ABANDONED COAL MINE LAND RESEARCH PROGRAM

TENTH PROJECT REVIEW SEMINAR

UNIVERSITY OF WYOMING
GILLETTE, WYOMING

NOVEMBER 5, 1998

The seminar series is sponsored jointly by the University of Wyoming, Office of Research and the Abandoned Mine Lands Program of the Wyoming Department of Environmental Quality.

METHODOLOGY FOR THE DESIGN AND DEVELOPMENT OF A GIS-BASED SPATIAL DECISION SUPPORT SYSTEM FOR ASSESSING THE HYDROLOGIC IMPACTS OF COAL MINING AND MINE LAND RECLAMATION IN WYOMING

J.D. HAMERLINCK, K.T. PEACOCK, G.E. JONES

Wyoming Abandoned Coal Mine Lands Research Program
Interim Project Review
November 1998

Methodology for the Design and Development of a GIS-Based Spatial Decision Support System for Assessing the Hydrologic Impacts of Coal Mining and Mine Land Reclamation in Wyoming

August 1, 1996 - March 31, 1999

Principal Investigators:
Jeffrey D. Hamerlinck, University of Wyoming; Kenneth T. Peacock, U.S. Bureau of Land Management; and Greg E. Jones, Powder River Coal Company

PROJECT OVERVIEW

This interim progress report provides a brief project background and summary of work undertaken over the 12-month period from November 1, 1997-October 31, 1998.

Problem Statement. The coal permitting process places heavy demands on both permit applicants and regulatory authorities relative to the management and analysis of hydrologic data. To meet these challenges, a need exists for the development of computer application tools capable of: 1) managing large quantities of spatial and non-spatial digital hydrologic data; and 2) providing an efficient means for utilizing such information in an integrated hydrologic impact analysis/modeling environment.

Objective. The primary objective of this research is to develop an integrated, modular spatial decision support system (SDSS) for assessing the hydrologic impacts of coal mining activities in the Powder River Basin of northeastern Wyoming. Components of the system will include existing surface and groundwater models (HEC-1; MODFLOW), integrated with a desktop geographic information system (ArcView). Upon completion, the project will deliver a GIS-based spatial decision support system "software application toolbox" for use by regulatory agencies and industry alike.

STATEMENT OF WORK

In November 1997, a revised statement of work was presented at the ACMLRP Project Review Seminar. Six primary tasks were outlined, with an increased emphasis on PHC determination applications. Tasks include the following:

TASK 1: STUDY AREA DATABASE DEVELOPMENT. Development of required base data layers for inputs to selected models for the Antelope Creek Watershed Study Area *(Completed prior to 11/97; however, study data sets ultimately selected from the Little Thunder Creek drainage)*.

TASK 2: HEC-1/GIS INTERFACE DEVELOPMENT. Essentially an ArcView interface and "applications toolbox" for HEC-1; will require two major tasks:

2a. Develop graphical user interface for model input parameter generation, including creation of necessary derived GIS coverages, hydrologic response unit delineations, and parameter estimation;

2b. Provide GIS output capabilities of modeling results for calibration and validation purposes.

TASK 3: MODFLOW/GIS INTERFACE DEVELOPMENT. Interface for GIS-based MODFLOW parameter input, analysis, and output generation; three major subtasks have been identified:

3a. Develop graphical user interfaces for creating necessary derived GIS coverage model inputs; grid generation and grid parameter population;

3b. Create functionality to directly convert data layers into readable MODFLOW arrays;

3c. Provide GIS output capabilities for portrayal of modeling results for calibration and validation purposes.

TASK 4: PHC MODELING SUPPORT AND BETA TESTING. Working in cooperation with a GIS/Hydrologic Modeling advisory group, the SDSS will be beta tested for PHC-type applications in an active coal mining area of the Little Thunder Creek (and Antelope Creek) watersheds.

TASK 5: USER GUIDE DEVELOPMENT. Development of a user guide for the completed SDSS, including an overview of component module functionality.

TASK 6: REPORT GENERATION. Includes two interim review reports, a Final Executive Summary Report and the Final Technical Report (based on user guide developed in Task 5).

RECENT ACCOMPLISHMENTS

Since November 1997, work has continued with a focus on Tasks 2 and 3. In February 1998, a survey questionnaire was mailed to environmental managers at all active coal mining operations in the Powder River Basin. The purpose of this survey was to obtain input regarding hydrologic modeling needs and existing GIS technology. This was followed by the establishment of an ad hoc GIS/hydrologic model integration technical advisory group, comprised of representatives from the mines, regulatory agencies, and hydrology consulting communities. Over the last six months this group has been extremely valuable to ongoing research in terms of providing feedback and suggestions regarding application design and development.

Task 2: HEC-1/GIS Interface Development. To date, preprocessing is nearly complete and currently functional. Preprocessing is performed entirely within ArcView and is responsible for generating the HEC-1 parameter input file. The input file contains the data that describes all necessary attributes for each delineated subbasin. These attributes include subbasin area, precipitation totals, precipitation distributions, and soils information. All steps for preprocessing are accessible as customized menu items within the "Surface Water" menu list. The menu items are listed sequentially to maintain the correct order of operations throughout preprocessing. For example, the user must first provide a digital elevation model (DEM) for the area of interest. From this point, the menu walks the user through watershed preparation, importing a soil grid, precipitation options, subbasin delineation, and finally the automated calculation of basin attributes.

Once preprocessing is finished, a functional HEC-1 input file is created and HEC-1 is launched. During the HEC-1 process, output hydrograph files are created for each of the delineated subbasins. These hydrographs will then be imported back into ArcView for postprocessing. Postprocessing will display the hydrographs as line plots with associated information regarding peak flow, peak times, and volume totals. This display is necessary for presentation and calibration. Postprocessing is the current focus of Task 2 efforts, with a target completion date of mid-December 1998.

Task 3: MODFLOW/GIS Interface Development. MODFLOW preprocessing has nearly been completed for the ArcView environment. All preprocessing functions are executed in the GIS and are responsible for generating necessary MODFLOW input files. The input files generated include those that are necessary to run a simple MODFLOW model: the Basic (BAS) Package, the Block-Centered Flow (BCF) Package, and the Strongly Implicit Procedure (SIP) Solver Package. (Future enhancements will include the Well (WEL) Package, the Recharge (RCH) Package, the Drain (DRN) Package, the Preconditioned Conjugate Gradient, Version 2 (PCG2) Solver Package, and possibly the General Head Boundary (GHB) Package).

All preprocessing operations are listed as menu items within the "MODFLOW Preprocessing" menu. The items are listed sequentially in order to guide the user through the necessary steps to build a groundwater model. First, the user must build a finite-difference mesh. This can be done interactively using a series of menu items. Once a finite-difference mesh is completed, the user can move on to various spatial analyses, using a conceptual model approach. The user has several options for spatial overlays that will allow them to populate the finite difference mesh with the values necessary to set up a model. Cell-by-cell editing is also possible. Once all data layers are created, the user can move on to build the MODFLOW input arrays, using the previously mentioned data layers.

Upon completion of the model input parameter generation, a functional MODFLOW model is created, and MODFLOW is started. During the MODFLOW model run, output files are created according to the operators input parameters. These output files can then be imported back into ArcView for postprocessing. Postprocessing will allow the user to calibrate the model. When the model is calibrated, the user can also move on to construct maps of drawdown. These drawdown figures are important in the submittal of PHC reports to regulatory agencies. At the time of this update, some effort has gone into automating postprocessing and calibration. Although postprocessing is not yet completed, the foundation has been laid for continuing work in this area.

PROJECT COMPLETION TIMELINE

1998
November: Complete HEC-1 and MODFLOW post-processing.
December: Beta testing; Debugging and refinement of interface

1999
January / February: Completion of extension documentation
February: Technology Transfer Workshop for Mining Community
March: Report Completion; Distribution of ArcView extension and CD-ROM product

Future: Presentation of results at 1999 ASSMR Meeting

PUBLICATIONS TO DATE

Hamerlinck, J.D. and J.R. Oakleaf. 1997. **Utilizing Geographic Information Systems Technology in the Wyoming Cumulative Hydrologic Impact Assessment Modeling Process**, in Proceedings, Vision 2000, 14th Annual Meeting of the American Society for Surface Mining and Reclamation, May 10-15, 1997, Austin, TX. p. 667-676.

Oakleaf, J.R. and J.D. Hamerlinck. 1997. **Integrating Geographic Information Systems Technology into Groundwater- and Surface-Water Modeling Associated with Wyoming's Cumulative Hydrologic Impact Assessment**, in Proceedings, Wyoming Water '97: What's New in the Toolbox-Applied Research for Management of Wyoming's Water Resources, April 21-23, 1997, Casper, WY. p. 25-33.

Peacock, K., A.J. Anderson, J.R. Oakleaf, S.P. Gloss, et al. 1997. **A study of techniques to assess surface and ground water impacts associated with coal bed methane and surface coal mining, Little Thunder Creek drainage, Wyoming**. Laramie, Wyoming: Wyoming Water Resources Center.

William A. Gern

From: Arlene Soto [SMTP:asoto@wyoming.com]
Sent: Friday, October 30, 1998 5:21 PM
To: Thad A. Wolfe; Bill Gern
Subject: Attorney information

Here is the attorney information I was discussing in our meeting today:

Jackie Studer
Davis, Graham & Stubbs
4410 Arapahoe
Boulder, CO 80303
303-939-8605

Thank you for taking the time today to discuss the PEAC project.

Arlene Soto

Student Research Apprentice Program (SRAP)

The Student Research Apprentice Program offers an 8-week summer research experience to scholastically superior high school students whose parents have not completed college. In the SRAP program, students spend their days working (8 hours) in the laboratory conducting various research tasks with UW professors and their research groups. SRAP is designed to provide hands-on training and experience to scholastically superior high school students in the sciences, mathematics, engineering, and food and agricultural science. To date, 128 students participated in the program.

Of the students in the Student Research Apprentice Program who have been tracked beyond high school, 85% are enrolled in or have graduated from college. Eighty percent of these graduated in a Science-Education-Math (SEM) discipline.

THE EFFECTS OF VARYING TOPSOIL REPLACEMENT DEPTH ON VARIOUS PLAN PARAMETERS WITHIN RECLAIMED AREAS

B. SCHLADWEILER, P. WOLKEN, L. MUNN, R. HAROIAN

1998
Abandoned Coal Mine Land Research Program
Progress Report

THE EFFECTS OF VARYING TOPSOIL REPLACEMENT DEPTH ON VARIOUS PLANT PARAMETERS WITHIN RECLAIMED AREAS

submitted by:

Brenda K. Schladweiler and Paige M. Wolken

BKS Environmental Associates, Inc.
P.O. Box 3467
Gillette, WY 82717

Dr. Larry C. Munn

Department of Range Management (Soil Science)
University of Wyoming Box 3354
Laramie, WY 82071

Rose Haroian

Powder River Coal Company, Rochelle Mine
Caller Box 3035
Gillette, WY 82717

November 5, 1998

PROJECT ABSTRACT

Within native ecosystems, plant cover, production and diversity are often affected by the amount, type and quality (physical and chemical) of the topsoil present. Reclaimed areas at coal mines have federally mandated post-mining cover and production standards which are not difficult to meet; however, pre-mine levels of plant diversity have been difficult to attain.

According to current mining regulations, a uniform topsoil replacement depth must be utilized over a given mine permit area. For mine permit areas that have widely varying topsoil depths within large portions of their permit area, this poses significant complications from a mine planning standpoint. Approving variances for such conditions at existing coal mines often results in concerns from the Wyoming Department of Environmental Quality. Widely varying topsoil availability is inherent to abandoned mine situations where topsoil is often lacking or very limited.

In order to address concerns over utilizing varying topsoil replacement depth within a given permit area to enhance plant diversity, the proposed research will: 1) determine if shallower replacement depths of topsoil enhance plant species diversity; 2) determine if shallower replacement depths of topsoil affect vegetation cover and production; 3) evaluate the quality of replaced topsoil through time and between variable replacement depths; and based on these findings, 4) determine if variable soil replacement depths enhance the development and/or differentiation of post-mine vegetation communities.

Based on these objectives, the following specific null hypotheses will be tested: 1) variable topsoil replacement depths do not influence vegetation cover and production; 2) variable topsoil replacement depths do not influence plant diversity; and 3) quality, in terms of electrical conductivity and pH, of the replaced topsoil layer will not deteriorate with topsoil depth.

Information derived from this study will be used to quantitatively assess the issue of variable topsoil replacment depths and resulting plant diversity, as well as other vegetation parameters. This issue is currently a concern within the state's mining industry, as well as the regulatory authority. Information from this study will be used to assess the direction of future reclamation work regarding vegetation/topsoil issues.

Principal investigators for this project include various vegetation and soil specialists with appropriate backgrounds to complete the research. PI's include: Brenda K. Schladweiler and Paige M. Wolken, BKS Environmental Associates, Inc.; Dr. Larry Munn, University of Wyoming; and Rose Haroian, Powder River Coal Company, Rochelle Mine. Additional input is being provided by Scott Belden, Powder River Coal Company and David Legg, University of Wyoming.

SUMMARY OF 1998 ACTIVITY

This project has been divided into five major tasks: I) review existing vegetation/soil information from the WDEQ-LQD and obtain permission from the WDEQ-LQD to conduct the proposed variable topsoil study on Rochelle Mine; II) establish and construct the study site at the Rochelle Coal Mine; III) obtain quantitative field data of three treatments on reclaimed areas and the corresponding reference areas; IV) summarize findings from the field sampling in No. AIII@ and provide annual/final recommendations; and V) disseminate that information to interested parties.

Task I of the project was primarily conducted in 1998 but is somewhat ongoing. Such reviewed resources included the mine permit volumes (Appendix D-8, Vegetation, and D-7, Soil) and annual reports for various mines throughout the state on record at the WDEQ-LQD offices in Cheyenne, Sheridan (for Campbell County), and Cheyenne (for Converse County). In addition to information gathering during Task I, written approval by the WDEQ-LQD was obtained (September 1998); a stipulation of Powder River Coal Company/Rochelle Mine=s involvement was written approval from WDEQ-LQD to conduct research on permanent reclamation with topsoil depths shallower than the designated mine plan replacement depth.

Task II of the project involved site preparation and plot construction on Rochelle Mine located approximately 10 miles southeast of Wright, Wyoming. Rochelle Mine provided the equipment and manpower necessary to construct the field site. Site selection was determined by specific mine limitations, i.e., spoil grading, spoil sampling, topsoil contractor schedule and seeding contractor schedule.

The study site location was rough graded in Spring 1998. Block construction activities were conducted from late August to October 1998 with the exception of the cover crop seeding which will be conducted in November 1998. A two year extension on this project enabled the cover crop aspect of typical reclamation at the Rochelle Mine to be maintained. The permanent reclamation seed mix will be seeded in Fall 1999 and was derived to represent the pre-mining Breaks Grassland vegetation type. Within the time frame of the study, the permanent reclamation will be evaluated for three growing seasons (2000, 2001, and 2002).

The chosen design alternative was randomized complete block (RCB) and was chosen based on mine limitations with equipment and available area. Within the RCB, one contiguous rectangular area was selected within the reclaimed topography with three distinct replicate blocks. Treatment alternatives included: 1) 22 inch Adesignated permit@ replacement depth; 2) 12 inch replacement depth; and 3) 6 inch replacement depth. The treatment blocks were constructed on: 1) a uniform site to control variables other than topsoil depth (e.g., similar slope, aspect, stockpiled topsoil source, and seed mix); and 2) a landscape position that would best represent a pre- and post-mine Breaks Grassland community. Slopes are generally 5:1 and are west-facing. The three designated depths were approximate over the treatment replicate and will have minor variation based on weather limitations present during 1998, topsoil source, and equipment utilized for topsoil replacement.

Treatment replication dimensions were 175 feet by 250 feet. A 25 foot buffer strip on all sides of the treatment replication was considered to minimize edge effect between replications due to equipment limitations. Therefore, a sample area of 125' x 200' was created within each treatment replication. Corners of treatment replicates were staked with appropriate depth indicators for equipment operators. Both Rochelle and BKS personnel were present during the course of study area construction to visually ensure proper depth placement.

Normal backfill suitability sampling of the study site was conducted by Rochelle Mine on 500 foot centers prior to topsoil placement. Approximate three-year-old stockpiled material was utilized for this area and was previously removed from former Breaks Grassland topography. Soils within undisturbed Breaks Grassland type consist of shallow entisols on side slopes and hill tops with moderately deep to deep entisols on fans and narrow drainages.

Existing Breaks Grassland and Upland Grassland native reference areas will be used to distinguish plant community development and differentiation between treatments. The RCB design was utilized in these native areas as much as possible. Three distinct areas were chosen in each reference area to represent the general slope, aspect and soil depth found in the reclaimed portion of the study. Within these three areas, general replication of the 22, 12, and 6 inch blocks were chosen.

In order to establish baseline soil fertility status at the reclaimed area treatments and reference areas, a minimum of 2 sample locations were collected within each reclaimed treatment replication. For general comparison purposes only, two samples within each of two native areas by soil depth were also gathered. Samples, at six-inch increments, were collected at 2 random locations within each respective treatment block before cover crop seeding on reclaimed areas in 1998. In the reference areas, samples were collected by horizon up to paralithic contact. Analysis parameters followed Table I-3 in WDEQ-LQD, Guideline 1 (1994). Listed analysis parameters include: organic matter, pH, electrical conductivity (EC), nitrate-nitrogen, phosphorus, potassium, soluble cations: calcium (Ca), magnesium (Mg), and sodium (Na), sodium adsorption ratio, texture and particle size analysis. The University of Wyoming Soil Testing Laboratory will conduct the analysis.

The study site will be marked after permanent reclamation seeding in the Fall of 1999. Original corners were surveyed by Rochelle personnel and can be easily remarked after equipment disturbance.

Task III will involve vegetation and soil quality field sampling and will be initiated in summer 2000. Field data collection will be conducted in 2000, 2001 and 2002. Cover, production, and plant diversity will be evaluated over all treatment levels.

INTERACTIONS INFLUENCING SELENIUM TOXICITY IN AQUATIC SPECIES ON RECLAIMED MINELANDS

M.F. RAISBECK, E.L. BELDEN

Interactions Influencing Selenium Toxicity in Aquatic Species on Reclaimed Minelands

11/5/98

M. F. Raisbeck, K. M. Orsted, E. L. Belden, D. A. Sanchez and R. Siemion
Department of Veterinary Sciences, University of Wyoming, Laramie, WY

Introduction

Many of Wyoming's coal deposits are closely associated with seleniferous shales. Selenium from these shales may be mobilized by the process of surface mining or reclamation potentially contaminating terrestrial and aquatic ecosystems. The latter is an especial concern in light of the fact that artificial wetlands are fast becoming an integral part of many reclamation plans for surface coal mines. These wetlands will attract significant numbers of migratory waterfowl, a class of wildlife that is both politically and biologically sensitive to Se contamination (O'Toole and Raisbeck, 1997). The "level of concern", established approximately 10 years ago for waterfowl protection in surface waters (5 ug/L), is under attack as insufficiently conservative; many environmental groups want it lowered to 1 or 2 ug/L. It should be self-evident that numbers like these pose a significant regulatory challenge to reclaiming drastically disturbed lands such as surface mines in potentially seleniferous areas, as well as potential toxic hazards to livestock and wildlife.

Sulfur (S) is also quite common in the western Great Plains of the U.S and is frequently collocated with Se. The visible presence of sulfate ("alkali") salts in playas was responsible for the erroneous attribution of chronic selenosis to "alkali" disease by farmers and ranchers in the region. Sulfate ion ($SO_4^=$) concentrations as high as 11,000 ppm have been recorded in the Powder River Basin of Wyoming, and concentrations of 2000-3000 ppm are fairly common in surface water impoundments such as stock ponds (Raisbeck, 1993). Under field conditions, elevated $SO_4^=$ concentrations have been associated with increased mortality in ducklings and geese (Wobeser and Howard, 1987; Mitcham and Wobeser, 1988).

Selenium and sulfur (S) share many chemical and physical properties. These similarities are reflected in the ease with which one element substitutes for another in biology and geology. For example, the Se geochemical cycle was originally inferred from the S cycle (Herring, 1990). It is thus likely that human activities, such as surface mining or irrigation, which mobilize one element, will also mobilize the other.

Given the likely co-occurrence of Se and S in the post-mining aquatic environment, a practical understanding of the interaction(s) between these elements is required to prevent poisoning in sensitive species that inhabit this environment. Hoffman et al., (1992) demonstrated that 0.42% dietary methionine (a S-rich amino acid) antagonized many of the toxic effects of 15 and 60 ppm selenomethionine (Semet) in mallards. This was probably due to competition at the amino acid level and thus not directly applicable to inorganic forms of S such as $SO_4^=$ which predominate in surface waters of the Powder River Basin.

Extrapolation from other organisms indicates that the toxicity of inorganic forms of Se such as $SeO_4^=$ is likely to be antagonized by simultaneous ingestion of S . Fertilizing high Se soils with elemental S or gypsum greatly reduced the Se content of wheat grown on these soils. Moderately elevated dietary S (as $SO_4^=$) lowered tissue Se concentrations in rats, sheep and cattle (Ganther et al., 1966; Boyazoglu et al., 1967; Pope et al., 1979). Most of the studies were primarily concerned with the possibility of S-induced Se-deficiency and thus examined the interaction at relatively low dietary Se concentrations. It remains to be seen if the aqueous, inorganic forms of Se present in Powder River basin surface waters will exacerbate or inhibit Se toxicity specifically in waterfowl.

The following experiments were thus undertaken to examine the interaction of toxic dietary concentrations of Semet and aqueous $SO_4^=$ in drinking water.

Materials and Methods

Model

Game farm mallards were utilized because they: 1) are one of the species at risk under field conditions; 2) they are available commercially; and 3) the bulk of previous Se research was done in mallards and there is a considerable knowledge base to draw upon. Young adult mallard ducks of both sexes were obtained from Whistling Wings (Monrovia, Ill.) and housed separately by sex in rubber floored, heated (10 C) animal rooms at the University of Wyoming Department of Veterinary Research Center. Upon arrival, each bird was sexed, weighed and identified with a leg band. Artificial lighting was provided as an 8:16 light:dark cycle to inhibit egg laying. Complete feed (Mazuri®Brand, Waterfowl Breeder Feed, PMI Feeds, Inc., St. Louis, MO) and drinking water were provided *ad libitum.*

After a 2-3 week acclimation period the birds were re-weighed, ranked by weight and from that ranking randomly assigned to one of 8 treatments (see below). At this time each hen was paired with a similarly ranked drake and placed in an 2 m^2 wire pen in a south-facing, open faced, concrete floored pen. Birds were sheltered from direct sunlight and rain, but received natural solar illumination from late Spring through the end of the experiment. After an additional 3 weeks to begin laying, the ducks were started on treated diets ("Day 0"). Each bird was inspected daily for signs of illness and any eggs laid collected and marked with a graphite pencil. The first egg laid by each hen was frozen for Se analysis, the second, third and fourth stored at 14 C for 14 day incubation, 28 day incubation or hatching, respectively. After a complete set was collected the cycle was repeated. Water consumption was monitored daily and feed consumption measured weekly by the method of weighbacks. Blood was collected by wing vein venopuncture into EDTA-treated, heparin-treated and untreated glass tubes at approximately 28 day intervals and stored at 5°C (EDTA) or -20°C (heparin and serum) until analyzed.

Experimental Treatments (first year)

The first year of the project was structured as a 2x4 (n=3 mated pairs) factorial experiment with two dietary Se concentrations (0 or 15 ppm added Se) and four drinking water $SO_4^=$ concentrations (0, 1000, 2000 or 3000 ppm added $SO_4^=$). Because feed refusal is possible with Se-treated diets, an additional 2 pairs were allocated as pair-fed controls to the Se-treated birds for each level of drinking water $SO_4^=$. These birds were fed only the amount of untreated feed (normalized to body weight) consumed by Se-treated birds.

The basal ration (0 Se) consisted of the same laying mash used previously (background Se = 0.28 ppm). Selenium rations were prepared by making a stock solution of L-Semet (Calbiochem, La Jolla, CA) in deionized water which was then thoroughly mixed by hand with basal ration at a rate of 10% (100 ml stock solution to 1 kg feed) and allowed to air dry. The stock solution was calculated to provide 15 ppm additional Se. Experimental ratios were prepared fresh every 2-3 days and stored in air-tight containers at 5°C until used. Subsamples of each batch were retained for Se analysis. Both rations were fed *ad libitum.* L-Selenomethionine was used because it is the form of Se that predominates and bioconcentrates in the aquatic food chain.

Water was provided *ad libitum* from polyvinylchloride water troughs. Troughs were washed daily and water was replenished as needed to ensure clean, palatable water was constantly available. Untreated (0 $SO_4^{=}$) water consisted of Laramie municipal water (less than 5 ppb Se). Sulfate was provided as equimolar amounts of sodium, potassium, magnesium and calcium sulfate to minimize possible effects of the individual cations. One thousand, 2000 or 3000 ppm $SO_4^{=}$ water was prepared daily by adding the appropriate weight of sulfate salts to 60 L of municipal water daily and stirring until completely dissolved.

Endpoints (first year)

Previous work in other laboratories has demonstrated that the most sensitive indicators of chronic selenosis in waterfowl are embryonic deformities (terata) and immune suppression (Heinz et al., 1989; Fairbrother and Fowles, 1990). Immune function and teratogenesis were thus selected as the primary biological markers of Se toxicity. Other endpoints included body weight, feed consumption, blood, egg and tissue Se concentrations, and clinical pathology.

Feed consumption was evaluated by placing a measured quantity of ration in each feeder and weighing back the remaining feed after 24 hours. An aluminum tray was placed under each feeder to catch any spilled or scattered feed. Serum was harvested from untreated blood samples and, together with EDTA-treated blood, sent to a commercial veterinary clinical pathology laboratory (Southwest Diagnostics, Phoenix, AZ) for a complete blood count (CBC), serum protein. Blood and tissue Se was analyzed by hydride-ICP (Tracey and Moller, 1990).

Immune function was evaluated by comparing delayed type hypersensitivity (DTH) and antibody production between treatment groups. On day 26 each duck was immunized with a subcutaneous injection of 2 mg of bovine serum albumin (BSA) in potassium alum adjuvant. Blood serum collected 2 and 4 weeks post BSA-immunization was analyzed for specific anti-BSA antibody by an enzyme linked immunosorbent assay (ELISA) procedure developed in our laboratories (Schamber, 1994). One week after BSA immunization, each duck was immunized with an intradermal injection of 0.2 ml complete Freund's adjuvant containing *Mycobacterium bovis*. Two weeks after immunization, birds were skin tested under the right wing by injecting bovine tuberculin intradermally. Swelling (indicative of a DTH reaction) of the site was measured with calipers and a millimeter ruler at 24 and 48 hours post-immunization.

Selenium induced teratogenesis was evaluated by gross *post mortem* examination of embryos at 14 and 28 days of incubation and ducklings at 14 days of age. After daily collection, eggs were stored at 14°C until incubated. No egg was stored for more than 7 days before incubation. Eggs were incubated in a forced air incubator at 35°C and 55-65% humidity. Incubated eggs were candled 3 times weekly to check for embryonic viability. Any non-viable eggs or any containing dead embryos were removed and refrigerated until they could be examined. After the appropriate incubation period, eggs were chilled to kill the embryos, opened and the embryos subjected to a standardized *post mortem* examination. Ducklings were transferred to a heated brooder after hatching and grown for 14 days before being euthanized with pentobarbital and necropsied.

At the end of the experiment, adult ducks were killed by cervical dislocation and subjected to a complete gross necropsy. Major organs were weighed and samples collected and frozen for selenium analysis.

Experimental Treatments (second year)
After examining the first year's results it was decided to forgo the pair-fed controls and increase the number of birds to permit n=6 pairs per treatment and decrease the dietary Se concentration to 8 ppm. The second year's experiment was thus structured as a 2x4 factorial experiment with two dietary Se concentrations (0 or 8 ppm added Se) and 4 drinking water $SO_4^=$ concentrations (0, 1000, 2000 or 3000 ppm added $SO_4^=$). Birds were examined daily and samples collected as during the first year.

Endpoints (second year)
Because neither treatment had any effect on clinical pathology, DTH reaction or primary antibody response during the first year, these procedures were dropped from the second year's protocol. Teratogenesis was evaluated at 14 days, 28 days and immediately after hatching rather than growing the ducklings for 14 days. Other procedures were similar to the first year.

Statistical analysis
Quantitative data (body weights, Se concentrations, feed consumption, organ weights and eggs laid) was subjected to analysis by ANOVA with computer packages from either SAS or Minitab using Se, $SO_4^=$ and days on diet as independent variables. Organ weights were normalized to brain weight prior to analysis. The incidence of terata was analyzed by chi-squared with Minitab.

Results

First year
Ducks receiving 15 ppm Se diets ate slightly less than did comparable control birds, but this difference was small compared to the overall variation in feed consumption. Ducks on Se diets and many of the pair-fed controls had rougher plumage than did controls. Selenium-treated ducks also appeared to have less water-repellent plumage and took longer to regrow feathers after molting, however there was none of the characteristic alopecia of overt selenosis (O'Toole and Raisbeck, 1997). Although Se-treated ducks ate a little less than did comparable 0 ppm Se birds, the difference was small compared to the overall variation in feed consumption. Only the pair-fed 3000 ppm $SO_4^=$ group actually lost weight relative to the other treatment groups (Figure 1). Drinking water $SO_4^=$ did not seem to modify these effects one way or another. Otherwise, all ducks behaved normally and showed no apparent signs of illness.

There were no differences between groups in any of the clinical pathological parameters measured attributable to either Se, $SO_4^=$ or to their interaction. Neither Se nor $SO_4^=$ caused any change in DTH to *M. bovis* or primary antibody response to BSA. Gross *post mortem* examination revealed only incidental lesions such as a salivary abcess in one 0/0 drake. Organ weights, normalized to brain weight for each bird did not differ significantly between groups. Blood Se concentrations were significantly higher in all Se groups than in any control groups. The mean blood Se concentration of the 15 ppm Se/3000 ppm $SO_4^=$ group became significantly less than the corresponding mean concentrations of the 15 ppm Se/0 ppm $SO_4^=$ near the end of the experiment (Figure 2).

Selenium-treated birds laid more eggs than did controls, however fewer of these embryos survived to hatch. Terata in eggs from Se-treated birds were qualitatively similar to what has been reported previously, i.e. gastroschisis, missing limbs and digits, missing or abnormally small eyes and marked keratin deformities, especially of the beak. There were none of the heart or liver defects reported by other workers. Many of the ducklings from hens on high $SO_4^=$ water exhibited a neurologic syndrome characterized by opithotonus, incoordination and falling over backwards. Affected ducklings that were force fed water tended to recover, but weighed less than their pen mates at 14 days.

Second year

There was no measurable difference in feed consumption between ducks on the 8 ppm diets and controls. All birds gained weight on experimental diets and exhibited only seasonal weight fluctuations. The 8 ppm Se/3000 ppm $SO_4^=$ group seemed to gain more near the end of the experiment, but the difference with other groups was not statistically significant. None of the ducks exhibited the plumage defects (poor water repellency, low gloss) seen in some Se treated ducks during the previous year. All ducks, regardless of treatment exhibited good general body condition and normal mating behavior. No medically significant lesions were discovered at *gross post morte*m examination. Mean body weights (Figure 3 & 4) and organ weight/brain weight ratios were statistically similar between treatment groups.

Hens in the 8 ppmSe/3000 ppm $SO_4^=$ again laid more eggs than control hens (Figure 5) and again fewer of these eggs were viable. The seasonal distribution of egg laying did not vary remarkably by treatment group. Terata in embryos from Se treated hens were qualitatively similar to those seen in 1996 (i.e. syndactyly, etc.), but deformed embryos constituted a greater percentage of eggs laid by Se treated hens and mortality during the first 2 weeks of incubation was less than in 1996. Conversely, a smaller percentage of eggs from all groups hatched in 1997. Embryos developed normally until approximately 2 days prior to hatching, but died sometime during the process of hatching. The incidence of terata was greater over all in $SO_4^=$ treated groups than corresponding controls (Figure 6).

Blood Se concentrations were significantly greater in Se treated ducks than controls but there were no significant differences between $SO_4^=$ treatment groups fed similar amounts of Semet (Figure 7). As might be expected, blood Se concentrations were less in 1997 than in 1996. Liver Se concentrations were also significantly increased by dietary Se, but not by drinking water $SO_4^=$. Albumin accumulated more Se than did yolk, but there were no discernable effects of $SO_4^=$ on Se concentrations.

Discussion

Exogenous sulfur, in the form of drinking water $SO_4^=$ did not alter the uptake or teratogenic effects of L-selenomethionine in mallard ducks. This is somewhat suprising in light of the number of reports in other species in which some form of dietary S results in decreased Se uptake, increased elimination, or both. Most of the latter however, employed Semet and methionine, or inorganic Se and some form of dietary $SO_4^=$ salt. Most were also targeted at Se deficiency and thus used smaller Se concentrations than we employed.

The relevance of methionine/Semet and $SO_4^=$/SeO_4 interactions under natural conditions in surface waters of the Powder River Basin is debatable. The primary source of Se in aquatic diets is Semet that has become concentrated by accumulating in successive levels of the food chain. Sulfur exposure will be from S-amino acids in feedstuffs and as $SO_4^=$ ion in drinking water. We believe the latter to be most important (i.e. of greatest magnitude). While there is no doubt some accumulation of S by the aquatic foodchain, it cannot achieve the thousand-fold bioconcentration attributed to Se and probably never exceeds a fraction of a percent. Given the relative contributions of water (large) and feedstuffs (small) to the total diet of waterfowl in Spring and Summer the $SO_4^=$ ion in water represents the greater potential source of dietary S.

Dietary selenomethionine did not cause specific signs of intoxication at either 8 or 15 ppm. This is consistent with previous studies in mallard drakes by this laboratory. Subjectively, there was some non-specific loss of condition in the 15 ppm birds, which may have been due to a slight decrease in feed consumption as it also occurred in the pair-fed controls. The loss of water repellency by treated ducks plumage was due to Se consumption as it did not occur in pair-fed controls. Given the predilection of Se for epithelial structures, it is reasonable to assume that this effect was Se-related and that the concentration fed (15 ppm) was near an overtly toxic dose.

Dietary S, as 3000 ppm drinking water $SO_4^=$, did not cause any overt health effects. During the first year, many of the ducklings hatched to high $SO_4^=$ hens developed a neurological condition similar to sodium ion toxicity in mammals. Subsequent investigation indicated that these were due to a combination of cation toxicity, particularly sodium ion and/or bacterial infections which occurred near hatching. This finding supports the hypothesis that $SO_4^=$ contamination is a problem for waterfowl primarily as a marker of other potential water soluble toxicants such as sodium. It is also quite distinct from the situation in mammals where concentrations greater than 2000 ppm have been proven lethal in ruminants such as cattle and deer.

Bibliography

Boyazoglu PA, Jordan RM, Meade RJ (1967) Sulfur-selenium-vitamin E interrelations in ovine nutrition. *J Anim Sci*, 26:1390-6.

Fairbrother A and Fowles J (1990) Subchronic effectsof sodium selenite and selenomethionine on several immune functions in mallards. *Arch Environ Contam Toxicol,* 19:836-844.

Ganther HE, Levander OA and Baumann CA (1966): Dietary control of selenium volatilization in the rat. *J Nutr,* 88:55-60.

Heinz GH, Hoffman DG and Gold LG (1989): Impaired reproduction of mallards fed an organic form of selenium. *J Wildl Manag*, 53:418-428.

Herring JR (1990): Selenium geochemistry – A conceptus. In*: Proceedings of the 1990 billings land Reclamation Symposium*, USGS circ 1064.

Kleczkowski M, Barey W, Klucinski W, Sikora J and Dembele K (1994): Effect of different

THE INFLUENCE OF POST-HARVEST AND PRE-PLANTING SEED TREATMENT ON SAGEBRUSH SEEDLING VIGOR

D.T. BOOTH, Y. BAI, and E.E. ROOS

Wyoming Big Sagebrush Seed Production from Mined Lands and Adjacent Unmined Rangelands

an extension of

THE INFLUENCE OF POST-HARVEST AND PRE-PLANTING SEED TREATMENT ON SAGEBRUSH SEEDLING VIGOR

D.T. Booth, Y. Bai, and E.E. Roos

Introduction

Wyoming Coal Rules and Regulations (DEQ-LQD 1995) require revegetation "... be self-renewing ..." There has been a significant research and technological development directed at reseeding sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* (Beetle and Young); however, measurement of the self-renewing capability of mined land sagebrush has received relatively little attention. We addressed this research need by measuring sagebrush seed production as affected by; (1) land status - mined or unmined; (2) by big game herbivory; and (3) by modification of the mother-plant environment.

Materials and Methods

Site Description

The study was conducted on the Dave Johnston Coal Mine, 40 km east of Casper, Wyoming. Five sites were located on the mine where mined-land sagebrush stands were in close proximity to stands of sagebrush on unmined rangeland. These included:

1. Fuel Island - The stand is along the main haul road, is more than 20 years old and has a south aspect. The unmined stand is 100-200 m south and 2-3 m lower elevation on the outside of the mine boundary fence and subject to livestock grazing.
2. Entry 50 - Located west along the main haul road, these plants are about 4 years younger than the Fuel Island stand. The unmined stand is also 100-200 m south, 1-2 m lower elevation, and also on the outside of the mine boundary fence.
3. 110 School - The stand was seeded in 1983. The unmined stand is located less than 50 m to the southwest and within the mine boundary fence. Both stands have a northwest aspect.
4. 60 Badger - The stand was seeded in 1985. The unmined is immediately adjacent to the seeded stand and 1 to 4 m higher elevation. The aspect of both stands is mostly southwest.
5. 4 School - Seeded in 1990 and has a south to southwest aspect. The unmined stand is southwest across a haul road, 2 to 6 m lower elevation, and on relatively level terrain.

Treatments and Experimental Design

The study was installed July, 1995, by selecting 48 plants (24 on mined land and 24 on unmined rangeland) that were as much the same size as possible. Three replications were installed on mined land and on unmined rangeland at each study site. Single sagebrush plants selected for the study were treated as follows: (1) a 1 m^2-piece of fabric mulch was installed around the base of the plant to reduce competition from herbaceous plants, (2) a windbreak was erected on the north and west side of the plant, (3) both mulch and a windbreak were installed, and (4) no treatment. Plants selected for these treatments were surrounded by a 1-m^2 fence of 1-inch wire net, then paired with an unfenced and untreated adjacent plant from which data were also collected. Thus our control variables (and number of treatment levels) were site (5), replication (3), year (2), land

(2), mulch (2), windbreak (2), and fence (2).

Seeds were harvested annually in late October or early November. The data collected included number of seed stalks harvested, the weight of bulk seed produced per plant; average seed weight, moisture, viability, germinability, and vigor. Soil moisture data were obtained from gypsum blocks buried beneath the canopy of treated plants. The blocks were read mid-month, April through October, 1996 through 1998.

Results

Seed Stalks - Number and Weight

Averaged across sites, stalk numbers and weights were 28 stalks weighing 7.3 g per plant from mined land plants versus 19 stalks weighing 2.0 g per plant from unmined land. Plants protected by fence averaged 39.8 seed stalks weighing 8.3 g compared to unprotected plants which averaged 7.7 stalks weighing 0.9 g. There is a significant site x fence interaction due to high variability in seed stalk production among sites but stalk production at all sites was 2 to 10 times greater from protected plants as from the unprotected ones.

Bulk Seed Yield per Plant

Plants on mined land averaged 12 g bulk seed per plant compared to 3 g per plant on unmined land. Seed yields by site were consistently greater on mined land except at 60 Badger. Plants growing on mined land and protected by fence averaged 22 g per plant, 14 times the average for unprotected plants on mined land and 38 times the average of unprotected plants on unmined land.

Seed Weight and Moisture

The overall average seed weight on unmined rangeland was 0.149 mg/seed compared to 0.194 mg for seed from reclaimed mine land. However, at 110 School and 60 Badger seeds from the unmined land were heavier than seeds from mined land. In 1996 seed from unmined land averaged 0.080 mg/seed, compared to 0.171 from mined land and 0.216 mg/seed from both types of land in 1997.

Surprisingly, fencing had a significant influence on seed weight and seed moisture. In both 1996 and 1997 unfenced mother plants produced lighter and drier seeds than fenced mother plants. Seeds from fenced mother plants averaged 4.6% moisture compared to 2.7% in seeds from unfenced mother plants.

Soil Moisture

Soil moisture varied by site, year, land, and mulch and in 1998 was only 57% of the 1997 soil moisture. Averaged across all other variables the soil moisture on mined land, and soil moisture under mulch was 29% compared to 25% on unmined land or under plants without mulch ($P<0.01$ and 0.02 respectively) .

Plant Mortality

Plant mortality occurred at 2 study sites. Three plants died at 110 School and 11 at 60 Badger. Mortality at 60 Badger represented 46% of the study's mined-land population at that site. All of the mortality occurred on mined land.

Seed Quality Analysis

Seed germination and vigor differed by site and year (P<0.05) but was not affected by land type, fencing, or treatments to modify the mother plant environment.

Discussion

Land Status - Mined versus Unmined Land

Three sites consistently yielded greater amounts of seed heads and 4 sites consistently yielded greater bulk seeds from mined land than from adjacent unmined land. Bulk seed yield of plants at 60 Badger was about equal to that of plants from unmined land. The mortality at 60 Badger suggests that this population is under some type of unusual stress and may not represent the general condition of mined land sagebrush.

Ninety percent of the time mined lands had greater soil moisture that unmined lands. This seems to be part of the reason for the superior seed production from mined lands. However, there were instances where soil moisture between the 2 types of land were not different but where seed production remain greater from mined land.

Herbivory - Fenced and Unfenced

The study produced strong evidence that herbivory by big game is a major influence reducing the reproductive potential of sagebrush - on or off mined land. It appears a most effective method of increasing sagebrush seed production on mined land would be to protect mother plants from big game herbivory.

Environmental Modification

We found that enclosing a plant in wire netting resulted in a beneficial modification of the environment. This was not expected, but may account for the less than expected influence of mulch and windbreak on the quantity of seed produced.

Conclusions and Recommendations

We conclude that the reproductive potential of sagebrush on mined land at the Dave Johnston Coal Mine exceeds that of plants on unmined land. However, this advantage is largely negated by big game herbivory. Modification of the mother plant environment also increased seed production, but that was much less important than excluding herbivores. We recommend that selected stands of mined-land sagebrush at the Dave Johnston Coal Mine be protected from herbivory and the seed harvested for new reclamation and for over-seeding reclaimed areas with low sagebrush densities. This would allow the mining company or contract harvesters to utilized the superior production of the mined land sagebrush stands. We recommend similar studies be conducted to compare seed production potential from mined and unmined lands at other locations.

Publications Resulting from this Grant

Booth, D.T., Y. Bai, and E.E. Roos. 1995. Wyoming big sagebrush seed quality as influenced by processing with an industrial debearder. Abstracts 1995 Meeting, American Society for Surface Mining and Reclamation.

Booth, D.T., Y. Bai, and E.E. Roos. 1995. Wyoming big sagebrush seed quality related to debearder operation during seed cleaning and storage. pp. 8. IN: Fifth International Rangeland Congress Abstracts. Dept. of Rangeland Resources, Utah State Univ., Logan.

Bai, Y., D.T. Booth, E.E. Roos. 1995. Influences of initial seed moisture and humidification on seed germination of Wyoming big sagebrush. pp 4. IN: Fifth International Rangeland Congress Abstracts. Dept. of Rangeland Resources, Utah State Univ., Logan.

Booth, D.T., Y. Bai, and E.E. Roos. 1995. Wyoming big sagegbrush seed quality as influenced by processing with and industrial debearder. p. 858. IN: Proceedings of the 12th Annual National Meeting of the American Society for Surface Mining and Reclamation. G.E. Schuman and G.F. Vance (eds). Abstract. ASSMR, Princeton, WV.

Booth, D.T., Y. Bai, and E.E. Roos. 1995. pp. 60. Wyoming big sagebrush seed quality related to debearder operation during seed cleaning and storage. In: N.E. West (ed.) Proceedings of the 5th International Rangeland Congress. Salt Lake City, Utah. 23-28 July. Society for Range Management, 1839 York St., Denver, CO. 80206.

Bai, Y., D.T. Booth, and E.E. Roos. 1995. pp. 27. Influences of initial seed moisture and humidification on seed germination of Wyoming big sagebrush. In:N.E. West (ed.) Proceedings of the 5th International Rangeland Congress. Salt Lake City, Utah. 23-28 July. Society for Range Management, 1839 York St., Denver, CO. 80206.

Booth, D.T., Y. Bai, and E.E. Roos. 1997. Preparing sagebrush seed for market: effects of debearder processing. J. Range Manage. 50:51-54.

Bai, Y., D.T. Booth, and E.E. Roos. 1997. Effect of seed moisture on Wyoming big sagebrush seed quality. J. Range Manage.50:419-422.

Bai, Y., D.T. Booth, and E.E. Roos. 1998. Technical Note: Measuring moisture content of small seeds. J. Range Manage. 51:179-180.

Bai, Y., D.T. Booth and J.T. Romo. 1998. Developmental stages of winterfat germinants related to survival after freezing. J. Range Manage. (Accepted / In press).

Hardegree, S.P., Y. Bai, D.T. Booth, and E.E. Roos. Pericarp removal has little effect on sagebrush seeds. J. Range Manage. 52:(In Press).

Bai. Y., D.T. Booth, and J.T. Romo. 1998. Winterfat (*Eurotia lanata* (Pursh) Moq.) seedbed ecology: Low temperature exotherms and cold hardiness in hydrated seeds as influenced by imbibition temperature. Annals of Botany 81:595-602.

Bai. Y., D.T. Booth, and J.T. Romo. Imbibition temperature affects winterfat(*Eurotia lanata* (Pursh) Moq.) seed hydration and cold-hardiness response. J. Range Manage. 52: (In Press).

EVALUATION OF PREVIOUSLY COLLECTED COAL MINE RELATED WILDLIFE DATA

T. MCDONALD, D. STRICKLAND

Evaluation of Wildlife Data Collected by Five Coal Mines in the Southern Powder River Basin, Wyoming

1998 PROGRESS REPORT

Prepared by

Trent L. McDonald,
M. Dale Strickland,
and
Paula S. Becker,
Western EcoSystems Technology, Inc
2003 Cental Ave
Cheyenne, WY 82001

Phone: 307-634-1756
Fax: 307-637-6981
E-mail: tmcdonald@west-inc.com

October 30, 1998

1. Introduction

This study was funded to answer several key questions about the wildlife data that coal mines collect. These key questions are: 1) do pre and/or post Appendix B monitoring data provide useful information for determining the response of wildlife populations to mines; 2) are the data collected under Appendix B meeting objectives established by DEQ and the Wyoming Game and Fish Department (WGFD) for the monitoring program; 3) are critical data not being collected under Appendix B; 4) can data under Appendix B be collected more economically and at the same time provide equivalent information about wildlife resources; and 5) can reporting formats be modified to improve the utility of wildlife monitoring data?

Phase 1 of our project was intended to provide information leading to recommendations regarding Phase 2. As of the date of this report, Phase 1 is complete and a decision regarding Phase 2 must be made.

The objectives of Phase 1 were to: 1) Evaluate the quality and quantity of wildlife data from five Wyoming coal mines, and determine appropriate methods for analysis; 2) Analyze the data from the five mines; 3) Recommend objectives and a completion option for Phase 2; and 4) Suggest future options for wildlife monitoring procedures and reporting formats. A secondary objective of Phase 1 is the conversion of existing data for the five mines from hard copy format into a readily accessible electronic format.

2. Methods

The five mines chosen for study during Phase 1 of the project were: 1) Jacobs Ranch, 2) Black Thunder, 3) North Rochelle, 4) Rochelle, and 5) North Antelope. All relevant sections of each mine's permit application and annual reports were photocopied and bound in labeled three-ring binders. A Microsoft Access™ (Version 7) database was constructed to hold the data. Data entry was performed by one individual trained to interpret the reports and locate data by type. Approximately 450 hours over 2.8 months were required for data acquisition and entry.

Trend analyses were the primary analytical approach in this study. We would have liked to conduct what we call Before-After-Control-Impact (BACI) analyses, but data for this purpose were insufficient because pre-mining information on control areas was missing. The trend analyses conducted here are offered as initial analyses. Full analysis of trends in abundance will require incorporating variables such as distance to the pit, tons of coal production, road density, average winter temperature, vegetation, etc. These mining variables are not a part of the wildlife data. Any trends observed in the following analysis should undergo further investigation and should not be viewed as final.

Trend analyses were conducted using Poisson regression techniques. Poisson regression is parallel to regular (Normal theory) regression except that responses (i.e., Y) are assumed to be a Poisson random variables. Poisson random variables are non-negative integers and are likely better approximations for counts than Normal random variables. When modeling density, the Poisson regression fit the equation,

$$\log(\mu_i/a_i)=\beta_0+\beta_1 x_{i1}+\beta_2 x_{i2}+\ldots+\beta_p x_{ip}$$

where μ_i was the (estimated) average count during the i[th] survey, a_i was total square miles searched during the i[th] aerial survey or length of the i[th] ground survey, β_0 through β_p were unknown parameters to be estimated, and x_{ij} was the value of the j[th] covariate during the i[th] survey. In all analyses, x_{i1} was date of the i[th] survey and the values of x_{i2} through x_{ip} depended on the number of mines in the analysis. For example, x_{i2} was 1 if the i[th] survey was conducted at the Jacob' Ranch mine and 0 otherwise, x_{i3} was 1 if the i[th] survey was conducted at the North Antelope mine and 0 otherwise. Other x_{ij} were defined analogously. The Poisson regression equation for raptor nest success analyses was the same as above except that either number of hatchlings or number of fledglings were modeled instead of density.

3. Results

Figure 1 shows a plot of pronghorn count per square mile surveyed during aerial surveys at all mines. Results of the Poisson regression analysis of aerial survey data showed a significant difference in trend across mines ($p<0.0001$, Poisson likelihood F test). Figure 2 shows a graph of the number of pronghorn seen per mile driven during ground surveys. If both areas reporting ground surveys are combined and a common slope is fit to the data, a significant decrease of −15.5% annually is observed for the years 1989 through 1996 ($p=0.002$, Poisson likelihood F test).

Figure 3 shows a graph of the number of mule deer seen per mile driven during ground surveys. When both areas are combined and a common slope is fit, the estimated annual change between 1993 and 1996 was 41.7% ($p=0.158$, Poisson likelihood F test).

Trend in the mean number of Golden eagle chicks hatched per nest was not significantly different from zero ($p=0.20$). The average number of Golden eagle fledglings per nest on all six study areas decreased significantly from 1.1 in 1980 to 0.6 in 1996, an annual decline of 3.5% ($p=0.025$). Figure 4 contains a graph of the Golden eagle fledgling numbers and estimated trend.

We estimate that the multi-mine average number of Swainson's hawk hatchlings per nest declined at an annual rate of 5.3% between 1981 and 1996 ($p=0.002$). We estimate that the average number of Swainson's hawk fledglings per nest declined at an annual rate of 6.1% from a high of 2.59 per nest in 1981 to a low of 0.96 per nest in 1996 ($p=0.001$). Figure 5 contains a graph of the Swainson's hawk fledgling numbers and estimated trend.

Lagomorph data only exist after 1990. When yearly trends in fledgling numbers are estimated between 1990 to 1996 without regard to lagomorph numbers, there appears to be a significant annual decrease in the number of Swainson's hawk and Ferruginous hawk fledglings per nest ($p=0.03$ and $p=0.002$ respectively). When yearly trends in fledgling numbers are estimated for the same time period taking into account the yearly average lagomorph counts, the trend in number of Swainson's hawk and Ferruginous hawk fledglings is still negative but it is not significantly different from zero ($p=0.56$ and $p=0.14$ respectively).

Figure 6 shows the count of sage grouse each visit to each of 7 leks. Fit separately, the estimated trend at all leks was negative and ranged from an annual decline of 61.4% to an annual decline of 6.8%.

4. Discussion

Based on our inspection of five mines out of approximately thirty in Wyoming, we suspect that the *quantity* of wildlife data state wide is adequate to meet most monitoring objectives and it is likely worthwhile pursuing analysis of this data. We are slightly apprehensive about the *quality* of wildlife data state wide. We feel that enough quality information existed in the five mines we studied to warrant entry and analysis, but if certain difficulties in the data from these five mines are ubiquitous throughout the state, analysis of the state wide data will be problematic. These difficulties relate to reporting of survey effort, survey area size, differences in reporting formats, and standardization of methods. We feel that the existing Appendix B will eventually yield data which are adequate to detect long term trends in wildlife populations via regression analysis. If Before-After-Control-Impact (BACI) analyses are desired, Appendix B will need to be modified to require collection of data on control areas.

We list recommended changes and/or enhancements to Appendix B which we feel should be considered the next time Appendix B is modified. We list our recommended changes from what we feel are the most important to the least important:

1. *Standardized reporting of wildlife data*: We recommend mines submit standardized raw data forms and electronic copies (dBase or text format) of all wildlife data, but very little text writeup.
2. *Standardized reporting of existing environmental and mining related variables*: We recommend key environmental and mining variables be reported alongside wildlife data.
3. *Regularly scheduled reports*: We recommend that either DEQ, WGFD, the mines, or an independent third party conduct analyses at regular intervals.
4. *Establish control areas*: We recommend establishing at least regional control areas.
5. *Replication*: If information is required on single mines, we recommend replication of certain surveys within year.
6. *Coordination:* We recommend that Appendix B provide more guidance on coordination by explicitly stating which surveys might be advantageously coordinated.

One goal of this study was to recommend a completion option for Phase 2 of the project. Options for completion of Phase 2 are the following: 1) startup of Phase 2 could be delayed several years until adequate standardized monitoring data were available; 2) Phase 2 could proceed by entering and analyzing all post-Appendix B data from all active coal mines in the state; 3) Phase 2 could enter and analyze selected baseline and monitoring data from all coal mines in the state; 4) Phase 2 could enter and analyze all baseline and monitoring data from all coal mines; and 5) data entry could be expanded outside the wildlife data of the five mines in Phase 1 to include variables such as vegetation, weather, distance to disturbance, etc. in an effort to get a more complete analysis of the Phase 1 data.

It is our professional recommendation that either completion option 3 or 5 be adopted.

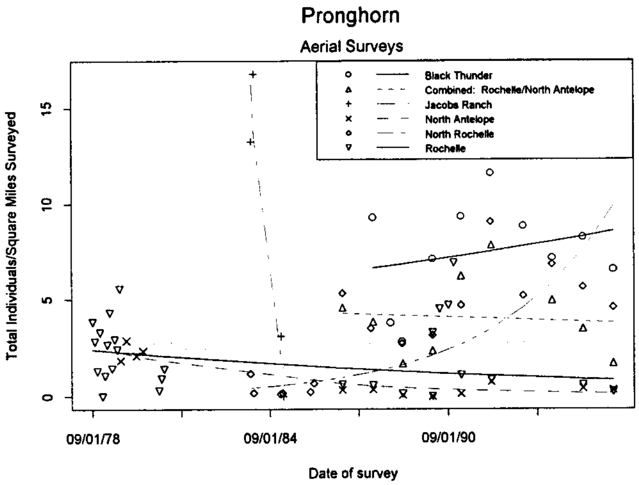

Figure 1. Pronghorn per square mile during aerial surveys. Significantly different trends in density index exist among mines ($p<0.0001$). $R^2 = 0.72$

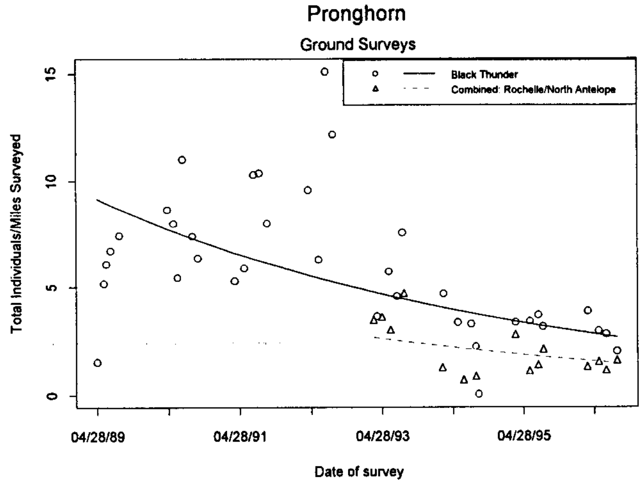

Figure 2. Pronghorn counts per mile of driving survey. Estimated annual change = -15.5% per year ($p=0.002$). $R^2 = 0.745$.

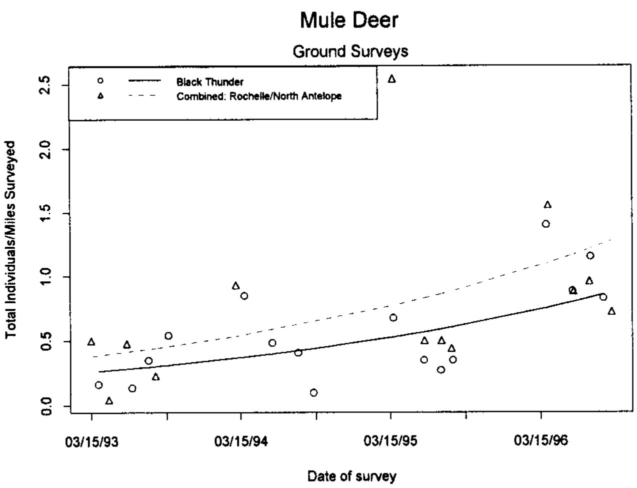

Figure 3: Mule deer counts per mile of driving survey. Estimated annual change = 41.8% per year ($p=0.158$). $R^2 = 0.346$.

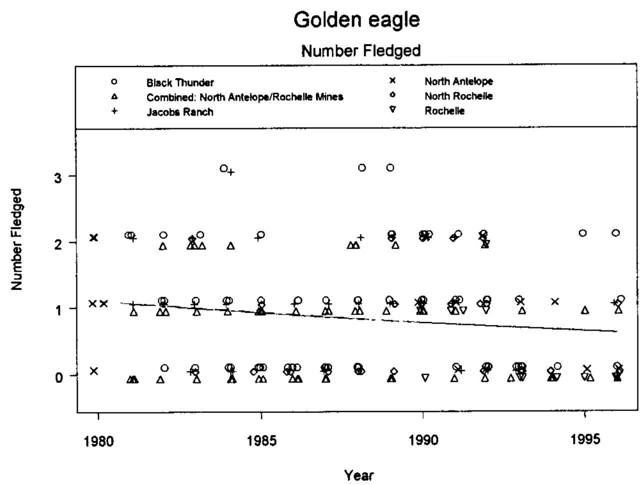

Figure 4. Number of golden eagle chicks fledged each year showing a significant annual decline of 3.5%. Counts are offset slightly to show overlapping points.

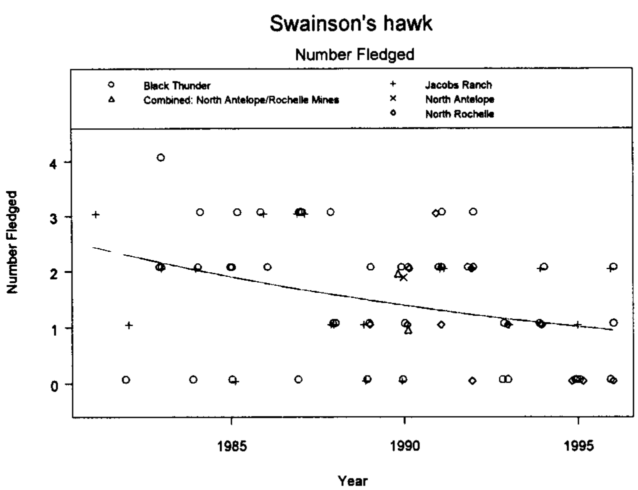

Figure 5. Number of Swainson's hawk chicks fledged per nest each year showing a significant annual decline of 6.1% ($p=0.001$). Counts are offset slightly to show overlapping points.

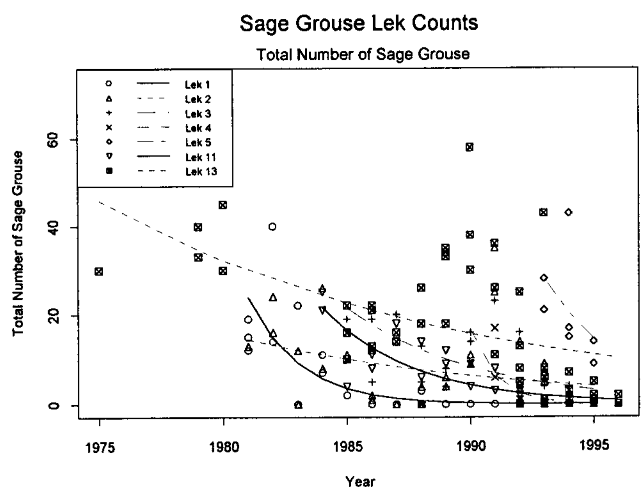

Figure 6. Total sage grouse attending known leks. Leks 1, 2, 3, 4, and 5 from Jacob's Ranch, lek 11 from Black Thunder, and lek 13 from Rochelle. Trends were significantly different across leks and all were negative.

CLIMATIC CONTROL OF SAGEBRUSH SURVIVAL FOR MINED LAND RECLAMATION

B. PERRYMAN, R. OLSON, A. HILD AND A. MAIER

University of Wyoming
Abandoned Coal Mine Land Research Program
Project Review Seminar
November 5, 1998 Gillette, WY

Climatic Control of Sagebrush Survival for Mined-Land Reclamation

Interim Progress Report

Principal Investigators:

B.L. Perryman, R.A. Olson, Ann L. Hild, and A.M. Maier

Introduction

Xerophytic shrubs such as big sagebrush (Artemisia tridentata) are a major component of rangeland throughout the western United States. Wyoming rangelands are no exception. Several species of shrubs are widely distributed across the state, and are often the dominant members of rangeland plant communities. Because of the almost ubiquitous presence of xerophytic shrubs and their importance to landuse strategies on Wyoming rangelands, regulatory agencies have legally mandated that shrubs be included in the reclaimed plant communities of disturbed mined-lands (Department of Environmental Quality, Land Quality Division: W.S. 35-11-112, Chapter IV, Appendix A, amended and approved by the Office of Surface Mining, August 1996). In most cases, the dominant shrub species present in baseline plant communities is big sagebrush. For this reason, big sagebrush is often the primary shrub involved in reclamation efforts.

Although big sagebrush is well adapted to the region when mature, establishment from seed has proven difficult. Problems with seedling establishment include: poor seed quality, low seedling vigor, failure to establish arbuscular mycorrhizal associations after disturbance, inability of cultural practices to meet microsite requirements, and the inability to compete with associated herbaceous vegetation. Even though establishment from seed has proven at best difficult, the fact remains that native, mature stands of big sagebrush occur on millions of hectares of surrounding undisturbed rangelands. Several researchers have indicated that the age class structure of big sagebrush stands is characterized by the existence of cohorts, and that there may be many years in between the establishment of successful cohorts. That is to say, cohorts are established in pulses. Since cohort establishment is episodic, there must be a control mechanism that is responsible for recruitment, persistence, and establishment success. A literature search suggests that climate (specifically amount and timing of precipitation, and temperature range) is the major controlling factor.

Implications

First, if a specific set of climatic conditions controlling cohort success can be elucidated, reclamation efforts such as cultural practices and the design of microsites can be concentrated in areas that offer a greater chance for success. Acreage scheduled for shrub stands can be identified and targeted to mimic the required climatic conditions, optimizing the use of resources by allowing reclamation specialists to focus their establishment efforts in a specific direction. Reclamation specialists will have a known, understood, and measurable target set of climatic conditions.

Secondly, the project will demonstrate the frequency with which these precise climatic conditions occur. It is highly possible that optimum or threshold conditions may only occur a few times a century on any given site. If threshold conditions are infrequent, planting big sagebrush each year on large acreages may not be an efficient use of resources. Identification of the threshold climatic conditions may eventually lead to a method of predicting success based on extended weather forecasts.

Study Objective

The objective of the project is to quantitatively evaluate the relationship of native big sagebrush cohort success, and monthly precipitation and temperature variables. The project will be conducted over a two year period and include all three subspecies of big sagebrush (Artemisia tridentata wyomingensis, A. tridentata vaseyana, and A. tridentata tridentata). The results will be applicable throughout the coal mining regions of Wyoming.

Statement of Work

The major parts of the research are:

Task 1) Collect shrub stem sections for three subspecies of big sagebrush from a network of sites containing native sagebrush stands.

Task 2) Determine cohort establishment years and age class frequencies utilizing dendrochronology techniques.

Task 3) Collect and summarize climate data from weather stations throughout Wyoming.

Task 4) Relate cohort origin years to climate data with the logistic regression model.

Work Completed To Date

Acceptable sample sites were identified during June 1997. Selection was based on location near (or triangulated between) National Weather Service climate recording stations, and on the presence of a least three different cohorts. The assessment of cohort presence was based on size class of sagebrush plants within a particular stand. A random sampling design using a baseline transect was employed to select individual plants for sampling. Seventy-five stem sections were taken from nine stands of each subspecies during the summer and fall of 1997 (2025 stem sections). Stem sections were removed by cutting each plant below ground level to ensure that the first year growth ring was included in the sample. Supplemental data including topography, aspect, shrub density, and soil texture were also collected for each stand. Annual growth-ring counts have been completed for all stands. The age of 2025 individual plants has been determined.

Collection of climatic data has been completed (18 weather stations) and is held in both hard copy and electronic forms. These data have been appropriated from the Wyoming Water Resources Data System (WRDS). Many of the climatic series begin in the 1940s while several stations contain records back into the early 1900s. All of the selected stations contain monthly precipitation and mean, high, and low temperature records.

Preliminary Results

Annual growth-ring counts for individual stem sections in each stand indicate the presence of distinct cohorts, with several to many years in between cohort establishment. Stands of A. tridentata wyomingensis in the Powder River Basin contain 6 strong age classes that are 6, 16, 19, 23, 27, and 34 years old. The oldest plant sampled in this region was 75 years old. Similarly, stands of A. tridentata wyomingensis near Casper, WY and Pinedale, WY contain distinct cohorts. The 6-, 19-, and 34-year-old cohorts in the Powder River Basin are also found near Casper. Three stands of wyomingensis near Pinedale contain a large, 63-year-old cohort. Sampling did not find similar cohorts between Pinedale, and Casper and the Powder River Basin. Age sampling within nine stands of A. tridentata vaseyana and nine stands of A. tridentata tridentata identified distinct cohorts shared by these subspecies. Strong 12-, 19-, and 50-year-old cohorts were present in the mountain big sagebrush stands. Strong 8-, 24-, and 27-year-old cohorts were present in the basin big sagebrush stands. The presence of cohorts or age classes shared between stands and subspecies that are spatially distant from one another further indicate that climate may be responsible for variation in age-class frequencies. Successful recruitment in native, undisturbed stands occurs infrequently. Logically, we can expect that big sagebrush seedlings planted on mined-lands will follow the same climatic recruitment patterns as native sites.

Work to Be Completed

Cohort and climate data have been placed in spreadsheet format. Climate data will be used in a nominal logistic regression utilizing the categorical variables, "successful seedling year" and "unsuccessful seedling year." The purpose of this procedure will be to examine the variance explained by one or more months of temperature or precipitation occurring before, during, or after the year of cohort establishment. A nominal logistic regression model will be generated for each subspecies by stand, regional, and statewide distribution.

A final executive summary will be presented in one year. Correlations between climate data and cohort origin years will be included in the report. The specific climatic conditions responsible for big sagebrush seedling recruitment and survival in native stands will be identified. Reclamation specialists will be able to use these data as recommended criteria for reestablishing big sagebrush on mined-lands in Wyoming.

Publications

Maier, A.M, B.L. Perryman, R.A. Olson, and Ann L. Hild. 1998. Climatic influences of big sagebrush recruitment and survival. Abstracts 1998 Meeting, Society for Range Management.

Perryman, B.L. and R.A. Olson. 1998. Implications of age-stem diameter relationships for ecologically based management of big sagebrush.

Abstracts

1998 Meeting, Abandoned Coal Mine Land Research Program.

GRASS COMPETITION AND SAGEBRUSH SEEDING RATES: INFLUENCE SAGEBRUSH SEEDLING ESTABLISHMENT

G. SCHUMAN, A. HILD

Grass Competition and Sagebrush Seeding Rates: Influence on Sagebrush Seedling Establishment

Interim Report to the ACMLRP
11/5/98

G.E. Schuman
A.L. Hild
Mary Fortier
Laurel Vicklund

High Plains Grasslands Research Stn.
USDA, ARS
Cheyenne, WY 82009

Department of Renewable Resources
University of Wyoming
Laramie, WY 82071

Amax Coal West Inc.
Belle Ayr Mine
Gillette, WY 82717

Introduction

Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is widespread across the West; and common throughout the Wyoming Basin, across the Continental Divide and east to the Black Hills (Beetle and Johnson 1982). Effective August 1, 1996, the mining industry is required to re-establish this species where it is the dominant shrub species prior to disturbance and where wildlife habitat is the key postmining land use (Wyoming DEQ 1996).

Two approaches, transplantation of greenhouse grown seedlings and direct seeding, can be used to achieve the required shrub density required by enactment of the recent shrub density standard. Direct seeding is the more desirable alternative; however, Wyoming big sagebrush has often proven difficult to establish from seed. Problems of establishing big sagebrush from seed include low seedling vigor, poor seed quality, and it inability to compete with herbaceous species (Frischknecht 1978 and Schuman et al. 1998). Seeding methods and soil quality have also been identified as factors relating to poor seedling establishment of big sagebrush (Monsen and Myers 1990 and Stahl et al. 1988). However; recent research by Schuman et al. (1998) and Stahl et al. (1998) have addressed several of these factors in the establishment of Wyoming big sagebrush on mined lands. Schuman et al. (1998), in research funded by the ACMLRP, found that big sagebrush seedling densities required by law can be achieved through the proper use of cultural practices. Schuman et al. (1998) found that grass seeded concurrently with the big sagebrush had the single greatest negative effect on sagebrush seedling establishment. Other research associated with this study showed that direct placed topsoil also resulted in significantly greater seedling densities within the first year (Stahl et al. 1998). They found that seedlings grown on fresh topsoil had significantly greater AM (arbuscular mycorrhizae) infection than those grown on topsoil that had been sterilized to remove the AM and that the infected seedlings exhibited greater drought tolerance than the non-AM seedlings.

Since herbaceous competition has been shown to be a critical factor in the successful re-establishment of big sagebrush on mined lands, research is needed to assess the level of herbaceous competition that can be tolerated by big sagebrush seedlings without reducing their establishment below the density required by recent shrub density standards.

Research Objectives

This study is designed to (1) assess the effects of several levels of herbaceous competition on Wyoming big sagebrush establishment, and to (2) assess the role of sagebrush seeding rate on sagebrush seedling density. This research will be accomplished in cooperation with Laurel Vicklund, Environmental Engineer, Amax Coal West, Inc. And will utilize a stubble mulch and direct placed topsoil. The study is located at the Belle Ayr Mine, Amax Coal West, Inc. near Gillette, WY.

Study Treatments and Implementation Plan

Specific treatments include: (1) grass seeding rates of 0, 2, 4, 6, 8, 10, and 14 kg PLS/ha and (2) sagebrush seeding rates of 0, 2, and 4 kg PLS/ha. These treatments will allow us to evaluate the effects of herbaceous competition and sagebrush seeding rates on sagebrush seedling establishment and the possible interaction between herbaceous competition and sagebrush seeding rate. The herbaceous competition will be created by seeding a mixture of western wheatgrass, slender wheatgrass and thickspike wheatgrass at the 7 seeding rates noted above. The study design will be a randomized block design with four replicate blocks. Each sagebrush by herbaceous treatment subplot will be 6 by 9 m. Six, 1m^2 quadrats will be established in each subplot prior to any plant emergence to assess grass and sagebrush seedling densities. Seedling counts will be accomplished four times in 1999 (first growing season) and three times in 2000 (second growing season).

Statement/Schedule of Work

The plots will be established on a 36 ha area that is being reclaimed by Amax Coal West, Inc. at the Belle Ayr Mine near Gillette, WY.

Task 1. Plot area located and delineated within large reclamation site seeded to barley--Summer of 1998.

Task 2. Grass competition treatments seeded in November/December 1998 as dormant seeding Sagebrush overseeded on grass seeding in January/February 1999.

Task 3. Establish and mark permanent quadrats--April 1999.

Task 4. Assess grass and sagebrush seedling densities--June, July, August and October 1999. Assess soil moisture and temperature at biweekly intervals within each block--April through September 1999.

Task 5. Assess sagebrush seedling densities in June, August and October 2000 and soil moisture and soil temperature biweekly--April through August, 2000.

Task 6. Initialize data summarization and analysis--October 2000

Task 7. Complete summarization and analysis of data and preparation of thesis--January through May 2001.

Task 8. Prepare Final Report of Project.

Progress Report

The field plots have been delineated and the grass competition treatments will be seeded within the next 30 days. A graduate research assistant has been selected, Mary Fortier. Mary comes to the University of Wyoming from Central Washington University and has experience in native vegetation ecology. Mary has started her course work toward the M.S. degree in Renewable Resources and will be working with us to collect all data associated with this project. She will also be working as an intern with Laurel Vicklund during the summers learning the many aspects of the reclamation and environmental responsibilities associated with mining. No data has been collected to-date.

Literature Cited

Beetle, A.A. and K.L. Johnson. 1982. Sagebrush in Wyoming. Wyo. Agr. Exp. Stn. Bull. 779, University of Wyoming, Laramie.

Frischknecht, N.C. 1978. Use of shrubs for mined land reclamation and wildlife habitat. p. 113-129. In: Reclamation for Wildlife Habitat. Ecol. Consult. Inc., Fort Collins, CO.

Monsen, S.B. and S.E. Meyer. 1990. Seeding equipment effects on establishment of big sagebrush on mine disturbances. p. 192-199. In: Proc., Fifth Billings Symposium on Disturbed Land Rehabilitation. Vol. 1., Reclamation Research Unit, Publ. No. 9003. Montana State University, Bozeman.

Schuman, G.E., and D.T. Booth, and J.R. Cockrell. 1998. Cultural methods for establishing Wyoming big sagebrush on mined lands. J. Range Manage. 51:223-230.

Stahl, P.D., G.E. Schuman, S.M. Frost, and S.E. Williams. 1998. Interaction of arbuscular mycorrhiza and seedling age on water stress tolerance of *Artemisia tridentata* ssp. *wyomingensis.* Soil Sci. Soc. Am. J. 62: In press.

Wyoming Department of Environmental Quality, Land Quality Division. 1996. Coal rules and regulations, Chapter 4, Appendix A, State of Wyoming, Cheyenne, WY.