MANAGEMENT AND CONSERVATION OF SAGE GROUSE, DENOMINATIVE SPECIES FOR THE ECOLOGICAL HEALTH OF SHRUBSTEPPE ECOSYSTEMS

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FINAL REPORT

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EXECUTIVE SUMMARY AND IMPLEMENTATION STRATEGY

A combination of drastically altered fire frequencies, livestock overgrazing, invasion by exotic plants, and agricultural development has transformed the shrubsteppe landscapes of western North America over the past 150 years. Landscape-scale bioengineering is needed to reconstitute balanced combinations of native plant species and restore the patch-scale mosaics of sagebrush, fortes, and perennial bunchgrasses that once comprised these fire-controlled landscapes.

The inextricable link between Sage Grouse and the sagebrush steppe ecosystems of western North America provides a sensitive indicator for the ecological health and integrity of these lands. There is widespread concern among federal and state agencies that Sage Grouse populations have undergone widespread, sustained decline, but reversal of this trend may be problematic because the viability of Sage Grouse populations depends on ecosystem- level and landscape-scale processes that present severe challenges for land management agencies.

To develop a comprehensive approach to Sage Grouse management and conservation, priorities for research, management, and inventory were generated from a conference that brought together scientists with expertise on Sage Grouse, shrubsteppe ecosystems, and analytic techniques for understanding wildlife populations.

PRIORITY RESEARCH RECOMMENDATIONS:

1. Optimal spatial dispersion patterns of seasonally-required habitats within landscape mosaics (see p. 10).

Landscape-scale, empirical field research is required to determine suitable spatial and proportional distributions of seasonally-required habitat types that will support Sage Grouse populations. A complementary modeling effort should be initiated to explore minimum area requirements and habitat dispersion patterns required for Sage Grouse population viability.

2. The relationship between habitat variation and Sage Grouse demographic variation (see p. 13).

Explicit quantitative models are needed to explore the relationship between habitat and population data. The primary goal of such an effort should be development of a Sage Grouse population model linked to a habitat preference model in order to understand Sage Grouse population response to habitat change. To successfully develop such models, comparative field studies must be initiated to examine Sage Grouse survival among habitat conditions, with particular emphasis on movements and fate of juveniles and the role of juvenile dispersal.

3. Genetic and geographic distinctiveness of Sage Grouse populations (see p. 15).

There is a critical need for genetic definition of subspecies and population isolates of Sage Grouse across the species' range as a prerequisite to effective management, conservation, and restoration of populations. The reality or unreality of Sage Grouse subspecies needs to be examined through the use of modern genetic and behavioral analyses.

4. Development and evaluation of restoration methodologies for balanced native plant communities (see p. 16).

Habitat restoration experiments at large spatial scales in conjunction with landscape-scale modeling efforts are needed for rangelands invaded by exotic forbs and annual grasses, for rangelands characterized by shrub over-dominance, and for degraded wet meadow and spring areas.

PRIORITY MANAGEMENT RECOMMENDATIONS:

1. Cessation of shrubsteppe conversion to non-native grasslands (See p. 18).

2. Restoration of a landscape-scale mosaic of natural habitats to be achieved through the introduction of fire at appropriate temporal and spatial scales and the re introduction of native perennial grasses, fortes, and shrubs (see p. 19).

3. Reduction of landscape fragmentation through consolidation of land holdings, and cessation of management actions that promote fragmentation of contiguous habitat blocks (see p. 20).

4. Restoration of early brood habitat for Sage Grouse (see p. 20).

PRIORITY INVENTORY/MONITORING RECOMMENDATIONS:

1. Ecologically meaningful inventory and classification of shrubsteppe lands integrated with GIS technology (see p. 21).

2. Adherence to rigorous standardization of lek count methodology (see p. 21).

IMPLEMENTATION STRATEGY

A strategic approach to implementation of the foregoing recommendations would initiate concurrent parallel efforts from each of the three areas of research, management, and monitoring. A successful implementation strategy for research would (1) immediately initiate work on Research Priority 3, the most straightforward of the four priority objectives, which could be completed in 12-18 months; (2) commence selection of sites and potential research groups for comparative, landscape-scale fieldwork. Sites selected would be used for closely coordinated, parallel field studies (by one or more research groups) described in Research Priority 1 and Research Priority 2, and would be conducted on the same demonstration areas. Modeling components of Research Priorities 1 and 2 should be initiated within one to two years following commencement of fieldwork; (3) Research Priority 4 could be subsumed within the BLM's recently initiated Vegetation Diversity Project (Pyke and Borman 1993) through slight expansion of program objectives and minor adjustment of existing research priorities. Linkage between these two efforts would provide benefits to both programs by promoting interaction between wildlife and plant research groups working toward complementary goals for restoration and enhancement of native plant diversity on western rangelands.

Immediate implementation of Management Priorities 1-4 is wholly compatible with, and would reinforce, efforts already underway within the BLM as the agency moves toward the adaptive management goal of improved ecological conditions on the western rangelands. Initiation of Inventory Priority 1 is the logical starting point for these efforts.

PREFACE

A two-day conference to examine Sage Grouse biology, conservation, management, and directions for future research was held under the auspices of the High Desert Ecological Research Institute on 22-23 November 1993 in Bend, Oregon[1]. The conference brought together the principal scientists conducting research on this species, along with scientists having expertise in relevant ecological systems, population analyses, or other strengths that could be brought to bear on problems related directly to the management and conservation of Sage Grouse. The objective was to create an interesting and stimulating mix of perspectives and research experience and from that effort derive a broader understanding of the problems and issues surrounding the present status and future prospects for the species. The topics addressed and the contributing participants are listed in **Appendix 1**.

The conference provided the basis for this report to the BLM for management, inventory, and future research on Sage Grouse. The recommendations contained in this report represent the author's synthesis and assessment of the information presented at the conference, but do not necessarily represent a consensus of scientific viewpoints, as there are fundamental differences of interpretation and opinion among management agencies and scientists concerning the management and conservation of Sage Grouse in the western United States.

A second goal of the conference was to serve as the nucleus for a landmark volume that will provide a comprehensive synthesis and summary of the current state of knowledge regarding Sage Grouse. This volume will be aimed at a very broad audience comprised of personnel from federal and state natural resource management agencies, the conservation and environmental communities, and the traditional scientific community of ornithologists, ecologists, and population biologists. Work will soon be initiated on this volume, which will be comprised primarily of chapters authored by conference participants.

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[1]Funding for the conference was supplied by the Oregon/Washington State Office of the Bureau of Land Management.

INTRODUCTION

No animal is more intimately associated with the vast sagebrush steppe ecosystems that cover much of western North America than the Sage Grouse *(Centrocercus urophasianus).* Although historically inhabiting more than 90 million acres across 14 western states and three Canadian provinces, the grouse's range by 1950 had been reduced steadily by more than 50 percent. In spite of continued habitat loss and fragmentation, and even though the species has been extirpated completely from three states and one province, eight states continue to administer hunting seasons for Sage Grouse. Regional management of Sage Grouse often is based on conflicting interpretations of inadequate data. There is little understanding of many fundamental aspects of Sage Grouse population biology or of the actual status of the species in many parts of its range.

Although the focus is on a single species, nearly all of the issues involved are related clearly to the health of sagebrush steppe ecosystems to which this species is so closely tied. The fate of Sage Grouse is inextricably linked to ecosystem level and landscape scale processes that present severe challenges for land management agencies whose activities likely have contributed substantively to the problem. Soil erosion and loss, depletion of scarce water resources, disappearance of native vegetation, and widespread invasion by exotic plant species pose significant and insufficiently addressed obstacles to the long-term viability of Sage Grouse and other native wildlife and to recovery of the ecological integrity of these ecosystems.

The scenario of a single species issue as surrogate for the ecological health of an entire ecosystem is not limited to Spotted Owls and old-growth coniferous forests. This pattern is likely to be repeated often in coming years, and the way such matters are addressed in the future can be influenced positively by the approach embodied in this document if adopted for conservation and management of Sage Grouse.

RESEARCH RECOMMENDATIONS

Priority areas for research consist of four interrelated sets of questions focusing on:

- Dispersion patterns of habitats within landscape mosaics;
- Demography of Sage Grouse populations in relation to habitat variation;
- Genetic and geographic distinctiveness of populations;
- Restoration of natural habitats.

1. Spatial dispersion patterns of seasonally-required habitats within landscape mosaics

The seasonally-varying habitat requirements of Sage Grouse define a facultatively mobile species with the ability to seek out and locate specific habitat types within a landscape mosaic. The requirement for a variety of seral stages and degrees of stand closure make the Sage Grouse a sensitive, extremely good indicator for the health of sagebrush steppe ecosystems at the landscape scale. The loss of this requisite landscape mosaic of natural habitats is the most common problem confronting Sage Grouse across the western United States. In much of its range, the species is faced with monotypic stand conditions in landscapes that have lost the interspersion of different stand classes. In other areas, the habitat mosaic is comprised of interspersed unsuitable and suitable habitats, rather than a mosaic of contiguous natural habitats.

Foremost among the research needs within the context of habitat dispersion patterns is the basic question of what is the optimal (or even suitable) distribution of habitat types at a landscape scale that will support a population of Sage Grouse. What are the "right" spatial dispersion patterns and relative amounts of seasonally-required habitats? The answer to this fundamental question is simply unknown.

Shrubsteppe landscapes should be viewed as mosaics of different habitats required and used by Sage Grouse at different points in their annual cycle. These habitats can be defined roughly by the relative proportions of shrub and herbaceous cover: Winter habitat, comprised of 25-40% shrub canopy closure; Breeding habitats consisting of nesting habitat comprised of 15-25% shrub canopy closure with at least 20% residual herbaceous cover, and brood habitat similarly comprised of 15-25% shrub canopy closure but with at least 10-20% cover of live forbs and grasses; and Summer & Fall habitat comprised of at least 15% shrub canopy cover and at least 10% live forb cover.

There is little agreement concerning which of these seasonally-required habitat types is most critical across different parts of the species' range. The single unifying theme throughout the entire geographic range is the universality of brood habitat loss. Suitable brood habitat tends to occur on deeper soils, which support sagebrush communities with diverse forb components, and generally is associated with adjacent seeps and springs. Typically these areas have been impacted greatly by livestock and associated water developments, or replaced entirely by agricultural development that often results in unsuitable spatial matrices of natural and agricultural habitats.

Sage Grouse movements to utilize seasonally-required habitats vary. Populations have been characterized as 1) "single stage migratory" in which birds move between a summer range and a combination winter/breeding range, 2) "two stage migratory" with birds moving among three elevationally distinct seasonal ranges: high elevation summer range, mid-elevation breeding (nesting) range, and low elevation winter range, and 3) non-migratory populations for which seasonally-required habitats are adjacent to one another.

Virtually all questions regarding the underlying patterns and causes of Sage Grouse movements flow directly from the question of relative amounts and spatial patterning of requisite habitat types: What are the determinants of whether a population will be one, two, or zero stage migratory? Are large home ranges the key to long movements? What factors underlie home range size variation? Is the loss of one or more seasonally-required habitats the primary determinant for long-distance movements? Alternatively, is there a genetic component underlying seasonal migrations in Sage Grouse?

Questions of distances moved in relation to habitat require well-designed multivariate studies to address spatial and temporal scaling of factors, not simply whether or not there is an effect of habitat on movements. Female home range size needs to be explored in ways that encompass numerous variables (such as forb density, sagebrush cover, precipitation, habitat dispersion patterns, etc.) within and among specific landscapes. A basis will then exist from which to approach questions involving higher order variables, such as how the density of nest sites varies in relation to measures like home range size or lek counts.

A. Fragmentation of shrubsteppe habitats

Modern-era fragmentation of shrubsteppe landscapes began in the late 1800s and continued to accelerate through the 1950s. Conversion and loss of sagebrush steppe habitat continues today. At its extreme expression, fragmentation has resulted in an average distance of little more than 50 m from Sage Grouse nests to edge of sagebrush habitat in Washington state - in essence, nearly everything inhabited by Sage Grouse in Washington shrubsteppe is edge habitat!

How is habitat fragmentation defined in a biologically meaningful way for Sage Grouse within the context of shrubsteppe? What is the threshold of landscape-scale fragmentation beyond which a Sage Grouse population cannot persist? Conversely, what is the size of an adequate habitat block i.e., one that will enable population persistence of Sage Grouse? 100 km^2? 50km^2? 10-15km^2? 1km^2? We simply do not know the answer or even the spatial magnitude of the correct answer. We know neither the minimum area of habitat required to support a population, nor how long it can be supported.

Perhaps more fundamentally, we do not know whether the question is one of *fragmentation* of shrubsteppe habitat or *loss* of shrubsteppe habitat (or both). Does fragmentation of shrub-steppe create the sort of edge-associated problems documented for fragmentation of forested habitats (e.g., increased nest predation)?

B. Models of minimum viable habitat area in relation to patterns of spatial dispersion

Complementary to empirical field research, modeling efforts should be undertaken to explore minimum area requirements and dispersion patterns of habitat necessary to maintain viable populations of Sage Grouse. What is the appropriate ratio among seasonally-required habitat types on a landscape scale, and is there geographic variation in the optimal ratio? What percentage of a landscape must be restored in order to support Sage Grouse? (Or phrased differently, what proportion of the landscape can be comprised of exotic annuals or of sagebrush monocultures devoid of native grasses and forbs - and still support Sage Grouse?)

Such a modeling effort could be used to direct selection of parameters for field experiments at landscape scales (p. 12), and could be used to prioritize subsets of possible field experiments. Modeling exercises should be viewed as requisite complements to field studies, not as substitutes for empirical research.

C. Landscape-scale field experiments

The BLM is the only agency with management jurisdiction over areas large enough to perform meaningful, landscape-scale, field experiments. There is a need to explicitly incorporate the bird (which should be viewed as a starting point, not an end point as well) and embed it into the landscape to ask questions about how we can measure Sage Grouse populations in a quantitative way while simultaneously incorporating landscape and vegetation relationships.

Among the most pressing questions requiring large spatial-scale approaches are:

- the impacts of livestock grazing on Sage Grouse (e.g., nest success, juvenile survival): comparison of livestock-free areas versus livestock under various grazing regimens, experimentally designed to block on plant community composition and moisture regime;

- prescribed burns to create community (spatial) mosaics, designed to block across geographic regions and across sagebrush subspecies (which vary in their response to fire).

It is critically important that a long enough temporal view be adopted in these studies to encompass reasonable boundaries on climatic variation. Suitable areas must be committed for time periods commensurate with natural processes governing these systems, i.e., with pre-European fire-return intervals as the relevant temporal scale. These intervals have been identified as 10-30 years, depending upon geographic region, topography, and plant community composition. Requisite temporal scales of this duration necessitate a concurrent modeling approach to achieve landscape-scale predictions in conjunction with empirical work.

Ideally, areas identified for long-term, large spatial-scale research should be retired from the normal use-permitting system and permanently dedicated to long-term research aimed at achieving fundamental understanding of management activities on shrubsteppe ecosystems. At present, there is little if any such understanding in the management of these systems.

Introductions of Sage Grouse through translocation are landscape-scale field experiments, although they have not been viewed explicitly in this context. Early efforts undertaken in Utah, Oregon, British Columbia, Montana, and Wyoming were conducted in a scientific vacuum - characterized by one conference participant as "dumping and hoping." Birds were released into areas where populations had diminished, but no records were kept as to sources of birds, timing of captures and releases, numbers and demographics of birds, etc. Such efforts are presumed to have failed. Recent efforts in the Sawtooth Valley of Idaho provide the best data to date and indicate 96-99% mortality of released birds within the initial three weeks of release!

Translocation efforts for Sage Grouse clearly illustrate the need for careful planning within the context derived from modeling results of habitat dispersion patterns and Sage Grouse demography (p. 13), and population viability of isolated populations (p. 15). Translocations without such preceding efforts likely are doomed to perpetuate past failures. Future translocation experiments should await the results of these modeling efforts and would benefit greatly from integrated planning among interested researchers drawn from a variety of disciplines and management agencies, in order to maximize the return on investment of research resources.

2. The relationship between habitat variation and Sage-Grouse demographic variation

Explicit quantitative models are needed to explore the relationship between habitat and population data. The primary goal is the development of a Sage Grouse population model linked to a habitat preference model in order to understand Sage Grouse population response to habitat change. In the absence of such a fundamental conceptual tool for management, we shall, in the words of one conference participant, simply continue to "count 'em until they're gone."

Verbal models already exist that identify associations between one or more demographic response variables and sets of predictor variables, usually related to some aspect of habitat. But neither the assumptions nor the variables needed to make population estimates are made explicit in verbal models, which cannot be analyzed quantitatively. An effort is needed to quantify these relationships so that they can be made amenable to analytical techniques, and thus useful for directing field studies to indicate which parameters are most critical.

The essence of the modeling process is to simplify and validate. Hence, initial modeling efforts should emphasize similarities rather than differences among populations, geographic regions, sagebrush types, etc. Initial efforts for Sage Grouse might focus on stage models with post-birth-pulse censuses; because life histories differ significantly between the sexes, separate male and female models may be appropriate. Subsequent efforts should be directed at development of spatially explicit models that can be integrated with GIS technology.

For Sage Grouse, landscape variation affects behavior, reproduction, and movement. Environmental variation affects those same parameters. Individuals vary in these parameters both within and between populations. How all these things come together to affect the fitness of the population and its likelihood of survival can be approached most fruitfully by a modeling effort. Different parameters may be differentially critical among geographic populations - a possibility best evaluated through modeling efforts followed by sensitivity analyses as a means to assess this question for different regions. Similarly, in the absence of adequate long-term data, the possibility of climate-driven population cycles in Sage Grouse can be best explored through modeling.

Development of a simple population model linked to explicit habitat variables will require measures of Sage Grouse survivorship and productivity, and the relationship of these parameters to habitat variation. Although enough information now exists to undertake preliminary model construction, the data needed to underpin an extensive effort are woefully inadequate because most habitat research has been disjunct from population research.

The parameters needed for a demographic model are survival, production, and population size. There are three primary techniques that have been used to generate empirical estimates of these parameters: telemetry studies, band return studies, and age-structure studies based on wing harvest data. Only telemetry studies appear to offer the promise of data with sufficient temporal and spatial replication to provide useful information within a reasonable number of years. Hence, complementary with a significant modeling effort, comparative telemetry studies of survival among habitat conditions should be initiated.

Long-term telemetry studies that follow individual marked birds over successive seasons also will provide data that can be brought to bear on the question of geographic and temporal components of what *genetically* constitutes a population for Sage Grouse. These data also would provide information on the degree to which individual birds are behaviorally flexible or inflexible in their seasonal movements among sites, which bears importantly on the choice of birds for translocations and introductions (p. 12).

A. Movements and fate of juveniles and the role of juvenile dispersal

Quantitative data for juvenile dispersal and survival in Sage Grouse are virtually nonexistent - a striking parallel with the central problem that initially challenged the understanding of Spotted Owl population dynamics. Dispersal typically occurs in August and September, and may be the critical mechanism whereby suitable habitat is located by young birds for subsequent seasons. The potential importance of habitat corridors in this context and the absence of data bearing on the use of corridors for dispersal once again raise striking parallels with focal research and management issues for Spotted Owls.

A program of field work and modeling explicitly focused on juvenile dispersal and survival is urgently needed to provide a quantitative understanding of this critical life history period in Sage Grouse.

B. Modeling population viability of isolated versus core "populations"

As remnant areas and the Sage Grouse populations they support become smaller and smaller, the risk of local extinction increases. As populations become increasingly isolated from each other, the potential for re-establishment by new immigrants becomes vanishingly small. Instead, isolated patches of suitable habitat begin to function as population sinks for birds dispersing from core populations. Far from hypothetical, such a scenario approximates the present situation in Washington where remnant Sage Grouse are becoming two disjunct populations that are entirely separate from each other, and entirely separate from conspecifics in other states.

Modeling efforts aimed at determining minimum area requirements (p. 12) should be linked to spatially explicit demographic models, which then can be used to explore questions of survival or viability for such populations. Unfortunately, data requirements for a modeling effort to develop population viability analyses and extinction probabilities exceed the demands of even simple demographic models. The same parameters necessary for demographic modeling are required in addition to estimates of their variances, as well as information on the temporal and spatial components of these parameters. The modeling effort described on pages 14-16 must precede the effort described here.

3. Genetic and geographic distinctiveness of Sage-Grouse populations

Sage Grouse mating systems are characterized by strongly skewed mating success among males - not uncommonly, only one or two males per lek perform 80-90% of all copulations. This obvious potential for reduced genetic variability will be of greatest consequence in small, isolated populations, which increasingly characterize Sage Grouse across much of their geographic range today. Rapid evolution of male traits can be driven by sexual selection under these circumstances and will lead inevitably to accelerated divergence among isolated populations.

Behavioral studies indicate that differentiation can be extraordinarily rapid and give rise to mating barriers among populations. The origin of such barriers to gene flow can be the incidental result of isolation and genetic drift, with sexual selection driving the speed of evolutionary divergence. The current process of widespread fragmentation of populations could not only amplify, but actually accelerate the pace of population differentiation in the absence of gene flow and lead to genetic impoverishment and even maladaption to local (altered) environments.

Given this scenario, there is a critical need for genetic definition of subspecies and population isolates of Sage Grouse across the species' range to meaningfully effect management, conservation, and restoration of populations. The northwest subspecies of Sage Grouse described nearly 50 years ago is based on the putative morphological differentiation of only eight complete specimens. The modern view of the basis for differentiating avian subspecies is that a combination of morphological, behavioral, and genetic data should be brought to bear on the question of subspecific differentiation.

The reality or unreality of Sage Grouse species / subspecies needs to be re-examined in the light of modern behavioral and genetic analyses. Data already in hand indicate the clear distinctiveness of populations inhabiting the Gunnison Basin of Colorado relative to all other populations, and certainly warrant at least subspecific status for the Gunnison Basin birds. To accomplish sufficient geographic sampling across the species' range would be quite straightforward. Samples are needed of vocalizations, wing muscle, and blood in order to adequately assess the degree of both behavioral and genetic differentiation among populations. These data would provide information on the genetics of small, fragmented populations that can be linked to modeling efforts for population viability (p. 15) and provide insight as to what might constitute minimum viable population sizes for Sage Grouse given the peculiarities of their mating system.

4. Restoration of natural habitats

Shrubsteppe ecosystems of western North America evolved as dynamic landscapes with climatic variation driving changes in fire frequencies. Species composition of plant communities likewise was dynamic prior to European settlement, and Sage Grouse evolved within the context of these fire-driven, temporally and spatially dynamic landscapes. The shrubsteppe landscapes of today are recent in origin and unique in composition - woody species have increased dramatically over the past 100-150 years, and livestock have played a key role in this increase. A combination of drastically altered fire frequencies, livestock overgrazing, invasion by exotic plants, and agricultural development has transformed the shrubsteppe landscapes of western North America.

Landscape-scale bioengineering is needed to reconstitute balanced combinations of native plant species through the use of prescribed and natural burning patterns to restore the patch-scale mosaics of sagebrush, forbs, and perennial bunchgrasses. The objective is to bum so that sagebrush is *not* removed entirely, and so that bums are neither temporally nor spatially uniform. Habitat restoration experiments are needed to establish the ecological efficacy of restoration (cf. Pyke and Borman 1993) and to evaluate potential methodologies for reconverting "treated" lands. Restoration of shrub structure without a diversity of native grasses and forbs, however, will fail to produce ecologically viable landscapes and will fail to restore functional populations of Sage Grouse.

Evaluation of the comparative efficacy of different restoration techniques is not a short-term endeavor and will require long-term dedication of land for experimentation and monitoring. Adaptive management will require serious restoration efforts with native plants, which will necessitate at least temporary removal of livestock (8-15 years) from areas being restored. Only after restored plants have been well established can livestock grazing regimens be evaluated for their potential compatibility with restored shrubsteppe landscapes.

A. Priority development and assessment of restoration methodologies for specific conditions

- annual-invaded ranges (recently burned versus unburned)
- crested wheatgrass seedings
- shrub-dominated burned areas
- spring/meadow riparian habitats

A central problem in any restoration effort is the role of erosion and loss of topsoil. Throughout the sagebrush steppe of the Intermountain West, the uppermost two to three inches of soil have been lost. Can areas be identified that possess decent soils in which to do experimental work? The previously widespread cryptogamic crust of mosses and lichens is gone and has proven extremely difficult to recover. A significant effort should be directed at evaluation of the ecological role played by the cryptogamic crust in establishment of native plant species and resistance to invasion of exotic plant species, and (if warranted) to the recovery of this crust.

Given the dynamics of these communities, loss of soil, and uniqueness of current plant species composition, options need to be explored for bioengineering community compositions that will function at the ecosystem level.

B. Modeling habitat restoration at landscape scales

In conjunction with empirical work devoted to restoration, a significant modeling effort should be initiated that incorporates plant ecologists with modeling expertise at population and community levels. The centrality of disturbance in the form of fire in these systems argues for the use of state-and-transition modeling approaches. An initial assessment should focus on determining which parameters are needed to support landscape models, and could be used to focus attention on those parameters that may be most critical for field experiments at landscape scales (p. 12). Questions such as 'What proportion of the landscape can be comprised of exotic annuals and still be tolerated by native perennial communities?' can be best approached through an analytical modeling effort.

MANAGEMENT RECOMMENDATIONS

1. *Cessation of shrubsteppe conversion to non-native grasslands*

For more than a century, sagebrush-dominated shrubsteppe lands have been subjected to extensive impacts and alterations from introduced livestock in western North America (Fleischner 1994). The current public controversy surrounding livestock grazing on the public rangelands of the West inevitably will come to focus on Sage Grouse as foremost among several potential surrogates for the health of shrubsteppe ecosystems. Past management of these lands has been oriented nearly exclusively toward commodity production, not ecological sustainability (USGAO 1991). Adaptive management for the long-term health and sustainability of these systems will require a reversal of past management priorities (USGAO 1988a, b).

From an ecological perspective for Sage Grouse, the most severe negative impacts on these ecosystems in recent decades have included development activities aimed at conversion of shrubsteppe to grasslands for livestock. Most prominent among these actions, especially in the period spanned by the 1960s and 1970s, was implementation of "brush control" policies on millions of acres of shrubsteppe through aerial spraying with herbicides, mechanical treatment, and the use of introduced fire, generally followed by seeding with crested wheatgrass or other exotic species. From the 1960s to the present time, meadows and other sensitive wet areas have been destroyed through spring permanence "improvements" in which natural springs have been transformed into pipelines for livestock use. In some areas, especially Wyoming and Montana, oil, gas, and coal development on federal lands likely have been responsible for even greater habitat loss than have management activities for livestock. In Idaho and Oregon, increased frequency and size of wildfires have produced accelerated conversion of shrubsteppe to exotic annual grasslands.

The shift from sheep to cattle since 1950 probably has resulted in general improvement of conditions in the uplands compared with earlier in this century. Ostensible improvement in uplands has been achieved, however, at the cost of unprecedented impact on moist habitats, which likely are now in their worst condition since European settlement of the American West (Chancy et al. 1990, USDI 1994: p. 25). Even with recent decreases in livestock AUM's, the presence of livestock at inappropriate times of year continues to be detrimental for Sage Grouse reproduction and recruitment. A shift from spring and summer grazing to fall grazing regimens in nesting and brood-rearing areas would likely benefit Sage Grouse populations.

Although the quality and reliability of population data for Sage Grouse vary among states (p. 22), the general pattern that emerges from a state by state assessment is one of apparent sustained decline in conjunction with increased conversion and degradation of sagebrush shrubsteppe on federal rangelands. Spray programs and other management actions that result in complete removal of sagebrush are anathematic to Sage Grouse. With regard to Sage Grouse management and conservation, habitat is clearly of utmost concern.

2. *Restoration of a landscape-scale mosaic of natural habitats*

- to be achieved through the introduction of fire at appropriate temporal and spatial scales and the re-introduction of native perennial grasses, forbs, and shrubs.

From a landscape-scale perspective, sagebrush steppe landscapes are fire adapted ecosystems with intrinsic fire frequencies that maintain landscape-scale mosaics of natural habitats. Although shrubsteppe ecosystems are fire adapted, different sagebrush species/subspecies evolved with characteristically different fire frequency intervals. Where the interval has been unnaturally lengthened (or shortened) through management activities, the landscape-scale mosaic pattern of different seral stages is altered profoundly. Poor livestock management, fire suppression, and the introduction of exotic plant and animal species has resulted in over-dominance by shrubs in many areas, with a consequent suppression of the native herbaceous community. Depending upon the type of sagebrush, as little as 20-30% shrub cover impedes, depresses, or eliminates the native understory component of these communities.

Vast expanses of late seral stage sagebrush, broken only by agricultural development and areas dominated by exotic plant species, constitute ecologically dysfunctional landscapes. There is an urgent need to restore a landscape-scale balance of native shrubs, grasses, and forbs - which ultimately also should restore other ecological processes, such as soil regeneration. The restoration goal of management should be vast contiguous expanses of native plant communities comprised of an interspersion of different successional stages and sagebrush stands of different age-classes. Hence, a management goal of creating landscape-scale heterogeneity of natural habitats where vast stands of monotypic sagebrush presently exist.

In many areas, the problem today is that fire frequency and extent have increased greatly, thus destroying the ability of big sagebrush to reseed naturally (since it does not resprout), while facultatively enhancing invasion and dominance by exotic plant species. A dramatic increase in fire frequency (e.g., 3-5 year intervals) leads to replacement of sagebrush by annuals, which further increases fire frequency and accelerates the degree to which such areas become steady-state systems of annual exotics.

The BLM has the opportunity to undertake a major effort aimed at reducing deleterious fire frequencies by use of native plant species (which are less fire-determinant than invasive, exotic, annual species), which would retard destructive fires and facilitate beneficial fires. Furthermore, in the present absence of a policy, the BLM should establish the policy of exclusively using native shrubsteppe species for re-seeding of burned or otherwise converted rangelands, and eliminate totally the use of exotic plant species in land management activities. Creation of such an unambiguous policy will spur rapid commercial development of viable seed sources representative of a range of species and genotypes for such use.

3. Reduction of landscape fragmentation

- to be achieved by consolidation of land holdings and cessation of management actions that promote fragmentation of contiguous habitat blocks.

Management and restoration of lands at ecologically appropriate spatial and temporal scales to benefit Sage Grouse will require consolidation of habitat blocks to produce landscape mosaics of contiguous natural habitats. Recent efforts by the BLM to acquire good ecological habitat in trade for degraded or very fragmented parcels should be continued and expanded with the preceding goals in mind to provide potential options for future management.

4. Restoration of early brood-habitat for Sage Grouse

In the few populations for which sufficient data exist, the annual population structure of Sage Grouse approximates 50% juveniles, 20% yearlings, and 30% adults. Clearly, if there is no annual production, populations plummet.

Chick diets are composed primarily of live forbs and insects, and forb availability is the key to the distribution of birds through the brood-rearing period. The most critical seasonally required habitat type by virtue of its loss throughout the geographic range of the species is brood habitat. Restoration of this type of habitat would achieve the greatest benefit not only for Sage Grouse but for a wide array of other wildlife species, as well. Restoration should include modification of former range improvements, in order to provide livestock-free wet meadows where springs previously existed.

INVENTORY/MONITORING RECOMMENDATIONS

1. Ecologically meaningful inventory and classification of shrubsteppe lands integrated with GIS technology

An accurate description of the current composition of shrubsteppe lands and the spatial dispersion of native plant communities relative to one another and to non-native communities is the essential and logical starting point for meaningful management and restoration activities. Without such information, realistic decisions concerning management actions cannot be made, and management instead approximates art rather than science.

The goal of landscape-scale demonstration projects (p. 12) to better understand the roles of fire and livestock grazing cannot be achieved without better information than is presently at hand. For example, management areas cannot be prioritized rationally for such efforts without more ecologically realistic descriptions and knowledge of the condition of shrubsteppe habitats. Integration with GIS based technology will provide a meaningful set of ecological benchmarks by which to evaluate rangeland habitats.

2. Adherence to rigorous standardization of lek-count methodology

What sorts of monitoring data for Sage Grouse would be worthwhile to collect in the future? Of the various "standard" categories of data collected historically, lek counts offer the greatest promise of meaningfully tracking population trends (p.23), but only if conducted rigorously.

Of greatest importance is that lek surveys must be conducted by area, not simply by visiting known lek sites. In order for leks to be counted properly, complete areal coverage of sample areas must be accomplished. For each lek, current sampling guidelines require four counts annually at 10 day intervals for adequate sampling. These guidelines should not be viewed as optional - they should be adhered to rigorously.

The vast majority of existing lek count data that have been analyzed for population trends is compromised severely by gross inconsistency. Lek count data from the state of Washington are typical of the data collected by most states: sources of variation include the number of visits per lek, too few visits per lek (only rarely have leks been visited more than once per year), weather variation among survey days, date of visit (early or late in lek season - often the survey date was not recorded), and uncertainty whether only males were counted or whether both sexes were counted (i.e., uncontrolled observer bias).

Existing lek data may be useful for demonstrating loss of populations when compared to current, correctly sampled, area-based lek data. Such data can serve as a baseline against which to judge that there has been decline, but cannot be used to indicate whether populations are stable or increasing (relative to historic data).

A two-tiered system of lek counts suggested by Clait Braun of the Colorado Division of Wildlife may serve as a way of integrating data from varying efforts: 1) intensive sampling that is area-based, with leks visited four times yearly, and 2) extensive sampling, restricted to known lek sites, with leks visited once yearly to provide information on activity (i.e., presence/absence of birds). Of the two sampling modalities, the latter should be considered only as an adjunct, not a substitute, for intensive sampling.

3. Prospects for a coordinated analysis of long-term Sage-Grouse population data

One goal of the conference was to evaluate the prospects for a coordinated statistical analysis of long-term Sage Grouse population data including spatial and temporal aspects of population fluctuations at local, regional, and range-wide scales. Population trends have been based primarily on four types of data: brood counts, banding studies, wing harvests, and lek counts, and these data were summarized by representatives from each of the primary states in the species' range (see Appendix 1). Based on these presentations, it is clear that the quality of the data simply cannot support any meaningful or statistically legitimate analytical approach to examine spatial and temporal aspects of population fluctuations at any relevant scale. There is no biological reality to the concept of populations in the extant data, which have been collected and organized largely by counties, management units, or other sorts of administrative rather than biological bases. Although some states possess reasonably good numerical trend data, such data cannot address cause-and-effect relationships or population-level patterns.

In addition to tremendous variation among states in the relative effort and care expended to assess Sage Grouse populations, significant problems exist for each of the four primary types of data. Brood counts, for example, can be very misleading: they may be high in drought years with low Sage Grouse production because broods are spatially clumped in the few good areas and thus easily counted. Conversely, numbers may be low in wet years with good production because animals are spread across much larger areas providing good habitat and thus under-sampled.

In hunted populations, banding studies with harvest rates achieving a maximum of only 5-10% (and therefore providing recoveries considerably less than 5-10% of banded birds) provide little data for great expense and effort. There have been only three major banding studies with Sage Grouse, but none were conducted specifically to ascertain survival and mortality, and thus were not designed for understanding population structure or dynamics.

Estimates of survival from wing harvest data, the type of data most available, are complicated by the likelihood that young birds may be more vulnerable to hunting, thus biasing estimates of survival based on wing data. Additionally, the timing of hunting has been variable among states (as well as within states), and often timed so that yearlings cannot be identified by wings due to the timing of molt. apparently insurmountable obstacles preclude coordination of hunting seasons among states to resolve this problem.

Lek data, with significant reservation, offer the best opportunity from among the sorts of data that have been collected traditionally for Sage Grouse. The critical caveat is that leks need to be properly counted - complete areal coverage must be accomplished (p. 21). For most states, the data are so inconsistent that they cannot meet the assumptions that underly appropriate analytical techniques. Unfortunately, such data harbor the potential for supporting grossly erroneous conclusions. For example, much of the lek data confounds group size with number of groups and with density. Such confusion leads to the quandary of having no idea what happens to number of males per lek versus number of leks as density varies. The inability to answer this basic question compromises the ability of extant lek data to provide reliable projections of population dynamics.

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THE HIGH DESERT
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The High Desert Ecological Research Institute, under the direction of Dr. David S. Dobkin, was established in 1993 to serve as a regional center for ecological research and policy analysis with a primary focus on natural resource issues related to the Intermountain West and the Pacific Northwest. The Institute conducts cooperative, multidisciplinary, long-term research on a wide range of problems in natural resource management and conservation in western North America.

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Appendix 1 - Final Program of the HDERI Sage-Grouse Conference

1. An Historical and Landscape Perspective of Past and Present Land Management Practices in Shrubsteppe Ecosystems

   Alan R. Sands, Bureau of Land Management, Boise, ID
   Erick G. Campbell, Bureau of Land Management, Portland, OR

2. A Landscape Scale Perspective of Temporal and Spatial Changes in the Intermountain Sagebrush Steppe

   Richard Miller, Northern Great Basin Experiment Station, Oregon State University, Burns, OR

3. Habitat Relationships of Sage Grouse

   Clait E. Braun, Wildlife Research Center, Colorado Division of Wildlife, Fort Collins, CO

4. Male Mating Strategies, Female Movements, and the Dispersion of Leks in Sage Grouse

   Jack W. Bradbury, Department of Biology, University of California San Diego, La Jolla, CA

5. Reproductive Isolation and the Reality of Species/Subspecies Distinctions in Sage Grouse

   Jessica R. Young, Department of Biological Sciences, Purdue University, West Lafayette, IN

6. Importance of Herbaceous Cover to the Reproductive Success of Sage Grouse

   John A. Crawford, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR

7. Movement and Habitat Use of Sage Grouse in a Fragmented Landscape

   Michael A. Schroeder, Washington Department of Wildlife, Bridgeport, WA

8. Efficacy of Sage Grouse Translocation Efforts

   Kerry P. Reese, Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID
   John W. Connelly, Idaho Department of Fish and Game, Pocatello, ID

9. Assessment of Sage Grouse Movements from Telemetry Data: What Do the Data Tell Us?

John W. Connelly, Idaho Department of Fish and Game, Pocatello, ID
Kerry P. Reese, Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID

10. Demographic Analyses and Population Dynamics Models: Possible Tools to Aid the Conservation of Sage Grouse

Barry R Noon, School of Forest Resources, University of Georgia, Athens, GA

11 & 12. Prospects for a Coordinated Analysis of Long-Term Sage Grouse Population Data: Spatial and Temporal Aspects of Population Fluctuations - Local, Regional, and Range-Wide Scales

Discussion led by:

Kenneth Pollock, Department of Statistics, North Carolina State University, Raleigh, NC

Based on individual presentations describing the long-term population data for each of the core states:

Montana: Robert Eng, Montana State University
Colorado: Clait Braun, Colorado Division of Wildlife
Wyoming: Brian Heath, Wyoming Cooperative Wildlife Research Unit
Utah: Michael Welch, Utah Division of Wildlife Resources
Nevada: San Stiver, Nevada Department of Wildlife
Idaho: Jack Connelly, Idaho Department of Fish and Game
Washington: Michael Schroeder, Washington Department of Wildlife
Oregon: George Keister, Oregon Department of Fish & Wildlife