these factors may not be enough to benefit sagebrush growth and establishment. We found two peaks of sagebrush establishment: 1966-1971 and 1976-1982. This data indicate that the seasonality and amount of precipitation and temperature is critical to sagebrush establishment. Sagebrush establishment is inhibited by cold Novembers and heavy January snow, which promote snow mold. Establishment is enhanced by early, wet springs. The combination of all the above variables acted together to produce the positive growth and establishment. Results form this study support our initial hypothesis that sagebrush establishment occurs in pulses. We also accepted our second hypothesis, environmental factors working in concert have a larger effect on sagebrush growth and establishment than any one factor alone.

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Table 1. Canonical Correlation variables and their correlation with community and environmental variables. "r" values close to 1 indicate a strong relationship between variables. Positive numbers indicate the variables increase and decrease together and negative numbers indicate that as one variable increase the other variable decreases. Northern Great Basin Experimental Range. 1990.

Canonical Correlation Variable	Input Variable	r value
Community 1	Ring Index	0.9250
Community 2	New Plant Density	0.8000
	Ring Width	0.6511
Environmental 1	Soil Moisture 0-8"	0.4370
	October Daily Maximum Temp	-0.4842
	April Daily Maximum Temp	-0.04355
Environmental 2	Herbaceous Plant Biomass	-0.4612
	January Precipitation	-0.5056
	March Daily Minimum Temp	0.4599
	April Daily Minimum Temp	0.4658
	November Maximum Daily Temp	-0.4442

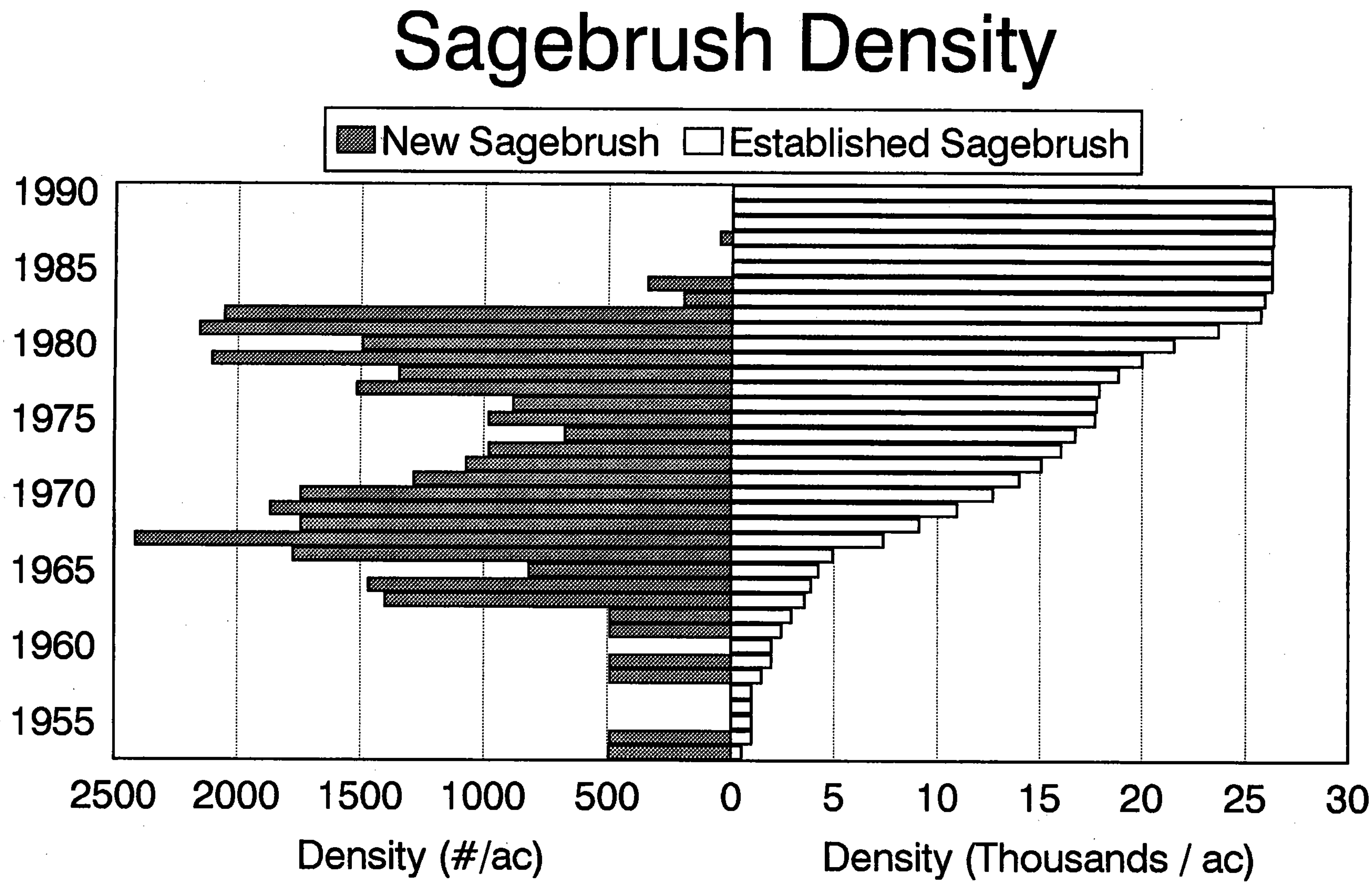

Figure 1. Density of new sagebrush seedlings and total density of all sagebrush from 1952 to 1990. Northern Great Basin Experimental Range.

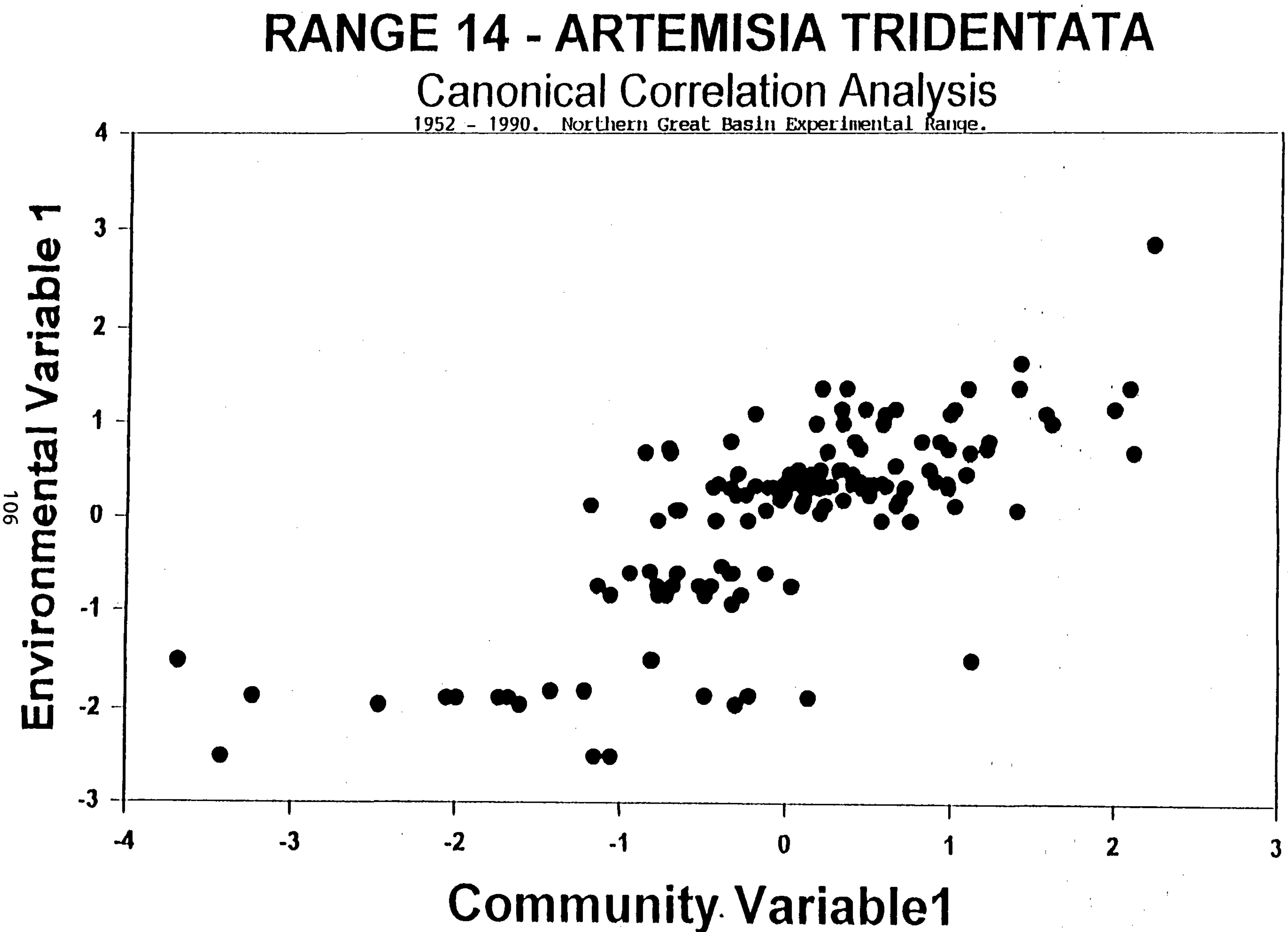

Figure 2. Scatter diagram of Environmental variable 1 and Community variable 1.

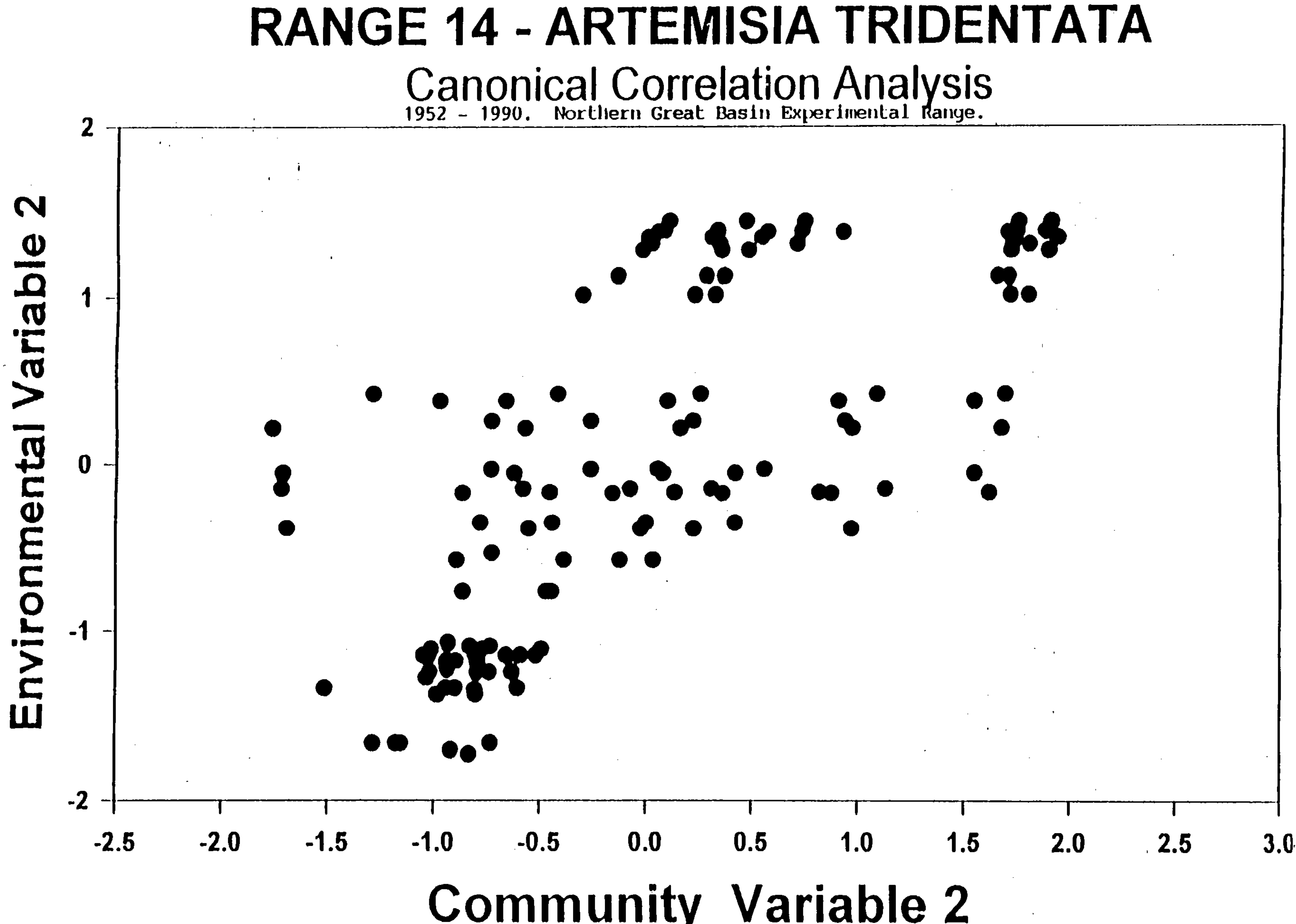

Figure 3. Scatter diagram of Environmental variable 2 and Community variable 2.