

A Chronosequence Feasibility Assessment of Emergency Fire Rehabilitation Records within the Intermountain Western United States—Final Report to the Joint Fire Science Program – Project 08-S-08

Open-File Report 2009-1099

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By Kevin C. Knutson, David A. Pyke, Troy A. Wirth, David S. Pilliod, Matthew L. Brooks, U.S. Geological Survey, and Jeanne C. Chambers, U.S. Forest Service

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Conversion Factors and Acronyms

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)

Acronyms

BAR	burned area rehabilitation
BLM	U.S. Bureau of Land Management
DOI	U.S. Department of the Interior
ES	emergency stabilization
ESR	emergency stabilization and/or burned area rehabilitation
LTDL	Land Treatment Digital Library
MLRA	major land resource areas
USDA NCRS	U.S. Department of Agriculture Natural Resource Conservation Service
USGS	U.S. Geological Survey

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Executive Summary

Department of the Interior (DOI) bureaus have invested heavily (for example, the U.S. Bureau of Land Management (BLM) spent more than \$60 million in fiscal year 2007) in seeding vegetation for emergency stabilization and burned area rehabilitation of non-forested arid lands over the past 10 years. The primary objectives of these seedings commonly are to (1) reduce the post-fire dominance of non-native annual grasses, such as cheatgrass (*Bromus tectorum*) and red brome (*Bromus rubens*); (2) minimize the probability of recurrent fire; and (3) ultimately produce desirable vegetation characteristics (for example, ability to recover following disturbance [resilience], resistance to invasive species, and a capacity to support a diverse flora and fauna). Although these projects historically have been monitored to varying extents, land managers currently lack scientific evidence to verify whether seeding arid and semiarid lands achieves desired objectives. Given the amount of resources dedicated to post-fire seeding projects, a synthesis of information determining the factors that result in successful treatments is critically needed.

Although results of recently established experiments and monitoring projects eventually will provide useful insights for the future direction of emergency stabilization and burned area rehabilitation programs, a chronosequence approach evaluating emergency stabilization and burned area rehabilitation treatments (both referenced hereafter as ESR treatments) over the past 30 years could provide a comprehensive assessment of treatment success across a range of regional environmental gradients. By randomly selecting a statistically robust sample from the population of historic ESR treatments in the Intermountain West, this chronosequence approach would have inference for most ecological sites in this region.

The goal of this feasibility study was to compile and examine historic ESR records from BLM field offices across the Intermountain West to determine whether sufficient documentation existed for a future field-based chronosequence project. We collected ESR records and data at nine BLM field offices in four States (Oregon, Idaho, Nevada, and Utah) and examined the utility of these data for the development of a chronosequence study of post-fire seeding treatments from multiple sites and different ages (since seeding) throughout the Intermountain West. We collected records from 730 post-fire seeding projects with 1,238 individual seeding treatments. Records from each project ranged from minimal reporting of the project's occurrence to detailed documentation of planning, implementation, and monitoring. Of these 1,238 projects, we identified 468 (38 percent) that could potentially be used to

implement a field-based chronosequence study. There were 206 ground-seeding treatments and 262 aerial-seeding treatments within this initial population, not including hand plantings. We also located a considerable number of additional records from other potential field offices that would be available for the chronosequence study but have yet to be compiled for this feasibility report.

There are a number of potential challenges involved in going forward with a field-based chronosequence study derived from data collected at these nine BLM offices. One challenge is that not all seed mixtures in ESR project files have on-the-ground confirmation about what was sown or rates of application. Most projects, particularly records before 2000, just list the planned or purchased seed mixtures. Although this could potentially bias assessments of factors influencing establishment rates of individual species for treatments conducted before 2000, a chronosequence study would not be intended to assess success solely at the species-level. Treatment success would be evaluated based on the establishment of healthy vegetation communities, such as the abundance and density of perennial species, regardless of their lifeforms (grasses, forbs, and shrubs) or their origin (native or introduced), relative to invasive annual grasses. A secondary challenge is that most seeding projects conducted before 1999 on either BLM or U.S. Forest Service lands had little monitoring information available compared to more recent projects. Although a chronosequence study would benefit from comparing current vegetation metrics to those collected immediately following the treatments, this may not always be possible. A preference would be placed on those projects with post-treatment monitoring documentation, but this is not absolutely necessary for success of the chronosequence approach. Finally, post-fire management of fire rehabilitation treatments can have significant effects on the condition and persistence of seeded vegetation. Information on post-fire management of treatment areas after the first 2 years largely is lacking in our present dataset. These data would need to be collected for study sites selected for a field-based chronosequence study. Given these caveats, there is still a sufficient population (at least 468) of well-documented post-fire seeding treatments from which to sample and conduct a robust chronosequence analysis of treatment success for the Intermountain West.

In a potential chronosequence study, the population of projects would be stratified into meaningful categories for distinguishing potential thresholds for seeding. The random-stratified sample of treatments that would be reassessed would be drawn from this population. These categories would include precipitation zones (low, <8 in.; medium, 8 to <12 in.; and high >12 in.), major land resource areas (similar to ecoregions, but related hierarchically to soil mapping units and ecological sites; for example, Snake River plains, Malheur high plateau), and timing of seeding (fall, winter, or spring). Once projects to revisit are identified, field sampling would be completed within previously seeded and unseeded areas with the same soils and climate (ecological site) to determine current vegetation and soil stability conditions. For sites with documented ecological site descriptions (as defined by the U.S. Department of Agriculture Natural Resource Conservation Service, the current interagency standard), these site descriptions could provide suggested relative dominance (cover or production) by species for life forms. These descriptions also would be used as a potential standard for comparisons in treated areas. Each site would be characterized according to topography, soils and pre- and post-treatment precipitation. Potential response variables measured at each study site would examine fuel loads and composition (relative cover or production) of all plant species grouped into meaningful categories such as shrub, grass, forb, native or introduced, or invasives. Abiotic response variables, such as surface cover of bare ground and litter, also would be collected. Data on natural variation (for example, post-treatment weather) and land-management activities (for example, livestock and wild horse herd management data) would be used as covariates in analyses. A study design that incorporates gradient analyses via multivariate statistics most likely would be the best approach for the chronosequence investigation.

Table 1 summarizes the products developed for this chronosequence feasibility study. A full and complete study design will be submitted for peer review and evaluation should the Joint Fire Science Program Board request it for potential funding.

Table 1. Crosswalk between proposed and delivered chronosequence feasibility study activities as outlined in the study proposal, April 30, 2008.

Proposed	Delivered	Status
Draft Feasibility Report	Draft Feasibility Report – Feb. 23, 2009	Submitted
Final Feasibility Report	Current Report	Submitted
Database	Land Treatment Digital Library with all ESR records collected from feasibility study	In Review

Introduction

Department of the Interior (DOI) bureaus, particularly the Bureau of Land Management (BLM), have invested heavily in emergency stabilization (ES) and burned area rehabilitation (BAR) of non-forested arid lands over the past 10 years (Government Accountability Office, 2003). The BLM obligated more than \$60 million in post-fire emergency stabilization during fiscal year 2007, with more than \$50 million of this invested in seeding native and non-native perennial grass species within the Great Basin, Mojave, and Sonoran Deserts. The primary objectives of these seedings commonly are designed to (1) reduce the post-fire dominance of non-native annual grasses, such as cheatgrass (*Bromus tectorum*) and red brome (*Bromus rubens*); (2) minimize the probability of recurrent fire; and (3) ultimately produce desirable vegetation characteristics (for example, ability to recover following disturbance [resilience], resistance to invasive species, and a capacity to support a diverse flora and fauna). Although these projects historically have been monitored to varying extents, land managers currently lack scientific evidence to verify whether seeding arid and semiarid lands effectively achieves the desired objectives. Current projects are usually funded for an initial monitoring period of 3 years (Robichaud and others, 2000; Government Accountability Office, 2003; Beyers, 2004), which may be too short when project success typically is determined by the establishment of mature, perennial grasses.

Several fully replicated perennial reseeding experiments recently have focused on the restoration of arid lands (for example, Allcock and others, 2006). Extensive ES and BAR (hereafter, ESR) project monitoring efforts from recent fires (since 2005) also have begun or are being planned (Wirth and Pyke, 2007; M.L. Brooks, Southern Great Basin, Eastern Colorado Plateau, and Mojave Desert, oral commun., December 2008; J.C. Chambers, T.A. Forbis, and E.A. Leger, north-central Great Basin, oral commun., December 2008; L.A. DeFalco, Mojave, oral commun., December 2008). These projects primarily are focused on perennial plant seedings that may take more than 3 years to achieve their desired results (for example, establish robust vegetation stands that are expected to compete with and reduce the dominance of non-native annuals). The timeframe necessary to achieve desired results often is beyond the scope of most experiments or ESR monitoring efforts. In time, these research and monitoring investigations will yield sufficient data to reduce the information gap that land managers face regarding success of fire rehabilitation treatments, but also will require a long-term monitoring commitment that is often difficult to support. Even if these current monitoring projects do result in the necessary long-term data to determine why seeding treatments succeed or fail, the conclusive findings will not be available for 10 years or more.

Although the results of recently established experiments and monitoring eventually will provide useful insights for the future direction of ESR programs, a chronosequence approach that evaluates which ESR treatments have been successful over the past 30 years could provide a comprehensive assessment about which treatments work where and under what range of environmental conditions. The chronosequence approach commonly has been used in forestry to understand various ecological phenomena including successional changes, woody decay patterns, or fine root dynamics over time following vegetation treatment and disturbance (Pyke and Zamora, 1982; Everett and others, 1999; Idol and others, 2000), but this study approach rarely has been used in rangeland ecosystems. By randomly selecting a statistically robust sample from the population of historic ESR treatments in the Intermountain West, this chronosequence approach would have inference for most ecological sites in this region. The overall objective we would like to achieve in a field-based chronosequence investigation would be to describe current vegetation conditions in previous ESR treatment areas at different ages after seeding to assess short and long-term recovery. To address this objective, we would compare (1) the establishment of seeded species; (2) dominance of cheatgrass, red brome, or other non-native annual plants that promote recurrent fire; (3) vegetation stand characteristics related to resilience, resistance to invasive species, and capacity to support a diverse flora and fauna (for example, sagebrush endemic species); (4) fuelbed characteristics, potential fire behavior, and actual fire occurrences; and (5) the use of seeded areas by selected wildlife species (that is, reptiles, small mammals, birds, ungulates) relative to the surrounding landscape.

Although a chronosequence approach to examine past ESR treatments potentially can improve the knowledge base associated with success or failure of reseeding projects, this approach also may present significant challenges. Although the BLM has monitored projects since about 1980, the use of disparate monitoring techniques and a lack of documentation of monitoring results or data in older projects (2000 and prior) have been noted previously (Pyke and McArthur, 2002). McArthur (2004) attempted to find locations in ESR projects in excess of 5 years where monitoring plots could be resampled and the same monitoring techniques repeated to compare short- and long-term effects of recovery. However, in eight BLM field offices, only five sites met his criteria. Although the McArthur (2004) study may have been too restrictive in its requirements (for example, it required being able to relocate monitoring sites), it exemplifies the potential difficulty in locating suitable older projects for resampling. We therefore felt it was first prudent to collect data from previous ESR projects during the time span of interest to evaluate the quality of information (for example, locations of projects, seed mixture lists, monitoring data or reports) that would be available for a more detailed and field-based chronosequence study. In this feasibility study, we collected ESR records and data at several BLM field offices during the summer and fall of 2008 and then examined the capacity to use these data for the development of a temporally and spatially balanced chronosequence study of post-fire seeding treatments from multiple locations and different ages (since seeding) throughout the Intermountain West.

Methods

Data Collection

Before the collection of field office records, BLM State ESR coordinators in Idaho, Utah, Oregon, and Nevada were interviewed to determine field offices that might yield extensive, high-quality ESR datasets. The main criterion for office visits was the occurrence of large numbers of ESR projects in the past 30 years. After field office selection, BLM personnel at those offices were notified of our project and approximately 1 week was scheduled for a visit. From one to three offices in Idaho, Utah, Nevada, and Oregon were visited from January to October 2008 (offices visited from January until May were associated with related projects).

One to two investigators met with BLM ESR and geographic information systems (GIS) personnel at each field office to become familiar with their archived ESR files and electronic data storage records. For each ESR project, all information available at the time of the visit was processed and collected. Projects implemented from 1999 onwards generally were available in digital format and were transferred to a portable hard drive. Hardcopy data from projects before 1999 or 2000 were electronically scanned to create a digital image of these projects. Spatial data related to ESR projects (fire and ESR project locations, fire frequency, ignition points, and trend or monitoring plot locations) were digitally transferred to portable hard drives.

Investigators evaluated each ESR project for the following information for an ESR chronosequence study: (1) pre-fire vegetation characteristics (for example, rangeland assessment reports, trend plot photographs or data); (2) fire data (for example, fire reports, burn severity mapping, post-fire vegetation mapping); (3) site preparation and seeding techniques, seeding rates, specific seed species mixture data, and location of seeded areas; (4) implementation data that described specifically when seedings occurred and any problems with application; and (5) post-seeding land-use management and vegetation monitoring data. Although each project rarely met all these requirements, as much data as possible related to ESR project and potential project success was extracted during the limited duration of the visit.

Data Consolidation and Review

Digital files and images of ESR projects were examined after field office visits, and data were entered in the Land Treatment Digital Library (LTDL), a database designed with robust query functions for digitally archived land treatment records. ESR documents retrieved during field office visits were examined for critical information necessary for implementation of a future ESR chronosequence project, and digital files also were hyperlinked within the LTDL database. The major on-the-ground objectives and treatments used in each project were identified and recorded, and spatial data (fire perimeter and/or treatment GIS polygons) for each project also was entered when available. If GIS digital data were not available for project spatial information, then hard copy data (for example, treatment or fire maps) scanned from the project files were hand-digitized and hyperlinked. This ensured that all spatial data were available at a later time for potential field investigations. Project documents were examined for seed mixtures related to seeding treatments and it was determined if the mixture represented a confirmed on-the-ground mixture versus a planned mixture; this is a common problem in ESR projects before 1999 (General Accounting Office, 2003). While planned seed mixtures are a valuable source of information, on-the-ground mixtures are preferred since planned mixtures are often changed based on seed availability. Hand plantings of seedlings also were recorded, and species mixtures for these

treatments were entered into the LTDL when available. When information (point photographs, density data, reports) related to ESR effectiveness monitoring was found, the project was recorded as monitored within the LTDL. All monitoring data from trend plots, monitoring locations, or other areas used to assess seeding goals were entered or hyperlinked in the LTDL to the appropriate file.

ESR projects entered into the LTDL prior to January 31, 2009, were queried to determine the types and quality of critical ESR chronosequence information available for an ESR chronosequence study. ESR projects were evaluated for three time periods (1980–89, 1990–99, and 2000–2007) to evaluate the temporal balance and consistency of the data. Critical information included the number of projects that had a plan, seeded species mixture data (planned or confirmed), effectiveness monitoring data, and associated spatial data for the project. Project polygons readily available within the LTDL also were used to determine the primary major land-resource areas (MLRAs) of ESR reseedings. MLRAs are similar to ecoregions, but related hierarchically to soils and ecological sites also described by the U.S. Department of Agriculture Natural Resource Conservation Service (USDA NRCS). Results presented were limited to MLRAs with at least 15 ESR seedings. All data were tabulated and graphed using SigmaPlot version 10.0 to visually evaluate the available information.

Results

To date, records from 730 ESR projects at nine BLM field offices in Idaho, Oregon, Utah, and Nevada were retrieved and entered into the LTDL (table 2, fig. 1). Typical documents that were often found associated with each project included fire rehabilitation planning documents (ESR plans, documentation of NEPA adequacy, and environmental assessments), follow-up project implementation reports (contract diaries, end of year reports, and implementation summaries), and monitoring documentation (data, photographs, or summary reports). Projects examined also often contained burned area assessments or fire reports that were prepared after the fire containment date.

For ESR seedings identified in these 730 projects, most included planning documents (89.9 percent) and also included post-seeding end-of-year reports or project summaries (64.7 percent). Verifiable monitoring documentation was recovered for 33.9 percent of the seeding treatments. A total of 1,238 actual seedings or plantings were found in the 730 ESR projects, with many projects having multiple treatments (for example, drill seed in combination with aerial seeding or drill seedings with different seed mixes). The most frequent application method was aerial seeding (45 percent of all seedings found, 63 percent of all acres treated). Drill seedings represented 37 percent (32 percent of all acres treated) of all fire rehabilitation seedings that were identified. Ground-based broadcast seedings and unidentified methods accounted for 8.6 percent of treatments (4 percent of acres treated) and hand plantings and seedings without information on the application method accounted for the remaining seedings (table 3).

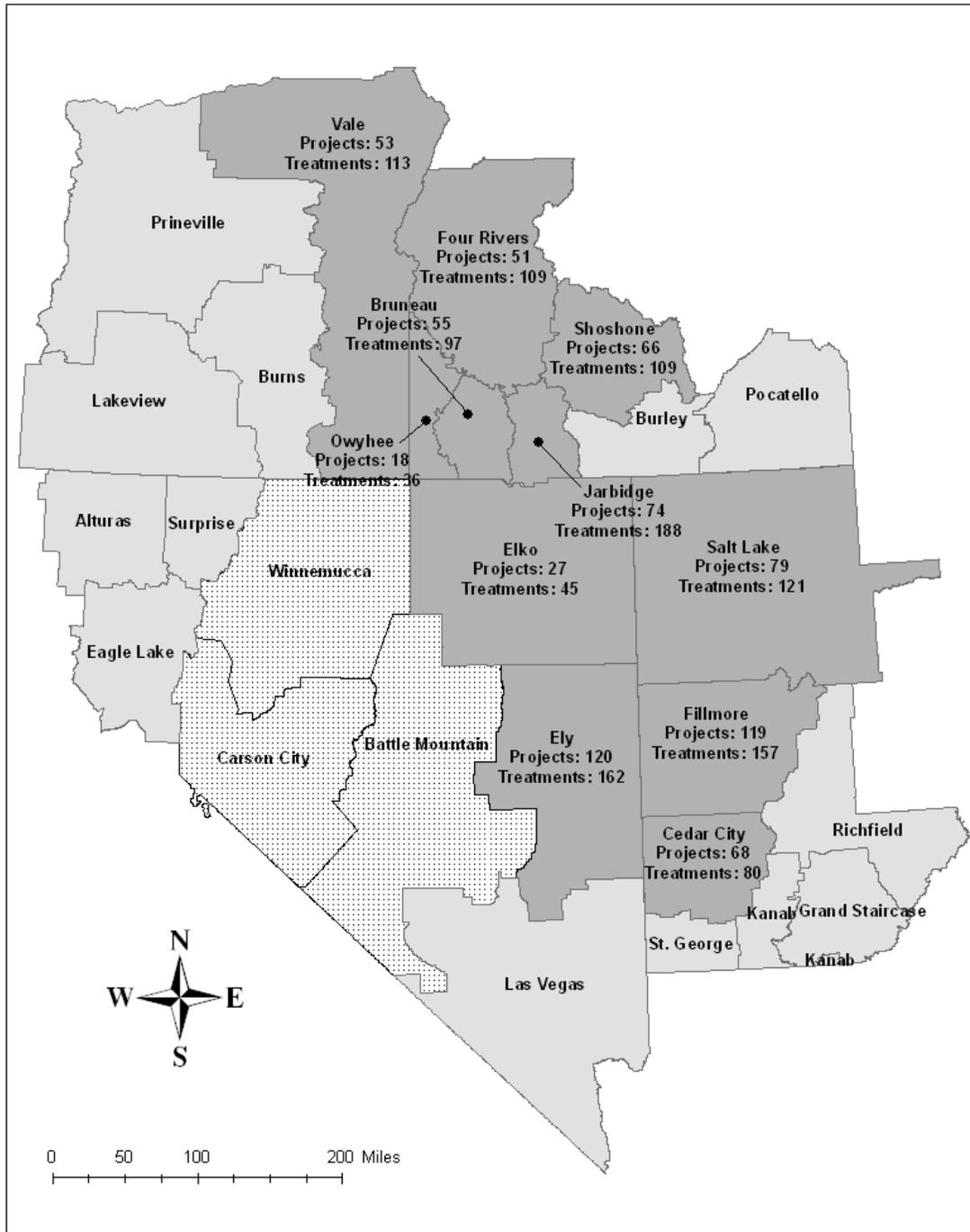


Figure 1. Location of BLM resource units where ES and BAR records were collected in the Intermountain West (dark gray), units where data has been identified but not yet compiled (stippled), and potential units where no data have been collected at this point in time (light gray).

Table 2. The BLM offices visited during January–October 2008 and the number of ESR projects identified.

[The number of seeding projects represents project files examined at each office that also had a minimum of one ESR/BAR reseeding. Number of seeding treatments represents the number of ESR treatments after accounting for multiple treatments in each project file]

State	Field office	Number of seeding projects	Number of seeding treatments
Idaho	Boise/Bruneau	55	97
	Boise/Four Rivers	51	109
	Boise/Owyhee	18	36
	Shoshone	66	130
	Twin Falls/Jarbridge	74	188
Nevada	Elko	27	45
	Ely	120	162
Oregon	Vale	53	113
Utah	Cedar City	68	80
	Fillmore	119	157
	Salt Lake	79	121

Table 3. Summary data of the number of projects sampled, documents and data found associated with projects, and the types and acreages of on-the-ground seeding projects available for a chronosequence study.

Summary feature of data collected	Quantity	Area (acres)
Total projects examined and sampled	730	
Number of treatments ¹	1,238	
Aerial seedings	562	1,910,791
Drill seedings	459	982,212
Broadcast/Other seedings ²	106	120,327
Hand plantings of seedlings ³	112	NA
Number of treatments with an identified plan	1,113	
Number of treatments with summary or end of year reports	801	
Number of treatments with documented effectiveness monitoring	420	
Number of with project shapefiles or other GIS data	1,059	

¹Each project typically had multiple treatments. This number includes only seeding treatments (aerial, drill, broadcast/other, or hand planting) found associated with each project and does not include other types such as check dams or fencing also specified as treatments in ESR planning.

²This category includes non-aerial broadcast seedings (for example, broadcast from ATV or fertilizer spreader) and seedings where the method was not clear but a known seeding was detected (for example, when a project had no planning documentation but a seeding clearly occurred from seed reports or monitoring documents).

³Hand plantings rarely had accurate figures for acreages and typically were described only in terms of the number of seedlings planted.

ESR project files found at the nine agency offices spanned the years 1980 through 2007 (fig. 2A). From 1980 to 1993, the average number of projects per year was 12. In 1994, the average number of projects increased sharply (fig. 2A). Most files that were examined contained a project planning document and geospatial data (fig. 2B-2C), and this finding generally was consistent across the time frame of the study. Project files examined before 2000 typically did not have accessible monitoring documentation associated with the files (fig. 2D), whereas most project files since 2000 included some monitoring data. Percentage of projects with accessible monitoring data in the 1980–99 time period ranged from 0 to just more than 50 percent on an annual basis (fig. 2D). Most projects in nearly all years included some sort of seed species mixture data used in treatments (fig. 2E).

Projects were tabulated according to State, seed mixture information, and monitoring status (table 4) by decade to determine which areas had the largest amount of information over time. In Idaho, project seed mixtures before 1990 included confirmed and planned seed mixtures, and 40 percent of these reseedings were monitored. Available monitoring documentation in Idaho decreased to 20 percent of projects found during the 1990s, and 54 percent of these projects had confirmed seed mixtures during this time period. The largest number of projects with implemented seed mixtures and monitoring documentation for Idaho were found in 2000–2007 (table 4). At Nevada offices, most projects examined were recent. Of the most recent projects (2000–2007), 66 percent had confirmed seed mixtures and monitoring documentation. Seeding project records from the Vale, Oregon office were predominantly recent (table 4). Only six ESR reseedings with confirmed seed mixtures were identified before 2000 in Oregon (table 4). Most Vale projects from 2000 to 2007 were monitored (71 percent, table 4). Similarly, few Nevada projects in the 1980s ($n = 20$) or 1990s ($n = 34$) had available records compared to the most recent decade ($n = 127$, table 4). Projects examined in Utah were dispersed more evenly in the 1980–2007 time period (table 4). Similar to other States, monitoring was most prominent in the recent decade, but there were a reasonable number of monitored projects from prior decades as well (table 4).

There were more than 400 aerial seedings and approximately 400 drill seedings with some type of documented confirmed or planned seed mixture (fig. 3). Most aerial and drill seedings before 2000, however, were based on planned mixtures and were not monitored, or monitoring information was not available (fig. 4). Of the project files analyzed, aerial seedings between 2000–2007 had the largest number of confirmed seed mixtures with available monitoring information (fig. 4A), and more than 100 seedings were identified that met this criteria. Aerial seeding data from 2000 to 2007 primarily included monitored projects with either a planned or a confirmed seed mixture available (fig. 4A). Aerial projects from the 1980s and 1990s tended to be fewer in number and had fewer monitoring documents available (fig. 4A). Drill seedings displayed a similar pattern to aerial seedings in terms of relative trends in monitoring documentation over time (fig. 4B). There were a reasonably large number of recent (2000–2007) drill seedings with both confirmed seed mixtures and monitoring (fig. 4B). Although the availability of monitoring information was not consistent across the entire period of interest, monitored aerial and drill seedings associated with ESR projects having either a planned or confirmed seed mixture were found in all decades (figs. 4A-4B).

The primary MLRAs of ESR projects evaluated included the Snake River plains, Owyhee Plateau, Great Salt Lake area, and the central Rocky and Blue Mountain foothills (fig. 5). More than 50 projects were identified within each decade in the Snake River plains MLRA. Owyhee High Plateau, Great Salt Lake, and central Rocky and Blue Mountain Foothills had substantial numbers of projects in the 1990s and after 2000 (fig. 5). The locations of primary MLRAs containing the most seeding projects corresponded with the offices visited (figs. 1 and 6).

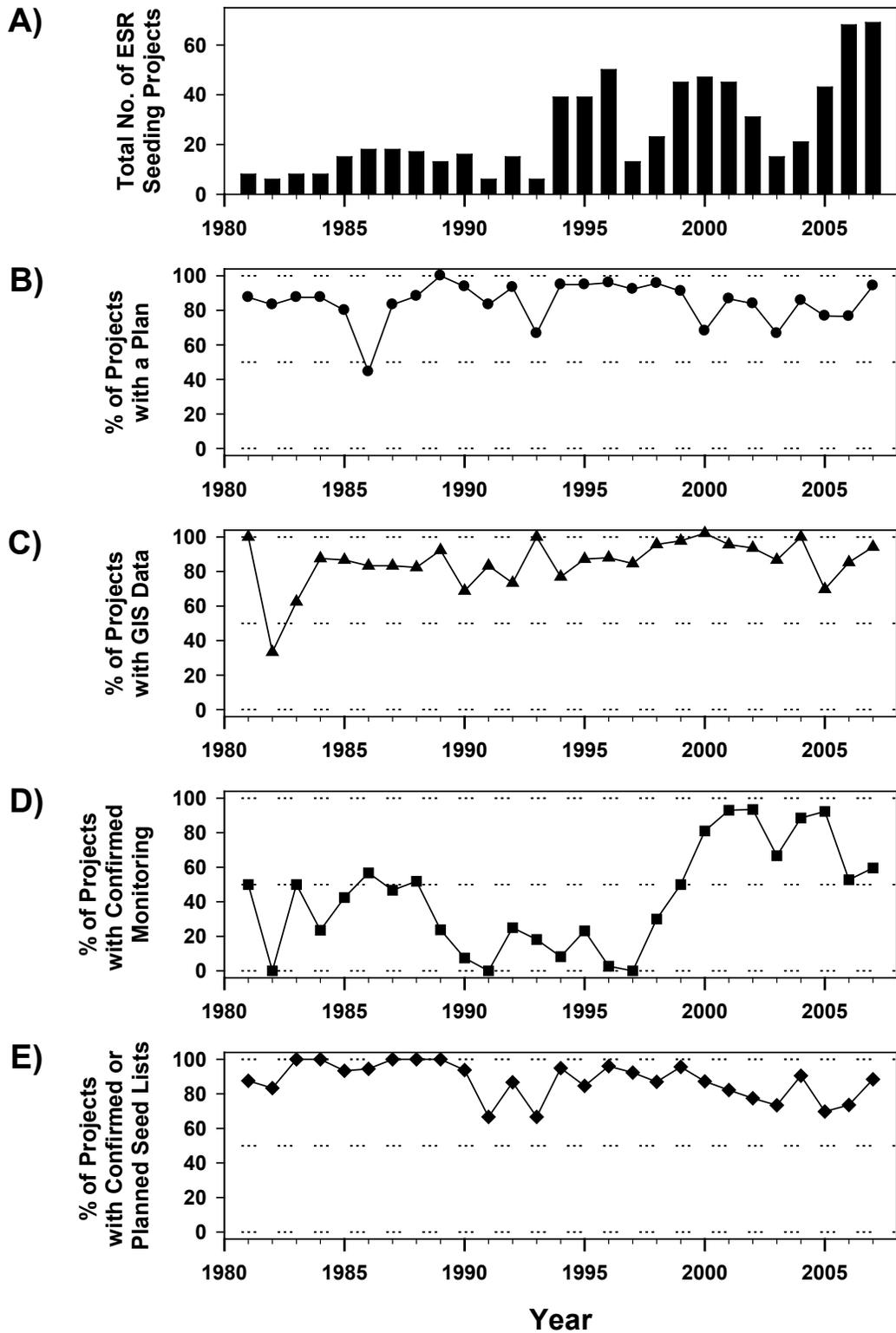


Figure 2. (A) Total number of projects and percentage of projects with: (B) a plan, (C) GIS data of the project location, (D) verifiable monitoring documentation, and (E) seed lists available from 1980 to 2007 for the nine BLM offices.

Table 4. Breakdown of ESR reseeding projects found at the nine BLM offices based on the type of seed mixture available and the monitoring status during the three decades (1980–89, 1990–99, and 2000–2007) of interest.

[Project seed mixtures were delineated based on the available seed information. Confirmed projects had data for the actual seed mixture at the time of seeding, and plan only seed mixtures were from projects where only the planned mixture was available]

State	Type of seed mix available	Was the project monitored?	Number of projects found from:		
			1980–89	1990–99	2000–2007
Idaho	confirmed	Yes	30	25	70
	confirmed	No	23	121	12
	plan only	Yes	18	30	21
	plan only	No	50	96	2
Nevada	confirmed	Yes	1	7	85
	confirmed	No	2	2	0
	plan only	Yes	0	8	42
	plan only	No	17	17	0
Oregon	confirmed	Yes	0	0	41
	confirmed	No	0	6	20
	plan only	Yes	0	0	19
	plan only	No	0	0	4
Utah	confirmed	yes	27	2	31
	confirmed	no	4	13	2
	plan only	yes	7	19	65
	plan only	no	25	95	27

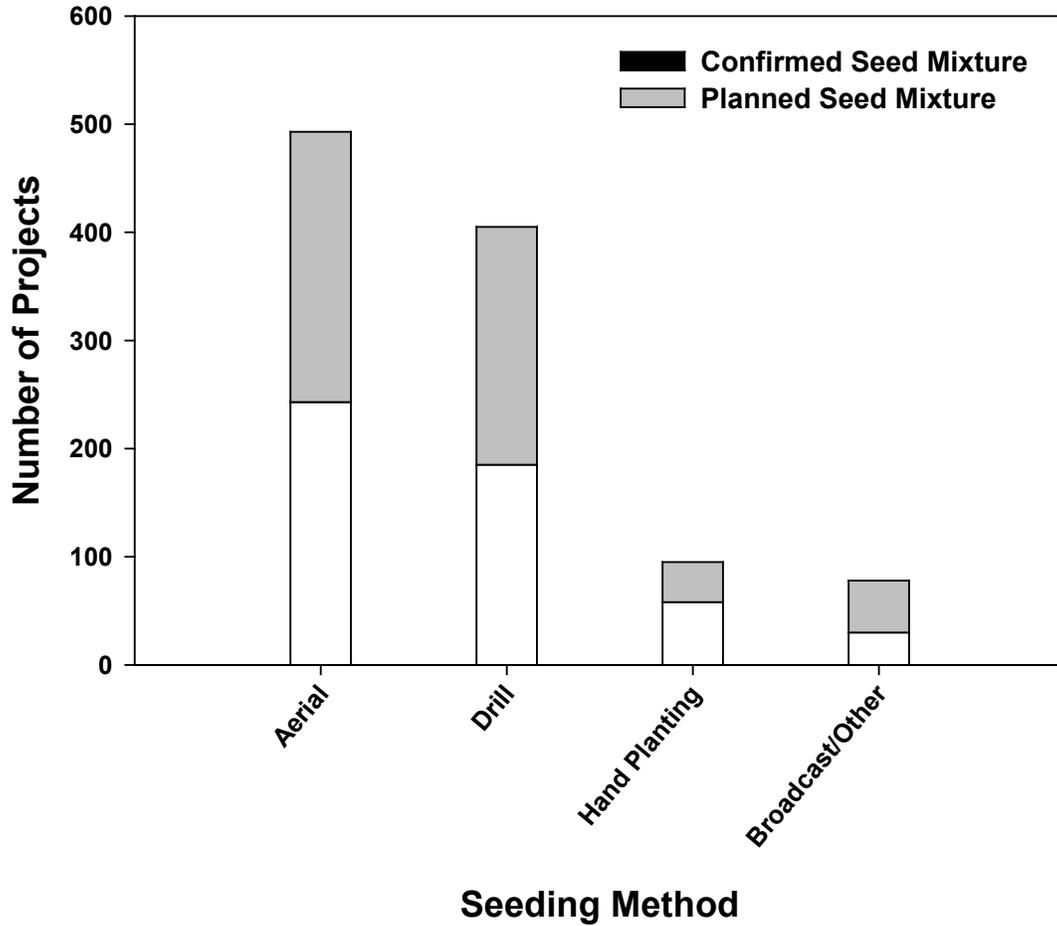


Figure 3. Total ESR projects identified based on seeding application type and the number of projects with on-the-ground implemented seeding mixtures (confirmed) versus only proposed seeding mixtures (planned). Projects with a planned mixture are seedings where no further information beyond the planning documentation was available about the actual rates or seed mixture applied when the seeds were sown.

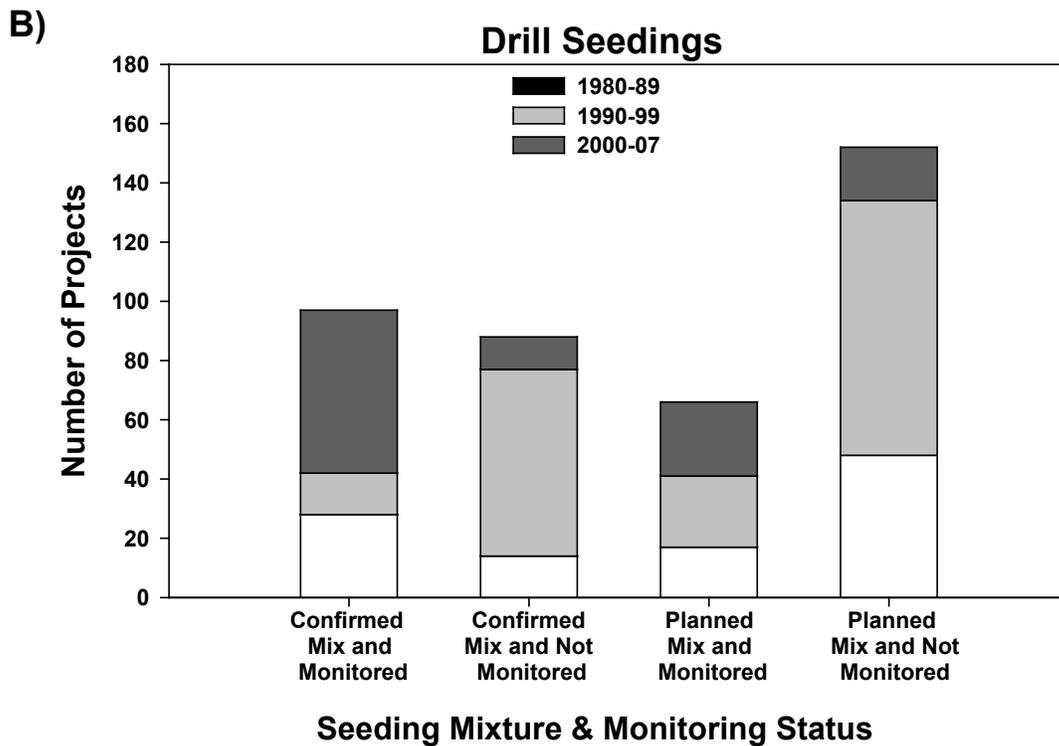
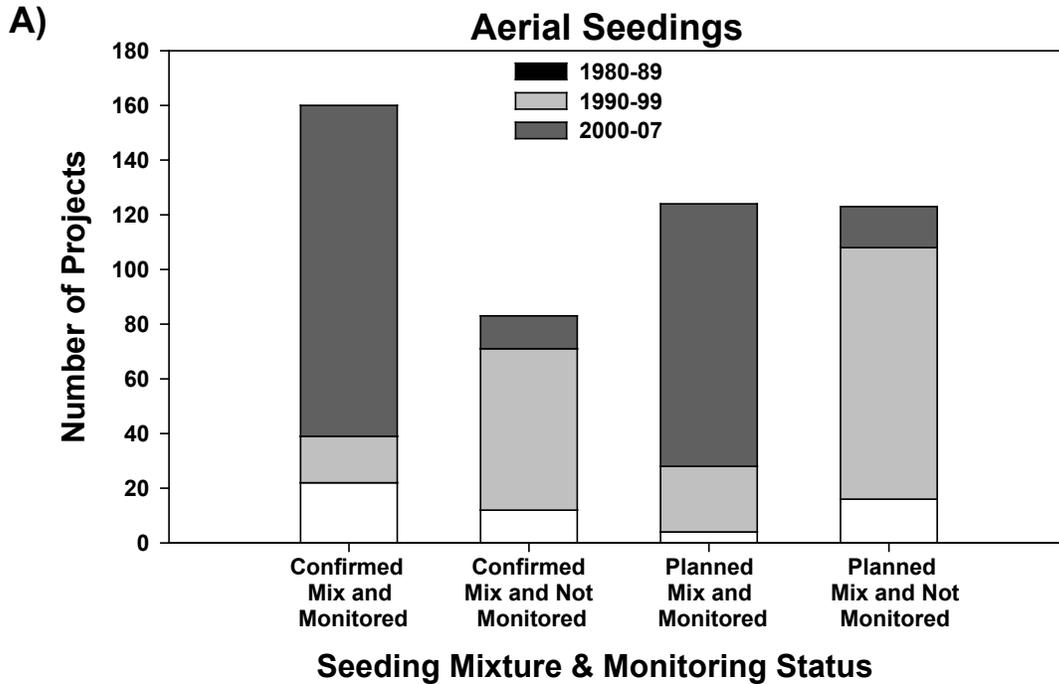


Figure 4. Seed mixture status (confirmed versus planned mix) and monitoring data availability (monitored versus not monitored) for aerial seedings (A), and drill seedings (B) of the nine BLM offices examined. Projects with a planned mixture are seedings where no further information beyond the planning documentation was available about the actual rates or seed mixture applied when the seeds were sown.

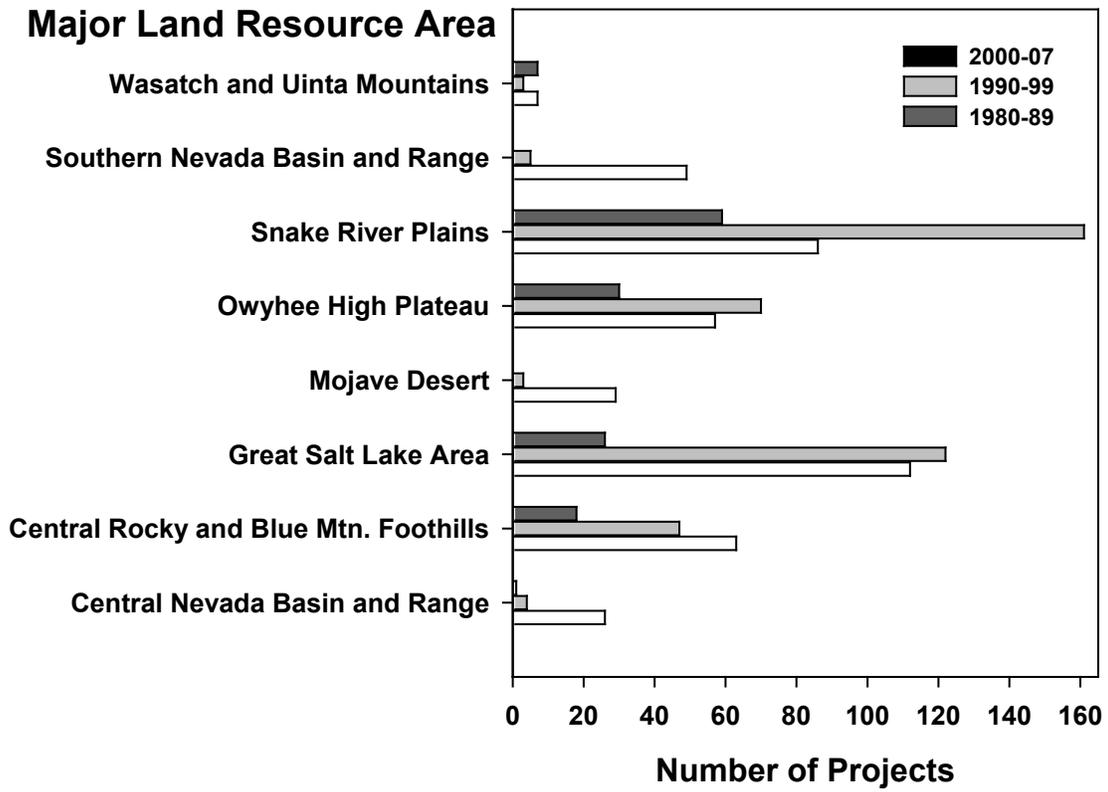


Figure 5. Number of ESR seeding projects within dominant (>15 seedings) Major Land Resource Areas (MLRAs) for 1980–89, 1990–99, and 2000–2007 from the nine BLM offices where ESR records were sampled.

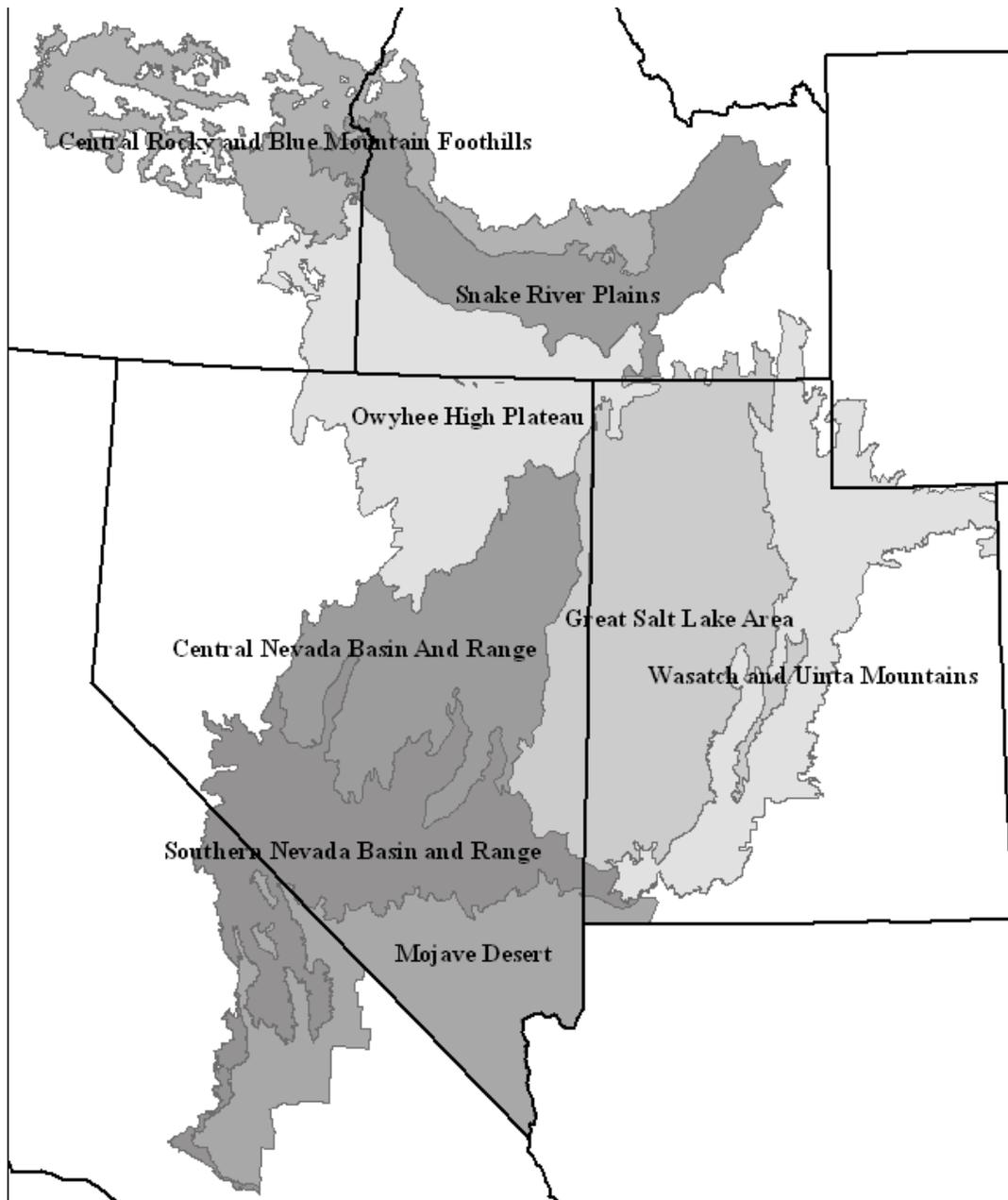


Figure 6. Location of the major land resource areas (MLRAs) with greater than 15 seedings found in the feasibility study.

In summary, there are 468 projects (206 ground seedings, 262 aerial seedings) that meet a minimum threshold of including: (1) a plan, (2) either a planned or confirmed seed list, and (3) some type of monitoring (table 5). These projects are not necessarily dispersed evenly across time or space. Projects in Oregon and Nevada were primarily recent (2000–2007), but projects in Idaho and Utah were more evenly distributed across each decade (table 5). These 468 projects, however, provide a large source population for potential sampling in a large-scale chronosequence study.

Table 5. Post-fire seeding projects that have a plan, seed list (planned or confirmed), and at least some type of monitoring by State, type of seeding, and timeframe.

[Aerial seedings will often overlap ground seeding projects and therefore may be monitored concurrently with ground seedings or not be able to be separated from results of ground seedings. Only one office in Oregon was visited and additional offices will be visited if project is continued. Plantings were not included]

State	Time frame	Ground seeding (any)	Aerial seeding
Idaho	1981 – 1989	30	9
	1990 – 1999	30	24
	2000 – 2007	38	30
Nevada	1981 – 1989	1	0
	1990 – 1999	5	6
	2000 – 2007	28	90
Oregon	1981 – 1989	0	0
	1990 – 1999	0	0
	2000 – 2007	33	17
Utah	1981 – 1989	11	9
	1990 – 1999	10	11
	2000 – 2007	20	66

Discussion

Preliminary information collected at BLM offices indicate that a chronosequence study in the Great Basin or Intermountain West region of the continental United States may be possible and will provide valuable information on post-fire seeding success for Federal land- management agencies. In a short time frame and from a relatively small subset of Intermountain West BLM offices, we were able to gather substantial records that documented project types, species sown and rates, and spatial locations for projects from 1980 to 2007. Fewer records were available during the 1980–89 period compared with the later periods. This pattern may be related to a lower amount of area burned on BLM lands during this time. Previous investigations of BLM ESR projects have reported an increase in fire size, frequency, and amount of area treated in rehabilitation projects during the following two decades (Pye and McArthur, 2002).

While we were able to collect a large number of ESR records with relevant information suitable for a chronosequence study, a regional examination of ESR projects throughout the Intermountain West would require the collection of equivalent data from areas not well represented in our feasibility study. Most offices visited for this chronosequence feasibility study were primarily from northern areas within the Great Basin (table 2, fig. 1). Areas of the Intermountain West that are not extensively represented include the Mojave desert and the Colorado Plateau regions. A chronosequence study only based on current data would provide inference primarily to shrub steppe ecotypes within the Great Basin region of the Intermountain West. Exhaustive collection of records within the remaining Great Basin, the Mojave and Colorado Plateau would still be necessary to allow a complete, regional assessment of ESR success throughout the Intermountain West.

There are a number of potential challenges involved in going forward with a field-based chronosequence study derived from data collected at these nine BLM offices. One challenge is that not all seed mixtures in ESR project files have on-the-ground confirmation about what species were applied or their associated seeding rates. Most projects, particularly records before 2000, just list the planned or purchased seed mixtures and proposed seeding rates. Although this potentially could bias assessments of factors influencing establishment rates of individual species for treatments conducted before 2000, a chronosequence study would not be intended to assess success solely at the species-level. In the event that such a study is initiated, treatment success primarily would focus on establishment of healthy vegetation communities, such as the relative abundances (cover or production) and densities of perennial native species (of grasses, forbs, and shrubs), perennial introduced species, perennial sown or suspected to have been sown species, and relative abundances of invasive annual grasses. A second challenge posed by the data available is that most seeding projects conducted before 1999 on either BLM or U.S. Forest Service lands had relatively little available monitoring information compared to more recent projects. This result is similar to that found in McArthur (2004) and suggests that little information on the initial success of older projects would be available for comparison to recently collected data. Although a chronosequence study would benefit from comparing current vegetation metrics to those collected immediately following treatments, this may not always be possible. A preference would be placed on those projects with post-treatment monitoring documentation, but this is not absolutely necessary for success of the chronosequence approach.

Finally, post-fire management of fire rehabilitation treatments can have significant effects on the condition and persistence of seeded vegetation. Information on post-fire management of treatment areas after the first 2 years is largely lacking in our present dataset. Post-fire treatments typically call for the suspension of grazing activities in the rehabilitation area for 2 years. Some of the projects examined included planning or other documentation that indicated grazing was indeed excluded from

rehabilitation areas; however, this documentation was not always readily available at field offices. Although we considered collecting grazing data for allotments and pastures during field office visits, we found these data difficult to find or consolidate while also collecting the ESR data. The short duration of this feasibility study also limited our ability to thoroughly identify and collect post-revegetation management data associated with ESR projects. Given the significant influence of post-fire management actions on ESR projects, it is essential that any available post-fire ESR management data be collected as part of a larger chronosequence study examining project success.

Prospective Chronosequence Study

Given the caveats discussed above and our initial data, we believe that the chronosequence approach to assess fire rehabilitation is feasible. The primary objectives of a full chronosequence study would be to:

1. Identify suitable study locations that were treated in time frames of interest (1980–89, 1990–99, 2000–2007) as well as untreated areas, within several MLRA's across the Intermountain West. This includes gathering further background information on each site including post-fire seeding management history.
2. Collect vegetation, soils, and fuels data about the current condition of each of the treated and untreated areas at each study location.
3. Analyze collected data to determine the long-term effects of post-fire seedings in combination with other post-fire management on plant communities (relative abundances of life forms and of invasive species), soil properties, fuelbed characteristics, and subsequent fire history.

The population of potential study sites would be composed of those sites where the necessary baseline data (rehabilitation plan, list of species sown, and some initial monitoring; table 5) are available and also augmented with additional post-treatment management data as discussed above. From the initial 468 sites, there are 18, 41, and 203 aerial seeding projects and 41, 46, and 119 ground seeding projects from the 1980–89, 1990–99, and 2000–2007 time periods, respectively. This number should increase as data entry is completed for the Elko field office and as other field offices are visited. These 468 sites make up the initial pool of potential sites to revisit for a chronosequence study. If these sites did not prove adequate to design a spatially and temporally balanced design, ESR seedings could be included that did not have any initial monitoring, which would add about 500 projects to the potential pool of study sites.

A logical approach in a chronosequence study would be to strategically select project areas that have both sufficient information to reconstruct initial treatment locations, dates, and seed mixtures, and interpretable post-treatment monitoring data. An expanded study would stratify project areas into meaningful categories for distinguishing potential thresholds for seeding from the initial population of postfire rehabilitation treatments collected during the pilot phase. These categories would most likely include precipitation zones (low, <8 in.; medium, 8 to <12 in.; high, >12 in.), major land-resource areas (for example, Snake River plains, Malheur high plateau), and timing of seeding (fall, winter, or spring). An adequate number of projects for meaningful statistical analyses would need to be chosen in all strata.

For a larger chronosequence study to be successful and relevant, project areas sampled would need to encompass all primary ecological regions within the study area (for example, major ecological site types within climatic zones) where ESR projects commonly are conducted. This may require further collection of ESR project files in a greater area within the Intermountain West (fig. 1). Once an adequate sample of projects have been identified, field sampling would take place within previously seeded and unseeded areas to determine current vegetation and soil stability conditions. Unseeded areas would be selected based on their suitability for comparison with treatment areas using potential sites within a target area of a project with the same ecological site. The most desirable unseeded areas primarily would consist of areas that were burned but that were not treated, either because it was convenient to use an existing feature such as a treatment boundary (a road, fence, or powerline) or because the entire area was unable to be treated.

A basic characterization of each study area would include topography (landform, slope, and aspect), soil type (with associated ecological sites), and pre- and post-treatment precipitation estimated from regional climate models. For locations with documented ecological site descriptions (as defined by USDA NRCS, the current interagency standard), these site descriptions would provide suggested relative dominance (cover or production) by species for life forms. These descriptions also would be used as a potential standard for comparisons in treated areas. Measured response variables for the biotic component would include fuel loads and composition (for example, relative cover) of all plant species grouped into meaningful categories such as grass, forb, shrub, seeded relative to non-seeded, native and introduced perennials, or invasive. Abiotic response variables would evaluate surface cover of bare ground, biological soil crusts, and litter. Data on natural variation (for example, pre- and post-treatment weather) and land-management activities (for example, livestock and wild horse herd management data) would be used as covariates to accurately interpret the results of postfire seeding treatments. A study design that uses gradient analyses via multivariate statistics likely would be the best approach for a chronosequence investigation.

A chronosequence study would provide critical information on the effects of both aerial and drill ESR seedings on species composition and fuel loads across environmental gradients within regions (Great Basin, Colorado Plateau, and Mojave Desert). Because both seeded and unseeded areas would be examined, it would be possible to evaluate the natural resilience, or recovery potential, of the sites, providing insights into when seeding may be necessary. A chronosequence study also would provide information on the effectiveness of ESR seedings. Although a large-scale and field-based chronosequence of fire rehabilitation projects may seem potentially difficult and cost-prohibitive, our findings in this feasibility study indicate that such an approach is possible and can provide relevant ecological data for suggesting improvements in future post-fire land management decisions. Because data for long-term success of post-fire reseedings are difficult to collect without long-term commitments to vegetation monitoring, the chronosequence approach, based on our findings, appears to be a sensible alternative that can improve this land management information gap.

A full and complete study design will be submitted for review and potential funding should the Joint Fire Science Program Board request it.

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