Greater Sage Grouse in Colorado
Statewide Conservation Planning Workshop

9 – 11 May 2006
Steamboat Springs, Colorado

WORKSHOP REPORT

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A Collaboration Between:
The Colorado Greater Sage-grouse Conservation Plan Steering Committee
Colorado Division of Wildlife
IUCN / SSC Conservation Breeding Specialist Group
Workshop Participants

Workshop Support Provided By:
Colorado Division of Wildlife

A contribution of The Colorado Division of Wildlife and the IUCN / SSC Conservation Breeding Specialist Group.

Greater Sage Grouse cover sketch courtesy Brian Maxfield

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EXECUTIVE SUMMARY

Introduction

Dependent exclusively on sagebrush ecosystems that define the ecology of much of western North America, the Greater Sage Grouse (*Centrocercus urophasianus*) was once distributed across twelve states of the western United States and three provinces of Canada. Greater sage-grouse currently occupy 700,000 km^2, or 56%, of their potential pre-settlement range, which once covered approximately 1,200,000 km^2 (Schroeder et al. 2004). The species is now lost from Nebraska and Alberta, and other peripheral populations are at increasing risk of extirpation. As a result of these declines, petitions have been filed to list the species under the United States Endangered Species Act.

In Colorado, Greater Sage Grouse occupy significant tracts of sagebrush habitat in the northwestern region of the state. Authors contributing to the completion of the Colorado Greater Sage Grouse Statewide Conservation Plan have identified six largely discrete regions where birds are found and have formed local working groups of concerned citizens, researchers, and managers dedicated to developing grouse conservation strategies at the local level. As in many other western states, there is concern over a variety of human activities – new housing development, oil and natural gas exploration, livestock grazing, surface mining, and hunting – that may unintentionally result in significant negative impacts to local Sage Grouse populations. These impacts might possibly destabilize the integrity of the sagebrush habitat or the populations themselves to an extent where the risk of local extinction is greatly increased. Therefore, it is critical that the potential impact of these activities is evaluated using sound scientific methodologies, and the results of these analyses are incorporated into the evolving statewide species conservation strategies.

In order to conduct this evaluation, and to assist in the development of conservation strategies to address threats to the species across the state, the Colorado Division of Wildlife (CDOW) approached the Conservation Breeding Specialist Group (CBSG), part of the Species Survival Commission of the IUCN – World Conservation Union, to design and facilitate a workshop process known as a Population and Habitat Viability Assessment, or PHVA for the Colorado population of the Greater Sage Grouse. CDOW invited CBSG to conduct this workshop in May 2006 on behalf of the Colorado Greater Sage Grouse Statewide Conservation Plan Steering Committee, composed of representatives from Bureau of Land Management (BLM), CDOW, Colorado State Land Board (SLB), Natural Resources Conservation Service (NRCS), US Forest Service (USFS), and US Fish and Wildlife Service (USFWS). Nearly 80 stakeholders from the public and private sector – including national, state and local government representatives, landowners, wildlife managers, and industry leaders – came together in Steamboat Springs to:

- Review detailed descriptions of human activities known to occur in Greater Sage Grouse habitat, and to evaluate their impacts on local bird populations;
- Identify other companion conservation issues of direct relevance to management of Greater Sage Grouse in Colorado;
- Develop meaningful and achievable conservation strategies for effective management of Greater Sage Grouse in Colorado, using detailed insights from a quantitative population risk assessment as a guide.

The PHVA Workshop Process

The PHVA workshop began on the morning of 9 May, 2006, with an opening greeting from Mr. Bruce McCloskey, CDOW Director, who spoke honestly of the need for proactive conservation management of the Greater Sage Grouse in Colorado (the species has yet to be listed as Endangered) and the importance of working together in good faith throughout the process. Lead facilitator Philip Miller from CBSG then introduced the general format of the PHVA workshop process, and asked the body of participants to introduce themselves and state their personal goals for the workshop as well as their own view of the primary challenges facing sustainable management of the Greater Sage Grouse in Colorado over the next 25 years. This session was followed by a pair of presentations on the status of the Statewide Conservation Plan and the biology of the Greater Sage Grouse. After brief presentations on CBSG's PHVA workshop process and the general concept of population viability analysis or PVA, Phil Miller then led the group through a detailed discussion of the structure and quantitative results of the PVA he conducted for the Greater Sage Grouse populations distributed across Colorado. This generated a considerable amount of discussion, as intended, and was important as background information to be used in the working group sessions to follow.

The Conservation Plan Steering Committee, working with CBSG workshop facilitators, identified five important topics to serve as the central focus of a series of working groups that would convene during the workshop and discuss relevant issues and strategies. These topics were: housing development; grazing; hunting; predation; and energy (oil and natural gas) development. Participants were invited to break up into these five groups, with CBSG team members and a local mediation / facilitation expert serving as leaders of the individual groups. An iterative process of working group sessions, followed by plenary presentations of working group activity and discussions, defined the remainder of the workshop agenda.

In preparation for the workshop, the Conservation Plan Steering Committee put together a pair of matrices that summarized the geographic specificity and intensity of the primary human activities known to occur on Greater Sage Grouse habitat, and that were the focus of the aforementioned working group topics. These matrices are presented at the end of this Summary. There was considerable discussion centered around the characterization of these activities, which will no doubt assist the creation of the Statewide Conservation Plan for the species.

The PVA demonstrated the sensitivity of Greater Sage Grouse populations to changes in female breeding and survival parameters, as well as average clutch size per successfully breeding female. In addition, the analyses indicated that human activities like harvest and oil and natural gas development, which affect Greater Sage Grouse demographic rates (e.g., survival and reproduction) directly, can have particularly severe consequences for the long-term viability of local Grouse populations. In particular, predicted levels of oil and natural gas development in selected regions of Colorado may have very significant negative consequences for local Greater Sage Grouse populations. Scientific data collected on Greater Sage Grouse populations in Wyoming suggest that development activity appears to directly impact the ability of female Grouse to survive and reproduce. These data, however, are subject to scientific scrutiny and may ultimately overestimate the impact of the development activity. Additional PVA models are likely to be constructed that will more realistically simulate the long-term characteristics of this development activity and its impact on local Sage Grouse populations.

The working groups consolidated the issues identified in the earlier introductory session, where appropriate, and amplified them to ensure clarity and level of importance. Participants were then asked to write a more informative "problem statement" for each issue and to prioritize these statements. The next step was to reach some enhanced level of appreciation of the available information pertaining to the working group topics and, perhaps more importantly, separate assumptions from hard fact and identify information gaps that may impede proper conservation decision-making. With this information in hand, management goals were identified and prioritized, and a set of detailed action steps – including comprehensive listings of those responsible for moving the recommendations forward and estimated timelines required for their completion – were developed for each high-priority goal. These action steps are then to be incorporated into the evolving Statewide Conservation Plan under the guidance of the Colorado Division of Wildlife, thereby increasing its effectiveness in achieving sustainable management of Greater Sage Grouse in a way that addresses the needs of a broad diversity of stakeholders.

Presented below are each working group's top-priority issue, followed by the goals specifically designed to address them:

Housing

Issue: Housing development in sagebrush ecosystems results in permanent loss of Greater Sage Grouse habitat to residential and commercial uses.

Goal: Short-term: reduce the loss of seasonally important sage-grouse habitat (both public and private) within occupied sage-grouse range in MWR, MP, NESR, and Zone 4B of NWCO populations, from housing development (and related commercial development and infrastructure).

Goal: Long-term: protect seasonally important sage-grouse habitat within occupied range based on priority areas identified by future management recommendations to housing development and related commercial development and infrastructure

Grazing

Issue: There is a lack of understanding of Greater Sage Grouse habitat and the relationship to herbivory.

Goal: Determine if there is a causal relationship between herbivory and Sage Grouse habitat quality and Sage Grouse population fluctuations.

Predation

Issue: There are political, societal and biological difficulties to create effective predator management..

Goal: Improve public understanding of the role of predation on Greater Sage Grouse populations.

Goal: Encourage timely, innovative strategies that include an adaptive management and monitoring scheme.

Goal: Identify the funding needed and secure necessary amount to implement predation strategies and goals in local plans.

Hunting

Issue: How do we effectively address the perception of hunting sage grouse when they have been petitioned for listing?

Goal: Change the perception about status of the sage grouse population by proactively providing accurate information about the sage grouse population, management and sustainability of hunting (short-term)

Energy

Issue: Monitoring, mitigation and management

Goal: Reduce spatial and temporal influence /footprint of oil and gas development in both occupied and suitable unoccupied Greater Sage Grouse habitat

The detailed reports from each of the five working groups can be found in Sections II through VI of this document, and the detailed report from the PVA analysis can be found in Section VII.

Matrix of human activities, their regional specificity, and their current and projected future intensity in each of the six regions supporting Greater Sage Grouse populations in Colorado. Regional abbreviations:
NW, Northwest Colorado; PPR, Piceance / Parachute / Roan; WHITE, Meeker / White River; NP, North Park; MP, Middle Park; ER, North Eagle / South Routt. N/A, not applicable. See accompany text for additional details.

Activity	NW	PPR	WHITE	NP	MP	ER
Grazing	High (both); stable to decreasing	Moderate; stable	Moderate; stable	Moderate; stable	Moderate; stable	High; decreasing
Housing	Low; increasing	Low; stable	Moderate; increasing	Low; increasing	High; increasing	High; increasing
Hunting	Low; stable	N/A	N/A	Low Increasing	Low stable	N/A
Oil/Gas	Moderate; increasing exponentially	High; increasing exponentially	Low; stable	Low; increasing (potential)	Low; stable	Low; stable
Surface Mining (Coal, etc.)	Moderate; increasing	Low; increasing (potentially)	Low; stable	Low Stable	Low; increasing	Moderate; increasing
Predation	Low; stable	Low; stable	Moderate; stable	Low; stable	Low; stable	Moderate; stable
Recreation	Low, increasing	Low, increasing	Low, increasing	Low, increasing	Low, increasing	Low, increasing

Matrix of human activities, their regional specificity, and their current and projected future intensity for individual management zones comprising the Northwest Colorado region. N/A, not applicable. See accompany text for additional details.

Area	Grazing	Housing	Hunting	Oil/Gas	Surface Mine	Predation	Recreation
Zone 1	High, stable	Low, stable	High, stable	Moderate, increasing	Low, stable	Low, stable	Low, stable
Zone 2	Moderate, stable	None	None	High, increasing greatly	Low, stable	Low, stable	Moderate, increasing
Zone 3A	Moderate, decreasing	Low, stable	Low, stable	Moderate, stable	Low, stable	Low, stable	Low, stable
Zone 3B	High, stable	Low, increasing	Moderate, stable	High, increasing	Low, stable	Low, stable	Low, stable
Zone 3C	Moderate, stable	Low, increasing	None	Moderate, stable	Low, increasing	Moderate, stable	Low, stable
Zone 4A	High, stable	Low, stable	None	Moderate, increasing	Low, stable	Low, stable	Low, stable
Zone 4B	Same as 3C	Moderate, increasing	None	Moderate, increasing	High, increasing	Moderate, stable	Low, stable
Zone 5	Moderate, stable	Low, stable	Low, stable	Low, stable	Moderate, increasing	Low, stable	Low, stable
Zone 6	Moderate, stable	Low, stable	High, stable	Moderate, increasing	Moderate, stable	Low, stable	Low, stable
Zone 7	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah

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Section II

Housing Development Working Group Report

Housing Development Working Group Report

Working Group participants:
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Megan McGuire, Bureau of Land Management
Pam Schnurr, CO Division of Wildlife
Jenn Logan, CO Division of Wildlife
Michelle Cowardin, CO Division of Wildlife
Ken Strom, Audubon Colorado
Barb Ver Steeg, CO Division of Wildlife (Recorder)
Luis Carrillo, CBSG (Facilitator)

Problem Statements

The working group identified the following general issues/problems pertaining to Greater Sage Grouse management in Colorado, with subordinate issues listed underneath each general statement. These problem statements are listed in order of priority, based on the degree of irreversibility and scope of impact to the species. Numerical value after each statement is the aggregate score obtained from the prioritization procedure, totaled across all working group participants.

1. Housing development in sagebrush ecosystems results in permanent loss of Greater Sage Grouse habitat to residential and commercial uses. [69]
    - Increased commercial development
    - Habitat loss; important seasonal habitats
    - Importance of second homes in some areas: Owners may not be as in tune with issues in local environment; also not tracked in census numbers; homes, and often even second homes are actually tracked by the county

2. Housing development in occupied and potential Greater Sage Grouse range results in reduced effectiveness of Greater Sage Grouse habitats (e.g., contaminant loading, reduced habitat patch size, increased habitat patch isolation). [39]
    - Housing distribution/habitat fragmentation
    - Increased contaminant loading, general pollution (e.g, fertilizer, pesticides, etc.) drainage issues
    - Disruption of movement, isolation of populations through habitat fragmentation
    - Ecological disruption: increased predator concentration (landfills, etc.)

3. Housing development increases human presence, pets, and activities that disturb sage-grouse behavior, potentially affecting survival and reproduction in Greater Sage Grouse populations. The effects may extend for some distance beyond development sites. [35]
    - Importance of 2nd homes in some areas: owners may not be as in tune with issues in local environment; also not tracked in census numbers, so not in projections calculated for the PVA; (homes, even 2nd homes) are actually tracked by the county
    - Domestic animals (increase in dogs and cats)
    - Recreation component: increased use on public and private land; all seasons
    - Human disturbance

- Increased commercial development

4. Greater Sage Grouse habitat is not recognized by current regulatory frameworks for pre-planning for housing development and mitigation of impacts on private lands. [29]

   - Private property rights
   - Subdivision of private land; opposition to regulation
   - Ranchettes; parcels over 35 acres are not regulated by county land use planning (S.B. 35)
   - Land-use planning; communication among local (county), state, and federal government agencies; e.g., county may not take into account habitat designations by state/federal agencies

5. Increasing water demand resulting from local and statewide population growth (housing development) can lead to changes in water use within sagebrush habitat, including altered streamflow, transfer of water rights, reduction of irrigated habitats, and inundation at storage sites. [26]

   - Loss of brood habitat: irrigated hayfields converted to housing (change in water use and water rights; conversion of agricultural water use/rights to municipal water use/rights)
   - Importance of 2nd homes in some areas: owners may not be as in tune with issues in local environment; also not tracked in census numbers, so not in projections calculated for the PVA; (homes, even 2nd homes) are actually tracked by the county
   - Increased water storage (e.g., reservoirs); not just local growth drives this
   - Front Range diversions

6. There is a lack of awareness of Greater Sage Grouse on the part of planners, developers, and housing residents, resulting in land management decisions that impact sage-grouse (habitat loss, habitat degradation, and disturbance to Greater Sage Grouse). [14]

   - Land-use planning; communication among local (county), state, and federal government agencies; e.g., county may not take into account habitat designations by state/federal agencies
   - Public education/Lack of awareness

Other issues of potential importance to Greater Sage Grouse management but not considered explicitly here include:

- Increase in roads (may recognize that it will be addressed separately), other infrastructure
- Increase of gravel pits for housing construction (generally located in floodplains)
- Invasive, exotic, and noxious weeds

Data Assembly and Synthesis

Issue 1:

Housing development in sagebrush ecosystems results in permanent loss of sage-grouse habitat to residential and commercial uses.

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Housing development is increasing in SG occupied habitat in Colorado in past 15 years.	Housing will continue to increase in SG occupied habitat	Amount and location of second home development (may be able to get some related info from NW Council of Governments web site)	Middle Park, Meeker – White River, NESR, Zone 4B of NWCO	Theobald 2005; CensusScope 2006
Very large ranches have been subdivided into large parcel (100+ acre) subdivision over which regulatory agencies have little control	Subdivision is expected to continue		Grand County	Grand County GIS, county planning records, aerial photography
35-acre parcels have been subdivided into 12/13-acre parcels	Subdivision is expected to continue		Grand County	Grand County GIS, county planning records, aerial photography
Current parcel data and population data that went into PVA model	Population projections, accompanying housing growth, distribution of future housing among parcel size classes	Commercial development	MP, MWR, NESR, NWCO Zone 4B	Colo. Dept. Local Affairs (PVA housing background document, rangewide plan)

Issue 2:

Housing development in occupied and potential sage-grouse range results in reduced effectiveness of sage-grouse habitats (e.g., contaminant loading, reduced habitat patch size, increased habitat patch isolation).

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Housing development has fragmented sagebrush habitat	Habitat fragmentation of sagebrush is deleterious to sage-grouse	Patch size (and other spatial parameters of habitat) requirements for sage-grouse Does habitat fragmentation affect sage-grouse movements?	All	Oyler-McCance et al. 2001
Residential properties apply chemicals at higher rates than do agricultural properties	Contaminant loading negatively impacts sage-grouse, directly or indirectly by affecting habitat			Data from water treatment plants, county extension agents, NRCS

Issue 3:

Housing development increases human presence, pets, and activities that disturb sage-grouse behavior, potentially affecting survival and reproduction in sage-grouse populations. The effects may extend for some distance beyond development sites.

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Human activities impact sage-grouse.	Activities associated with housing development would have similar impacts on sage-grouse.	No rigorous studies of specific impacts of human activities on sage-grouse.	All, more concentrated in some areas than others.	See CCP sections on Recreation, Roads, Energy Development
Free-roaming dogs and cats negatively impact ground-nesting birds.	Dogs and cats negatively impact sage-grouse.			Warner (IL paper), CCP Recreation section
Impacts of human activity may extend some distance beyond development sites.	Activities associated with housing development would have similar impacts on sage-grouse.			Holloran 2005, Lyon and Anderson 2003

Issue 4:

Sage-grouse habitat is not recognized by current regulatory frameworks for pre-planning for housing development and mitigation of impacts on private lands.

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
S. B. 35 limits the ability of counties to regulate development on private parcels >35 acres in size.	This law will continue for the foreseeable future.		All	S.B. 35
Most county and municipal governments do not include regulations to protect sage-grouse habitat.			All	County land use regulations, H.B. 1041
Regulatory measures that apply on public lands may not be enforceable on private property.			All	U.S. Constitution and federal law
Three petitions to list GrSG under the ESA have been evaluated by the USFWS.	Future petition(s) are anticipated.		All	USFWS Federal Register notice

Issue 5:

Increasing water demand resulting from local and statewide population growth (housing development) can lead to changes in water use within sagebrush habitat, including altered streamflow, transfer of water rights, reduction of irrigated habitats, and inundation at storage sites.

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Demand for water is increasing statewide.	Demand will continue		All, but impacts may be concentrated in some areas.	Statewide water supply initiative (DNR 2005, H.B. 1177)
Documented shift from agricultural to municipal uses of water.	Shift will continue			Statewide water supply initiative (DNR 2005, H.B. 1177)
There are identified gaps between water demand and supply.	Water storage and inter-basin transfers are likely to be used to address those gaps.	Location of new water storage areas.		
	Increased water consumption, water storage, and inter-basin transfers will decrease sage-grouse habitat.			

Issue 6:

There is a lack of awareness of sage-grouse on the part of planners, developers, and housing residents, resulting in land management decisions that impact sage-grouse (habitat loss, habitat degradation, and disturbance to sage-grouse).

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
Local governments do not require planners, developers, and housing residents to be educated about sage-grouse.	Planners, developers, and housing residents are not currently informed about sage-grouse.		Varies by local government.	Local land-use regulations
Local governments do not require land-use planning that considers impacts on sage-grouse.	Local land-use planning does not currently adequately protect sage-grouse.		Varies by local government.	Local land-use regulations

Management Goals and Strategies

Issue 1:

Housing development in sagebrush ecosystems results in permanent loss of Greater Sage Grouse habitat to residential and commercial uses.

Goal 1.1

Short-term: reduce the loss of seasonally important sage-grouse habitat (both public and private) within occupied sage-grouse range in MWR, MP, NESR, and Zone 4B of NWCO populations, from housing development (and related commercial development and infrastructure).

Action 1.1.1

Using GIS, identify occupied and seasonally important Grouse habitats and leks that are at highest risk of development.

Responsible parties: CDOW GIS and Wildlife Conservation Section
Timeline: May 2007
Collaborators: County planning and GIS
Resources: Parcel and ownership data; Seasonally important sage-grouse data set (CDOW SAM data); 0.04 FTEs
Results: Map and background data will be produced
Consequences of inaction:
Obstacles:

Action 1.1.2

Identify areas for potential conservation actions (e.g., management plans, easements, Farm Bill programs, land exchanges, acquisition), and share this information with interested stakeholders.

Responsible parties: CDOW GIS and Wildlife Conservation Section
Timeline: November 2007 and ongoing
Collaborators: NRCS, NGO's, BLM, USFS, Land Trusts, local work groups

Action 1.1.3

Incorporate sage-grouse considerations into existing easements and management plans as opportunities arise.

Responsible parties: CDOW GIS and Wildlife Conservation Section
Timeline: May 2011
Collaborators: Land Trusts, Landowners, local work groups

Action 1.1.4

Identify and pursue funding sources for protection of identified areas, and encourage collaborative conservation funding opportunities.

Responsible parties: CDOW GIS and Wildlife Conservation Section
Timeline: May 2007 and ongoing
Collaborators: NGO's, Land Trusts, federal agencies, local work groups

Action 1.1.5

Set specific goals for amount of priority areas to protect.

Responsible parties: Local work groups
Timeline: May 2009
Collaborators: CDOW, federal agencies, NGOs, lead researchers
Resources:

Action 1.1.6

Pursue opportunities to protect identified areas (e.g., management plans, easements, land exchanges, acquisition).
Responsible parties: CDOW, Wildlife Conservation Section
Timeline: May 2007 and ongoing
Collaborators: NGO's, Land trusts, local work groups, federal agencies, State Land Board

Action 1.1.7

Establish a mechanism for tracking conservation easements that include protection for sage-grouse.
Responsible parties: CDOW, Wildlife Conservation Section
Timeline: May 2008
Collaborators: Land Trusts, Counties

<u>Goal 1.2</u>

Long-term: protect seasonally important sage-grouse habitat within occupied range based on priority areas identified by future management recommendations to housing development and related commercial development and infrastructure

Action 1.2.1

Obtain funding from identified sources.
Responsible parties: CDOW Wildlife Conservation Section
Timeline: May 2012 and ongoing
Collaborators: NGO's, Land Trusts, GOCO, federal agencies

Action 1.2.2

Protect identified areas from housing development through implementation of short-term actions.
Responsible parties: CDOW Wildlife Conservation Section
Timeline: May 2012 and ongoing
Collaborators: NGO's, Land Trusts, GOCO, federal agencies, counties

Action 1.2.3

Review, update, and monitor short-term actions.
Responsible parties: CDOW Wildlife Conservation Section
Timeline: May 2012 and ongoing
Collaborators: NGO's, Land Trusts, GOCO, federal agencies, counties

Action 1.2.4

Monitor and track land-use changes and infrastructure development in relationship to occupied and seasonally important habitats and leks.
Responsible parties: CDOW GIS and Wildlife Conservation Section
Timeline: May 2012 and ongoing
Collaborators: Counties

Issue 2:

Housing development in occupied and potential sage-grouse range results in reduced effectiveness of sage-grouse habitats (e.g., contaminant loading, reduced habitat patch size, increased habitat patch isolation).

<u>Goal 2.1</u>

Short-term: Reduce fragmentation of sage-grouse habitat within occupied habitat resulting from new housing development..

Action 2.1.1

Identify and map areas where new development could potentially fragment existing populations.
Responsible parties: CDOW GIS and Wildlife Conservation Section
Timeline: May 2008
Collaborators: County governments, developers

Action 2.1.2

Monitor leks and other seasonally important sage-grouse habitat in jeopardy of fragmentation due to development.
Responsible parties: CDOW Field Operations and Terrestrial, and Wildlife Conservation Sections
Timeline: May 2008 and ongoing
Collaborators: NGOs, federal agencies

Action 2.1.3

Meet with land management agencies and local developers to address and recommend management actions to mitigate adverse impacts to sage-grouse habitat.
Responsible parties: Local work groups
Timeline: May 2007 and ongoing
Collaborators: Developers, County Governments, CDOW, Land Trusts, federal agencies, industry (utilities) landowners

Action 2.1.4

Create guidelines or recommendations to highlight the effects of habitat fragmentation (due to housing and related infrastructure) on sage-grouse populations.
Responsible parties: CDOW Wildlife Conservation Section and GIS
Timeline: May 2011
Collaborators: County Governments, federal agencies, NGO's

<u>Goal 2.2</u>

Long-term: reduce fragmentation of sage-grouse habitat within occupied and potential resulting from new housing development

Action 2.2.1

Conduct research to determine (1) sage-grouse habitat patch size and configuration needs, and (2) fragmentation impacts on movements and population isolation.
Responsible parties: CDOW Avian Research Section
Timeline: May 2012 and ongoing
Collaborators: Universities, Research Institutes, landowners

Action 2.2.2

Prioritize sage-grouse habitat areas to protect or reduce impacts from habitat fragmentation due to housing and related development.
Responsible parties: Local work groups
Timeline: May 2012 and ongoing
Collaborators: CDOW, NGO's, Land Trusts, federal agencies, developers

Action 2.2.3

Encourage local governments to develop land-use recommendations or guidelines to reduce habitat fragmentation from housing and related development.
Responsible parties: Local work groups
Timeline: May 2012 and ongoing
Collaborators: Counties, CDOW, NGO's, Land Trusts

Action 2.2.4

Develop predictive models to monitor and assess impacts of habitat fragmentation in sage-grouse habitat.
Responsible parties: CDOW Avian Research Section
Timeline: May 2012 and ongoing
Collaborators: Universities, Research Institutes, USGS, NGO's

Goal 2.3

Reduce the introduction into sage-grouse habitat of contaminants and invasive plants from housing development

Action 2.3.1

Identify potential contaminants and assess the impact on sage-grouse.
Responsible parties: CDOW
Timeline: May 2008
Collaborators: CDPHE

Action 2.3.2

Develop information materials regarding the impacts of contaminants and invasive plants on sage-grouse.
Responsible parties: CDOW
Timeline: May 2011
Collaborators: NRCS, CDPHE

Action 2.3.3

Recommend seed-mix guidelines that are beneficial to sage-grouse (e.g. as used in Farm Bill programs and private land owner, developer, and local government habitat modifications).
Responsible parties: Local work groups
Timeline: May 2007 and ongoing
Collaborators: CDOW, NRCS, Extension offices, Land Trusts, NGO's, developers, landowners, county governments

Action 2.3.4

Recommend re-vegetation techniques for disturbed areas to decrease noxious and invasive weeds
Responsible parties: CDOW Field Operations Section
Timeline: May 2007 and ongoing
Collaborators: NRCS, counties, Extensions, BLM, developers, Utilities

Goal 2.4

Long-term: prevent the introduction into sage-grouse habitat of contaminants and invasive plants from housing development

Action 2.4.1

Encourage NRCS to formally adopt seed type recommendations in short-term action.
Responsible parties: Local work groups
Timeline: May 2012 and ongoing
Collaborators: CDOW, NRCS

Action 2.4.2

Encourage local governments to formally adopt revegetation requirements for disturbed sites.
Responsible parties: Local work groups
Timeline: May 2012 and ongoing
Collaborators: CDOW, NRCS, local governments, Land Trusts

Action 2.4.3

Develop and implement ongoing outreach program for homeowners regarding contaminants and noxious/invasive weeds (e.g., workshops, brochures).
Responsible parties: Local work groups
Timeline: May 2012 and ongoing
Collaborators: CDOW, CDHPE, NRCS, Land Trusts, NGO's, counties

Goal 2.5

Increase sage-grouse habitat effectiveness in existing developed areas

Action 2.5.1

Develop and implement ongoing outreach program for homeowners regarding contaminants and noxious/invasive weeds (e.g., workshops, brochures).
Responsible parties: Local work groups
Timeline: May 2012 and ongoing
Collaborators: CDOW, CDHPE, NRCS, Land Trusts, NGO's, counties

Action 2.5.2

Reduce fragmentation of sage-grouse habitat by encouraging low-impact siting of roads and utilities, as opportunities arise.
Responsible parties: CDOW Field Operations Section and Wildlife Conservation Section
Timeline: May 2012 and ongoing
Collaborators: Local governments, landowners, federal agencies, utility companies

Action 2.5.3

Prioritize areas for increasing sage-grouse habitat effectiveness within and adjacent to existing developments.
Responsible parties: CDOW
Timeline: May 2012 and ongoing
Collaborators: Local work group, federal agencies, landowners, Land Trusts

Issue 3:

Housing development increases human presence, pets, and activities that disturb sage-grouse behavior, potentially affecting survival and reproduction in Greater Sage Grouse populations. The effects may extend for some distance beyond development sites.

Goal 3.1

Reduce disturbance associated with human presence and activities, including pets

Action 3.1.1

Recommend seasonal closures or restrictions within sage-grouse habitat on public lands in close proximity to housing developments.

Action 3.1.2

Work with local governments to encourage homeowner associations and individual homeowners to adopt and enforce pet control measures in and near sage-grouse habitat.

Action 3.1.3

Incorporate information about the impacts of human disturbance on sage-grouse in other outreach efforts to homeowners (see Goal 6).

Issue 4:

Greater Sage Grouse habitat is not recognized by current regulatory frameworks for pre-planning for housing development and mitigation of impacts on private lands.

Goal 4.1

Incorporate sage-grouse habitat conservation into land-use planning decisions.

Action 4.1.1

Provide information to local, state, and federal governments on sage-grouse habitat requirements and status, location, and possible effects of different land uses (including right-of-way and inholding access across public lands) on sage-grouse. Provide examples of policy language.

Action 4.1.2

Work with county planners and commissioners to develop and modify land use and zoning plans to protect sage-grouse habitats (e.g., clusters, density credits, special zoning overlay districts, and development rights transfers).

Issue 5:

Increasing water demand resulting from local and statewide population growth (housing development) can lead to changes in water use within sagebrush habitat, including altered streamflow, transfer of water rights, reduction of irrigated habitats, and inundation at storage sites.

Goal 5.1

Mitigate the impacts to and/or protect seasonally important sage-grouse habitat from increasing water development.

Action 5.1.1

Identify areas of overlap between seasonally important sage-grouse habitat and aquatic and riparian ecosystems.

Action 5.1.2

Identify where existing water uses affect those areas of overlap.

Action 5.1.3

Monitor Colorado Water Conservation Board actions regarding water rights or uses that might affect the ares overlap (e.g., get on mailing list, attend hearings.

Action 5.1.4

Work with water development interests to seek avoidance, changes to, or mitigation for water projects thtat could affect sage-grouse.

Action 5.1.5

If a large reservoir project appears likely near sage-grouse habitat, consider the potential impacts to sage-grouse from indirect effects such as recreation, real estate development, and road realignment.

Action 5.1.6

During regional and statewide water planning efforts provide information on relationships between sage-grouse habitat and water uses.

<u>Goal 5.2</u>

Assure adequate water distribution and flow in sage-grouse brood-rearing habitat.

Action 5.2.1

Work with willing landowners and public agencies to keep water rights tied to existing uses in local areas.

Action 5.2.2

Work with willing landowners to develop or maintain brood-rearing habitat, or replace lost or impacted habitats.

Issue 6:

There is a lack of awareness of sage-grouse on the part of planners, developers, and housing residents, resulting in land management decisions that impact sage-grouse (habitat loss, habitat degradation, and disturbance to sage-grouse).

<u>Goal 6.1</u>

Increase the awareness of sage-grouse conservation among land-use planners and developers, and housing residents.

Action 6.1.1

Compile existing information and guidelines pertaining to human impacts on sage-grouse.

Action 6.1.2

Develop key messages, focused on different types of development (e.g. high or low density rural housing), to include in informational materials.

Action 6.1.3

Prepare and distribute informational materials about sage-grouse to land-use planners, developers, landowners, utility companies, and housing residents.

Action 6.1.4

Develop and implement ongoing outreach program (e.g., workshops, homeowner associations, landowner cooperatives) for homeowners regarding housing development impacts on sage-grouse.

Action 6.1.5

Encourage local agencies, landowners, groups, and interested parties to elicit local representatives' support of decisions regarding sage-grouse conservation actions.

Action 6.1.6

Install sage-grouse information signs (e.g., road crossing signs, kiosks) where appropriate.

Greater Sage Grouse in Colorado
Statewide Conservation Planning Workshop

9 – 11 May 2006
Steamboat Springs, Colorado

WORKSHOP REPORT

Section III
Grazing Working Group Report

Grazing Working Group Report

Working Group participants:
Jean Stetson
Brendan Moynihan
…
Danny Morris, CBSG (Facilitator)

Problem Statements

The working group brainstormed the following list of issues and problems:

1. Elk numbers in Western CO are a problem. Want more information and solutions.
2. Treat wildlife and domestic grazing at the same level.
3. "General herbivory" should be discussed.
4. Good ranching practices make good sage grouse habitat, can be a good tool.
5. Personal property rights.
6. Sage grouse have better reproduction with higher herbaceous cover OR herbaceous cover may limit reproduction.
7. Economic viability for private landowners. Allow them to make a living.
8. Understanding and evaluating stocking rates with livestock and wildlife (elk).
9. Timing of herbaceous plant removal.
10. Value of the open space and the habitat they provide for grouse.
11. Not enough information on what vegetation grouse need, ie how big of sagebrush for winter survival.
12. Residual plant management strategies
13. frequency, timing and intensity of defoliation.
14. Impacts from different types of livestock and ungulates to sagebrush ecosystem.
15. Economic importance of elk and deer to communities from hunting and non-consumptive wildlife recreation from all wildlife including sage grouse.
16. Management of grazing distribution whether domestic or wild.
17. Social issues lacking, private landowners want to be treated as a partner, and not feel threatened. Work on partnerships.
18. Cheaper and easier to plan proactively and take action now than if the species is listed.
19. Recognition of the stewardship of the private landowners, they are true conservationists.
20. Domestic livestock numbers have gone down in every county, wild ungulates numbers have gone up. Wild spend 50% of time on private land.
21. Private landowners have to compete with wildlife.
22. Important to understand the specific landscape, a baseline assessment of what the habitat is capable of, before guidelines are set for habitat.
23. Need more water development for distribution and grouse.
24. Catastrophic wildfire (from beetle kill trees) could affect sage grouse habitat.
25. Plan needs to based on science not conjecture (intuitive)
26. Do Federal agencies really have the ability to manage grouse?
27. Negative language towards domestic grazing should not be in plan.
28. Insufficient funding

This larger list of issues was condensed and prioritized to result in the following set of problem statements:

1. There is a lack of understanding of grouse habitat and the relationship to herbivory.
2. There is a lack of Best Management Practices for sagebrush habitat while maintaining a forage base for domestic and wild herbivores.
3. There is a lack of cooperation, communication and respect and understanding between stakeholders.
4. There is a lack of understanding and respect for socio-economic balance between stakeholders.
5. There is a lack of sufficient funding for habitat projects, monitoring etc.
6. There is a lack of understanding what catastrophic events can do to Grouse populations and how to plan ahead for them.

Data Assembly and Synthesis

Issue 1:

There is a lack of understanding of grouse habitat and the relationship to herbivory.

Facts	Assumptions	Information Gaps
Preferred seasonal habitat requirements	There is a direct relationship between grazing and nest disturbance	Is there is causal relationship between grazing and declining grouse populations?
A given site's potential to grow appropriate sagebrush habitat	Effects of trampling: Livestock studies have not been applied to wild ungulates	
	The effects of other grazers other ungulates, eg: geese, gophers, etc. Insects?	
	High and low population of grouse are not grazing related, usually climate.	
	Grazing has direct effects on sage grouse	

Issue 2: There is a lack of Best Management Practices for sagebrush habitat while maintaining a forage base for domestic and wild herbivores.		
Facts	**Assumptions**	**Information Gaps**
Historical co-existence between wild and domestic herbivores		We don't know how to manipulate distribution of wild ungulates
Grazing can influence vegetation attributes in sagebrush habitats. Can use prescribed grazing to influence vegetation		We don't know which grazing system is more beneficial for sage grouse in site specific situations
Ranchers want to optimize long term sustainability of sagebrush ecosystem and protect the vegetative resource		We don't know the carrying capacity for sage-grouse in a given habitat

Issue 3: There is a lack of cooperation, communication and respect and understanding between stakeholders.		
Facts	**Assumptions**	**Information Gaps**
Landscape management approach and involvement of all stakeholders is required for management to be successful	That there is in fact a lack of communication	
	Lack of consideration of time coordination of initiatives	
	Lack of knowledge of what the stakeholders are doing	

Issue 4: There is a lack of understanding and respect for socio-economic balance between stakeholders.		
Facts	**Assumptions**	**Information Gaps**
It is important to maintain the economic viability of ranches in order to maintain large expanses of sage-grouse habitat		The socio-economic value of sage grouse (birdwatching, hunting, etc.)
Management operations for livestock and sagebrush cost money		A more precise estimate of the detrimental impact of losing ranches to communities
Wildlife impacts the socio-economics of communities		

Issue 5: There is a lack of sufficient funding for habitat projects, monitoring etc.		
Facts	**Assumptions**	**Information Gaps**
Not enough money to go around, for both landowners and agencies		Don't know who to ask / how to find the right avenue of approach
Often are too many strings/constraints attached to funding		
Long term funding over time (maintenance/monitoring) is often not available		
Lack of funding to get good science, for cost/benefit		
Priorities will need to be developed for proper spending		
Have to have money to implement state plan		

Issue 6: There is a lack of understanding what catastrophic events can do to Grouse populations and how to plan ahead for them.		
Facts	**Assumptions**	**Information Gaps**
	Events could impact sage grouse habitat and populations or could eliminate a sub-population We have an adequate understanding disease fire and drought/severe winter Small isolated populations are more at risk of extirpation from catastrophic events There are mgmt techniques that can reduce the risk of catastrophic fire	

Note: Catastrophic events will be covered under fire, drought and disease sections of the Statewide Plan, so the working group decided not to cover this topic here.

Management Goals and Strategies

Issue 1:

There is a lack of understanding of Greater Sage Grouse habitat and the relationship to herbivory.

Goal 1.1

Determine if there is a causal relationship between herbivory and Sage Grouse habitat quality and Sage Grouse population fluctuations.

Action 1.1.1

Conduct a iterature review of grazing systems and effects to vegetation parameters needed by sage grouse.

Responsible parties: BLM, Brendan Moynihan
Timeline: ASAP
Collaborators:
Resources: $30,000

Action 1.1.2

Evaluate the effect of herbivores on quality of sagebrush habitat (e.g., Grass and forb abundance, diversity, and vegetative structure) and its relationship to sage-grouse productivity, demographics and population viability. Use results to develop grazing management. options for sage grouse habitat.

Responsible parties: CDOW, research institutions
Timeline: Start by 2011
Collaborators: BLM, USFS, Private landowners
Resources: $200,000 per year
Results:
Consequences of inaction:
Obstacles: No control site available, will have to design study around no control

Action 1.1.3

Monitor effectiveness of grazing mgmt. options developed from research above. Use monitoring results to adjust mgmt. options (adaptive mgmt.) It is critical for all stakeholders to be involved in the design of the monitoring plan.

Responsible parties: Local working groups, CDOW
Timeline: Start by 2011
Collaborators: BLM, USFS, Private landowners, NRCS, CSU SOP
Resources: $50,000 per year
Results:
Consequences of inaction:
Obstacles: Available time

Action 1.1.4

Provide some incentives to private landowners to participate in research and monitoring actions. For example: if a rancher is requested to rest a pasture for a research project, help him find other pasture to graze or compensate financially.; fencing, water developments, etc.

Responsible parties: NRCS, BLM, USFS, CDOW, NAGP, CSU coop extension
Timeline: Ongoing
Collaborators: Private landowners

Issue 2:

There is a lack of Best Management Practices for sagebrush habitat while maintaining a forage base for domestic and wild herbivores.

<u>Goal 2.1</u>

Determine if there is a direct relationship between physical presence of herbivores and disturbance of grouse, ie: nest disturbance, trampling and disturbance on breeding leks.

Action 2.1.1

Conduct a literature review of herbivores and their direct disturbance effects on sage grouse.

Responsible parties: BLM
Timeline: ASAP
Collaborators: CDOW

Action 2.1.2

As results become available on research, distribute them to local work groups.

Responsible parties: BLM, CDOW, NRCS, USFS, CSU coop
Timeline: Ongoing
Collaborators: Local work groups

Goal 2.2

Develop grazing management options that provide for both sage grouse seasonal needs and sustainable agriculture that provides large areas of sage grouse habitat as well as open space.

Action 2.2.1

In cooperation with the local work groups, develop a menu of grazing management options that support the local work group objectives. This will provide the flexibility needed for site-specificity.

Responsible parties: LWG, BLM, USFS, NRCS, CSU coop, SLB
Timeline: By May 2008
Collaborators: CDOW, private landowners
Resources: Funding will be determined by project; see funding goal.

Action 2.2.2

Develop plan for wild ungulate grazing that considers ungulate distribution and habitat carrying capacity.

Responsible parties: CDOW
Timeline:
Collaborators: BLM, USFS, landowners

Action 2.2.3

Monitor effectiveness of grazing management options used at the local level. Use monitoring results to adjust management options (i.e., adaptive management). It is critical for all stakeholders to be involved in the design of the monitoring plan.

Responsible parties: LWG, BLM, USFS, NRCS, CSU coop, SLB
Timeline: By May 2011
Collaborators: CDOW, private landowners

Issue 3:

There is a lack of cooperation, communication and respect and understanding between stakeholders.

Goal 3.1

Foster and facilitate information sharing to improve communication and cooperation and respect among stakeholders.

Action 3.1.1

Ensure that private land managers are invited to land management decision meetings that involve sage grouse habitats.

Responsible parties: BLM, USFS, SLB, USFWS, CDOW
Timeline: Ongoing
Collaborators: Private landowners, local work groups

Action 3.1.2

Develop a public outreach/education program about domestic and wild grazing and SG needs. Create a traveling display to go to schools, county fairs, etc..

Responsible parties: CSU Extension
Timeline: Ongoing
Collaborators: Local work groups, other stakeholders

Action 3.1.3

Develop a website for local working groups to share info. Link from CDOW website?

Responsible parties: CDOW?
Timeline: Ongoing
Collaborators: Local work groups

Action 3.1.4

Establish controlled or regulated tours to ensure educational aspects of SG habitat.
Subpoint: Educate existing guides

Responsible parties: Local work groups
Timeline: Ongoing
Collaborators: Private landowners, Chamber of Commerce

Action 3.1.5

Develop elementary, middle and high school curriculum that includes grazing and grouse management, to fit Colorado standards

Responsible parties: CDOW, CSU extension
Timeline: Ongoing
Collaborators: LWG's, and schools

Issue 4:

There is a lack of understanding and respect for socio-economic balance between stakeholders.

Goal 4.1

Continue to foster sustainable and economically viable ranching community, while also providing high quality sage-grouse habitat.

Action 4.1.1

Assist local work groups to develop procedures to conduct cost-benefit analysis of economic impact of grazing management options.
Subpoint: Help compensate landowners for cost of implementation of management options and facilitating practices.

Responsible parties: LWG's, CDOW, BLM, USFS, all stakeholders
Timeline: Ongoing
Obstacles: Consideration is not always given that all hardships are not monetary

Issue 5:

There is a lack of sufficient funding for habitat projects, monitoring etc.

Goal 5.1

Provide for a level of grazing by wild ungulates that maintains or improves sage grouse habitats, while maintaining those economic benefits that are derived from wild ungulates.

Action 5.1.1

Mail letters to LWG's when starting the CDOW Data Analysis Unit planning process for elk and deer.
Responsible parties: CDOW
Timeline: As needed
Obstacles: LWG's, private landowners

Action 5.1.2

Conduct cost-benefit analysis of economic impact when planning for the management of the wild ungulates.
Responsible parties: CDOW
Timeline: As needed
Obstacles: LWG's, private landowners

Issue 6:

There is a lack of understanding what catastrophic events can do to Grouse populations and how to plan ahead for them.

<u>Goal 6.1</u>
Identify funding sources and develop a process to set priorities for conservation of sage grouse populations.

Action 6.1.1

Assist the local working groups in developing a process to evaluate management options for funding habitat improvement projects. On statewide issues, CDOW will prioritize.
Responsible parties: CDOW, all agencies involved
Timeline: As needed
Obstacles: LWG's, private landowners, HPP

Greater Sage Grouse in Colorado
Statewide Conservation Planning Workshop

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Steamboat Springs, Colorado

WORKSHOP REPORT

Section IV

Predation Working Group Report

Predation Working Group Report

Working Group participants:
Mike Grode, CO Division of Wildlife
Erin Robinson, Center for Native Ecosystems
Dave Moreno, USFDA – APHIS
Mark Monger, Middle Park Working Group
Tom Remington, CO Division of Wildlife
Mike Phillips, CO Division of Wildlife
Jeff Comstock, Club 20 and Moffat County
T Wright Dickenson, NW Colorado Working Group
Terry Ireland, USFWS
Dave Keiper, Colorado Rural Electric Association
Jill Schlegel, North Eagle / South Routt Working Group
CJ Mucklow, Colorado State University
Liza Rossi, CO Division of Wildlife (Recorder)
Cathy Neelan, North American Mediation Associates (Facilitator)

Problem Statements

The working group engaged in a lengthy discussion before coming up with a prioritized list of the primary predation-related issues pertinent to Greater Sage Grouse management in Colorado. Ultimately, the group decided to focus largely on the political and societal aspects of the issues they identified in order to provide a more broad viewpoint beyond the traditional biological viewpoints.

The prioritized list is given below, with numerical scores after each statement obtained from the prioritization procedure, totaled across all working group participants

1. Challenges exist in developing research that quantifies the impacts of predation and identifies the types of predators. [47]
2. Infrastructure, including power lines, fences etc. may affect predation. [44]
3. Further information is needed on the role of predation and how it impacts sage-grouse in all life stages. [44]
4. Information is lacking on the historic link between predator control from livestock industry and sage-grouse population numbers. Historical pattern that SG numbers high were at same time as when livestock industry doing the greatest amount of predator control. [39]
5. There are political, societal and biological difficulties to create effective predator management. [33]
6. Recognition of the role that habitat, and habitat change, could play and have played in impacting rates of predation as well as types and numbers of predators. [30]
7. Laws exist that have helped increase the number of predators at the expense of sage-grouse. This applies to all infrastructure in agriculture, power lines, etc. [21]
8. There has been a general increase in the numbers and types of native predators and new predators impacting SG. [19]

Data Assembly and Synthesis

Issue: There are political, societal and biological difficulties to create effective predator management.			
Facts	**Assumptions**	**Regional Specificity**	**Information Gaps**
Amendment 14 passed, but by only 2%	Majority of public will not support predator control.	NW CO culturally different from other parts of CO	Better informed public about benefits of pred control to increase SG
Exit polls showed Ag did not support	Public will support predator control for well documented needs		Lack of info on effects of predation.
Counties have statutory authority to fund predator control for benefit of agriculture industry. Do not have authority to manage wildlife for the benefit of wildlife.	General Public assumes that only coyotes affect SG		Lack of info on what level and type of control could actually increase SG #
Statutory authority to manage WL for the benefit of WL lies with CDOW (for non listed species). Listed species --authority lies with USFWS	General Public assumes that pres don't affect SG		
APHIS has ability to eliminate problem predators and proved permits to others			
Most mortality in Sage Grouse is due to predation			
Identity of predators changes over time and from place to place			
Predator control can work and has worked in certain citations (e.g. waterfowl) but must be maintained for X time and must target entire suite of predators			
The role of habitat	More cover means		Don't know how

cover is important to protect form avian predators, less for mammalian predators (nesting habitat)	protection for nesting		habitat change affects predator change

Issue: There has been a general increase in the numbers and types of native predators and new predators impacting Greater Sage Grouse.			
Facts	**Assumptions**	**Regional Specificity**	**Information Gaps**
Some predators (e.g., red fox) have expanded their range	Assumption that there has been a change in predators numbers	House development brings unique suites of predators	Info lacking to identify the change in predator type and quantities from historical numbers. But it does not matter!
Human expansion has influenced predator numbers and types			Define the reasonable of level of predator control needed to increase or sustain SG pop.
Some predators can adapt more easily to human disturbance and increasing human numbers better than others			What is a good balance between SG number and predators?

Issue: Recognition of the role that habitat, and habitat change, could play and have played in impacting rates of predation as well as types and numbers of predators.			
Facts	**Assumptions**	**Regional Specificity**	**Information Gaps**
Different habitat needs have been identified for different SG life stages	Assumed that we understand grouse habitat requirements from NP studies only and that apply to other areas. Might be different elsewhere	BMPs identified in local plans	Lack of knowledge of range of natural variability for sagebrush types across range
As vegetation structure changes, predator composition changes			Minimum sagebrush patch size needed
Invasive species have increased throughout SG range – continuing to spread			Info on what type of sagebrush and age class are necessary
Still substantial areas of functional sagebrush communities			Lack of knowledge on impacts of sagebrush manipulation on SG demographics. Have not done these experiments. Don't know how vegetation treatments affect nest success
Fire cycles are part of the sagebrush ecosystem	Fire suppression has altered habitat and potentially affected predation		Link between invasive species affects and predators and predation
			Info missing on role between predation, habitat, and nutrition (insects). Link between habitat and nutrition? How habitat provides nutrition to enable chicks to escape predation.
Infrastructure provides perching for predators	Assumption that perches increase predation rates		How is infrastructure different from natural disturbances?
		Regional specificity on the impact of power	Disturbance distance from power lines.

	lines. Some areas may have a larger impact than others (e.g. geographical profiles)	Recommendations for infrastructure of distance to protect critical habitat with regional specificity on power lines and fences Relative effectiveness of all different predator control methods to reduce predation. Cost/benefit analysis. Relative effectiveness of predator deterants for power lines

Throughout the working group discussions, many participants had a major issue with the predation component of the Threats Matrix, prepared by the Conservation Planning Steering Committee in advance of the workshop. The group felt that, instead of predation being considered to be low in intensity and stable in future trend in the NW CO region, it should in fact be considered high in intensity. This is a bit of "apples to oranges" problem; threat matrix comes from science team, in terms of relative impacts affecting long term preservation of species compared to other threats. Predators are natural – but indeed, predators do definitely impact SG.

The group does not want the body of workshop participants to leave this meeting with the idea that predation is not an important issue for Greater Sage Grouse management.
For NW working group, okay with some recognitions. The NW group does not agree with the Matrix as it is, and its representatives are registering strong disagreement with Matrix as it stands now the way the steering committee has it. If state plan comes out with this kind of a table, they will be fighting mad. Will question the importance placed on the local work groups if matrix stays the same.

W need to decide as a group if the management goal is to prevent extinction in the Greater Sage Grouse in Colorado, or to increase grouse numbers. Resolving this question will help us determine if predation is a minor or major threat.

Management Goals and Strategies

Issue 1:

There are political, societal and biological difficulties to create effective predator management..

Goal 1.1

Improve public understanding of the role of predation on Greater Sage Grouse populations.

Action 1.1.1

Develop a public relations campaign to improve understanding of predator/Sage Grouse relations.
Responsible parties: CDOW, SGSC – prepare materials; CSU Extension
Timeline: Ongoing pending information gaps
Collaborators: CREA; BLM; CO Cattlemen's Association; Farm Bureau; Local Work Groups; Society for Range Management
Results: Educational materials
Obstacles: LWG's, private landowners, HPP

Goal 1.2

Encourage timely, innovative strategies that include an adaptive management and monitoring scheme.

Action 1.2.1

Establish annual meeting to coordinate Local Working Groups.
Responsible parties: Local Working Groups (rotating on an annual basis)
Timeline: On an annual basis with 3 month advance notice
Collaborators: CDOW
Results: Coordination; outreach
Obstacles: State funding

Action 1.2.2

Encourage and allow risk taking.
Responsible parties: High-level decision makers
Timeline: Ongoing
Collaborators: All stakeholders
Results:
Obstacles: Adverse consequences; bureaucracy

Goal 1.3

Identify the funding needed and secure necessary amount to implement predation strategies and goals in local plans.

Action 1.3.1

Develop process to fund LWG strategies.
Responsible parties: CDOW – SGSC
Timeline: Immediate
Results: Clear process; dispersal of money

Action 1.3.2

LWGs identify funding needs and submit proposals.
Responsible parties: Local working groups
Timeline: July 15, 2006 – Begin annual funding cycle program
Collaborators: CDOW
Results: Proposals

Action 1.3.3

Identify funding sources and secure funding.
Responsible parties: CDOW – SGSC
Timeline: July 16, 2006
Collaborators: NRCS, CDOW, USFWS, and other funding sources
Results: Funding

Action 1.3.4

Report outcomes to SGSC.
Responsible parties: LWG and Research Professionals
Timeline: Annual Basis
Collaborators:
Results: Regular reporting

Issue 2:

There are political, societal and biological difficulties to create effective predator management..

Goal 2.1

Challenges exist in developing research that quantifies the impacts of predation and identifies the types of predators.

Action 2.1.1

Establish process between CDOW, Federal Agencies, and LWG to develop research priorities at a CO rangewide level.
Responsible parties: CDOW – SGSC; LWG; Federal Agencies
Timeline: Immediate
Collaborators: CSU Extension
Results: Clear process that incorporates LWG priorities; effective communication between researches and LWGs

Action 2.1.2

Document and monitor current predator population levels in SG habitat.
Responsible parties: CDOW; APHIS; CO Department of Ag
Timeline: Begin 15 July 2006
Collaborators: Landowners
Results: Understanding of changing predator population levels and predator communities; better understanding of natural variability in predator populations
Obstacles: Funding

Action 2.1.3

Undertake research to better understand predation as it relates to SG mortality at all life stages..

Responsible parties: CDOW; Universities; Utilities; LWGs; Researchers
Timeline: Begin 15 July 2006
Collaborators: Landowners, federal agencies
Results: Increased understanding of:

- Effects of predation on all life stages
- How habitat impacts predation rates
- Natural temporal and spatial variability in sagebrush systems (age class, fire intervals, etc.)
- Required patch size to sustain SG
- How vegetation treatments impact nest success
- How invasive species impact predation rates
- Role between nutrition, forbs/insects, and chick vulnerability to predation
- Impacts of infrastructure, power lines, roads and fences on predation
- Differing role between native and new predators

Consequences of no action: Ineffective predator control; Species listed under ESA
Obstacles: Funding

Action 2.1.4

Secure funding for research on information gaps related to predation.

Responsible parties: CDOW – SGSC; LWGs
Timeline: Begin 15 July 2006
Collaborators: CSU; USFWS; WGA; NRCS
Results: Funding

Action 2.1.5

Increase the understanding of which management actions are most biologically effective in increasing reproductive success.

Responsible parties: CDOW – SGSC; LWGs
Timeline: Upon review of research reports
Collaborators: CSU; USFWS; WGA; NRCS
Results: Increased understanding of biological effectiveness and reasonable levels of predator control
Consequences of no action: Misallocation of funds, resources (including wildlife), and time

Action 2.1.6

Increase the understanding of the most cost effective management actions to increase reproductive success.

Responsible parties: CDOW – SGSC; LWGs
Timeline: Upon review of research reports
Collaborators: CSU; USFWS; WGA; NRCS
Results: Increased understanding of cost effectiveness and reasonable levels of predator control
Consequences of no action: Misallocation of funds and time

Goal 2.2

Design and implement an adaptive management program.

Action 2.2.1

Design an effective and consistent monitoring program to determine if management actions are achieving desired results.
Responsible parties: CDOW
Timeline: ASAP
Collaborators: LWGs, SRM

Action 2.2.2

Work with implementing parties to complete and report monitoring results.
Responsible parties: LWGs, land managers, CDOW; Utilities
Timeline: As treatments are conducted
Results: Sharing of results between LWGs

Issue 3:

There has been a general increase in the numbers and types of native predators and new predators impacting SG.

Goal 3.1

Manage predation to get stable to increasing SG populations.

Action 3.1.1

Identify appropriate types of predator control.
Responsible parties: CDOW – SGSC; Department of Ag; LWG
Timeline: Short term
Results: Appropriate types of control that lead to increased sage-grouse numbers

Action 3.1.2

Implement types of predator control, as necessary and appropriate.
Responsible parties: APHIS, LWGs, land managers
Timeline: Following research outcomes
Results: Appropriate types of control that lead to increased sage-grouse numbers

Action 3.1.3

Appropriately use legal framework within existing laws to apply management techniques necessary to increase SG population, including:

1. Colorado Amendment 14
2. Bald and Golden Eagle Protection Act
3. Migratory Bird Treaty Act

Responsible parties: APHIS, USFWS, CDOW
Timeline: When deemed necessary
Results: Appropriate types of control that lead to increased sage-grouse numbers

Greater Sage Grouse in Colorado
Statewide Conservation Planning Workshop

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Steamboat Springs, Colorado

WORKSHOP REPORT

Section V
Hunting Working Group Report

Hunting Working Group Report

Working Group participants:
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Harvey Nyberg, Colorado Wildlife Federation
Tony Apa, CO Division of Wildlife
Dean Gent, NW Colorado Working Group
Ann Timberman, USFWS
Doug Armstrong, CBSG (Facilitator)
Kent Prior, Parks Canada (Recorder)

Problem Statements

The working group brainstormed the following general issues, and then followed this up with a process of condensing the statements into a more succinct set of prioritized problem statements.

<u>General issues</u>

1. Compensatory vs. additive mortality – better and more data is necessary to determine which mechanism governs mortality in Greater Sage Grouse
2. Zones - NW Group creation of zones, within which 100 males / lek would be required in order to allow hunting.
3. Reconciling Management, Conservation, & Management – For example why allow hunting? How can it be justified if the species is being considered as a candidate species for listing under ESA? Issue of credibility if on the one hand we're talking about hunting and on the other we're encouraging conservation. This could be a problem if 'selling' and buy-in to the plan is required.
4. Harvest Statistics – How credible are the numbers available? Traditionally relied on volunteer phone surveys. Quality and comprehensiveness of harvest statistics are questionable.
5. Data through Hunting – that may otherwise be unavailable. Alternatively, the ends may not justify the means. Data may also be highly biased depending on the how and extent of data collection.
6. Desire to Preserve Hunting Tradition – but clearly in some circles there's concern over hunting if this is a species of special concern that may be on the tipping point for persistence
7. Language is Important – for some populations we may not need to speak about recovery as opposed to management, whereas others have almost certainly lost ground and are thus possible targets for recovery
8. Opportunity to Build Relationships – especially between hunters and land owners, both have the same interests at stake – healthy sage grouse populations, share common long-term goals

<u>Prioritized problem statements</u>

1a. How do we effectively address the perception of hunting sage grouse when they have been petitioned for listing?
1b. How do we disseminate accurate information sage grouse populations and management?
2a. There is a need to improve the quality of harvest and hunter information so we can better assess possible (or relative) impacts on sage grouse populations.
2b. We need more accurate data to better understand the impact of hunting on sage grouse populations (i.e., compensatory vs. additive mortality).

3. How do we strengthen the relationship of hunters and landowners to benefit sage grouse and habitat?
4. How do we adjust hunting seasons to respond to significant changes in populations?

Data Assembly and Synthesis

Issue: How do we effectively address the perception of hunting sage grouse when they have been petitioned for listing?	
Fact	**Assumption**
Personal experience of people questioning individuals	Not addressing the issue effectively
Majority of public doesn't hunt but doesn't object to hunting	Not addressing the right group

Issue: How do we disseminate accurate information sage grouse populations and management?	
Fact	**Assumption**
Believe there was a comment to USFW regarding harvest in response to listing petition	
Newsletter and releases have not addressed the issue of grouse hunting directly	
Recent article in Colorado Outdoors article addressed issue but circulation is narrow, not targeting proper audience	
Denver Post columnist Charlie Meyers occasionally addresses grouse hunting	
NW sage grouse working group posters to raise awareness of conservation program, distributed locally	
Historic news releases but none recently, usually addressed projects and treatments	
Inaccurate information (leaflets) needs to be updated	

Issue: There is a need to improve the quality of harvest and hunter information so we can better assess possible (or relative) impacts on sage grouse populations.	
Fact	**Assumption**
Wing receipt barrels put out by DOW, voluntary deposit of wings by hunters, unknown compliance, timely evaluation of wings Phone survey of HIP no. hunters, based on sample size and distribution - estimates by county are probably insufficient (high SE, low power), statewide estimates are probably representative Previous surveys (mail, checkpoints) Annual lek counts serve to help estimate population size and trends, limited participation by WG, but this information is evaluated and incorporated in an ad hoc manner, it is not considered in a consistent manner	

Issue: We need more accurate data to better understand the impact of hunting on sage grouse populations (i.e., compensatory vs. additive mortality).	
Fact	**Assumption**
Published evidence is equivocal, with different studies supporting both positions. Johnson & Braun – compensatory to a threshold level (unidentified). Connoly – due to low winter mortality, hunting may be additive to overwinter mortality. Braun & Beck – suggests hunting compensatory. Crawford – compensatory. Additional information for other upland birds. Gibson – unpublished abstract, suggests hunting additive mortality keeping populations below carrying capacity. Current projects – Rotella is currently evaluating the impact of hunting sage grouse in Montana. Two study areas, 2 treatments (hunted vs. not), 3 year duration	Truth is probably a combination of both, more or less, depending on context – varies by state and local population

Issue: How do we strengthen the relationship of hunters and landowners to benefit sage grouse and habitat?	
Fact	**Assumption**
Limited hunter involvement in local working groups	
North American Grouse Partnership – may involve hunters	
Habitat partnership – supports in part sage grouse habitat projects (e.g., spring development, brush beating, fertilization), involves sportsmen	

Issue: How do we adjust hunting seasons to respond to significant changes in populations?	
Fact	**Assumption**
NW group – informal, 3y average of 100 males / lek in zone requirement to allow hunting in a zone	
Middle Park – informal, recommends specific site closure in plan depending on area population threshold (675 males across leks over 3y), procedure for emergency closure based on spring lek count, reduction of estimated population by 10% may precipitate	
DOW – formal regular 5-y review to set season / harvest across next 5 y, plus annual adjustments per zone as necessary (e.g., exceed threshold), and emergency-based immediate closures or adjustments	

Management Goals and Strategies

Issue 1a:

How do we effectively address the perception of hunting Greater Sage Grouse when they have been petitioned for listing?

Goal 1a.1

Change the perception about status of the Greater Sage Grouse population by proactively providing accurate information about the sage grouse population, management and sustainability of hunting

Action 1a.1.1

Inventory all existing education and awareness materials (to foster sharing of accurate information)such as brochures, posters from DOW, Working Groups primarily as well as secondarily information from other states, BLM, NWF, USFWS, Audubon, NAGP. May include information produced about Greater, Gunnison, Sharptail Grouse.

Responsible parties: CDOW Information and Education Division, Michelle Cowardin, Harvey Nyberg
Timeline: October 2006
Collaborators: DOW, Working groups
Results: Materials collected

Action 1a.1.2

Conduct an initial and annual review of information materials for accuracy & gaps and production of new material(s) as required, multiple products, multiple target groups.

Responsible parties: CDOW Information and Education Division
Timeline: Production of initial products – Fall 2007; distribution by Spring 2008; following years for subsequent materials
Collaborators: Working groups, biologists, researchers, contributors (donors)
Resources: Time by I&E for message development & design- 3 months; print production - $10,000
Results: Materials collected

Action 1a.1.3

Develop an integrated communication strategy (includes treatment of perception & hunting issue) to reach key audiences (e.g., urban public).

Responsible parties: CDOW Information and Education Division
Timeline: October 2008 for communication strategy; immediate where possible for articles
Collaborators: CSU Extension, working groups, BLM, USFWS, NRCS, Forest Service, Steering Committee
Resources: 1000 hours annually (encompassing all sage grouse issues)
Results: Products that might fall out of a communication strategy:

- article in Colorado Outdoors about grouse status
- Series of general audience articles & news releases for local papers on topics such as research, working groups plans and actions, grouse population status, statewide plans, management techniques and actions.
- articles in regional and local papers
- websites
- Hunter education program products
- FFA products

Target Denver Post, Rocky Mtn News for larger, review articles about grouse

Action 1a.1.4

Local Working Groups are encouraged to initiate articles in local papers about their activities.
Responsible parties: Dean Gent, NW Colorado Working Group
Timeline: October 2006 – Include example in their report
Collaborators: NW working group - Other local working groups are engaged to initiate articles in their local papers
Resources: None necessary
Results: Article in local paper by October and included in working group report

Issue 2a:

There is a need to improve the quality of harvest and hunter information so we can better assess possible (or relative) impacts on sage grouse populations

Goal 2a.1

Obtain more accurate information on hunters and harvest – (short-term)

Action 2a.1.1

Identify and implement more effective ways to determine hunter statistics (e.g., establish a required free permit, improve phone survey).
Responsible parties: CDOW biometrician
Timeline: Implement by Fall 2007
Collaborators: USFWS Arapaho refuge (possible study site)
Resources: 1 month design time by biometrician; prepare improved phone survey
Results: Accurate information on hunters

Action 2a.1.2

Evaluate and improve ‘wing barrel program’ to obtain better harvest statistics.
Responsible parties: CDOW
Timeline: Implement by Fall 2007
Collaborators: USFWS Arapaho refuge (possible study site); volunteers to manage barrels
Resources: Cost for additional barrels & survey forms if required; time to evaluate and improve
Results: Provides accurate information on harvest; timely evaluation of wings

Issue 2b:

We need more accurate data to better understand the impact of hunting on sage grouse populations (i.e., compensatory vs. additive mortality)

Goal 2b.1

Foster & support the collection of data to clarify the compensatory vs. additive issue and possible thresholds – (long-term)

Action 2b.1.1

Execute experimental field study designed to specifically address the compensatory vs. additive issue (model after Rotella study in Montana). Would collect data for other issues as well.
Responsible parties: CDOW
Timeline: Initiate by Spring 2009
Collaborators: Other western status and federal agencies (USGS, USFWS)
Resources: $200,000 per year over 5 to 10 years
Results: Accurate information on hunters

Issue 3:

How do we strengthen the relationship of hunters and landowners to benefit sage grouse and habitat?

Goal 3.1

Strengthen relationship between hunters and landowners – (long-term)

Action 3.1.1

Encourage sport people (hunters) to participate in local working groups and statewide plan with the objective of supporting landowner efforts to conserve sagebrush habitat by actively identifying and recruiting hunters to participate in local working group.

Responsible parties: Colorado Wildlife Federation –Harvey Nyburg
Timeline: By October 2006 meeting
Resources: None

Action 3.1.2

CDOW contact sportsmen's groups and organizations (i.e. sportsmen council) to encourage participation in sage-grouse conservation.

Responsible parties: CDOW
Timeline: Spring 2007
Resources: $1,000

Issue 4:

How do we adjust hunting seasons to respond to significant changes in populations?

Goal 4.1

Develop a system for adjusting season length, bag limit, and areas of closure / re-opening that is rigorous, predictable, and responsive to changes in sage-grouse populations

Action 4.1.1

Develop an adaptive harvest management system for Colorado that formalizes the current local working group trigger system to close or open areas.

Responsible parties: CDOW, Local Working Groups
Timeline: Discuss at October meeting 2006, implement by 2008
Resources: Time

Action 4.1.2

CDOW implement an intensive monitoring system of population and harvest to refine the adaptive harvest model periodically to effect season length and bag limit.

Responsible parties: CDOW
Timeline: 2008
Resources: Negligible if improved harvest data is used

Greater Sage Grouse in Colorado
Statewide Conservation Planning Workshop

9 – 11 May 2006
Steamboat Springs, Colorado

WORKSHOP REPORT

Section VI
Energy Working Group Report

Energy Working Group Report

Working Group participants:
Marianna Raftopoulos, NW Colorado Working Group
Kathy Hall, Colorado Oil and Gas Association
Kim Kaal, CO Division of Wildlife
Al Pfister, USFWS
Joe Gumber, Piceance / Parachute / Roan Working Group
Sean Norris, Chevron Inc.
Ed Hollowed
Karin Eichhoff, CO Division of Wildlife
Steve Smith, The Wilderness Society
Kent Crowder, North Park Working Group
Renee Rondeaux, CNHP
Reed Morris, Colorado Environmental Coalition
Larry Claxton, Xcel Energy
Stephen Flaherty, Western Gas Resources
John Toolen, CO Division of Wildlife
Tom Blickensderfer, CO Division of Wildlife
Robin Sell, Bureau of Land Management
Brad Petch, CO Division of Wildlife
Rebecca Soileau, CBSG (Facilitator)
John Gray, Greater Sage Grouse Conservation Planning Steering Committee (Recorder)

Problem Statements

The working group brainstormed the following list of issue / problem statements of relevance to the issue of energy development in Greater Sage Grouse habitat, and this list was then condensed into four broad categories. Finally, the categories were prioritized according to two criteria: 1) the importance of resolving this issue in the context of the Statewide Plan – is it achievable and does it benefit the long-term conservation of Greater Sage Grouse; and 2) do we need to have this issue addressed to move forward including addressing conflict. Numerical values for the prioritization are given in brackets.

Monitoring, Management and Mitigation [56]

- Do we have the ability to develop a valid monitoring plan to assess the impacts from energy development?
- Do we have the ability to develop a valid monitoring plan to assess the restoration of sagebrush ecosystems?
- In conservation plans, the current discussion for oil & gas industry does not incorporate adaptive management to accommodate development.
  Currently BLM or other conservation plans (guidelines) don't include Adaptive Management Methods for accommodating development
- The level of protection that might be needed might be underestimated based on current projections. Magnitude of development beyond 15 years is very threatening
- Seems like there are a lack of incentives for industry to have more flexibility in developing current leases in GrSG habitats

- Buffers around infrastructure use the broad-brush approach of guidelines and may not provide adequate flexibility or protect the birds. There is not enough justification/rationale incorporated for evaluating on a site by site basis. One size does not fit all.
- What constitutes meaningful mitigation for habitats- how can you offset Impacts?
  What constitutes long term and meaningful mitigation; what are the tools for mitigation, eg: vegetative treatments to offset impacts?
- There is skepticism about benefits of mitigation.
- We need to insure that there is not so much flexibility that there are no enforceable guidelines/steps.

Research and Modeling [53]

- From a landscape scale, How much energy development can a GrSG population withstand?
- Lack of knowledge/research about the effects of O&G development on GrSG populations. General skepticism about what we know – need more research, skeptical about existing research.
- The duration of recent research (length of the study) might not be adequate – Holloran's work may be given too much credibility.
- Lack of peer review of existing research.
- Current research focused on effect but the causal relationship wasn't clearly made (as a means of formulating solutions). E.g. Cause (O&G development) and effect (impacts to SG population) were not proven.
- Current scenarios (in the model) for development do not include reclamation in impact assessment & doesn't consider long term changes or various stages of development.
  Problems with Holloran's results from Wyoming study that don't give credit for reclamation.
  Current scenarios in PVA don't include reclamation, timing of impacts or long term changes in impact assessment.
- Pre-conceived notions of oil & gas industry impeding progress in modeling/discussion. There is a general lack of understanding of processes. And assumptions used in models may not/are not realistic.
  We need to get beyond the pre-conceived notion that Oil and Gas are the Black Hats – this attitude may impede progress in the modeling and discussion of issues. There is a general lack of understanding of processes used in industry.

Guidelines and Policy [33]

- Seems like there are a lack of incentives for industry to have more flexibility in developing current leases in GrSG habitats
- Buffers around infrastructure use the broad-brush approach of guidelines and may not provide adequate flexibility or protect the birds. There is not enough justification/rationale incorporated for evaluating on a site by site basis. One size does not fit all.

Communication [28]

- Because of lack of data, people are skeptical about existing research.
- Recommendations from this plan may limit landowner's ability to develop/manage their property – limit their rights.

- Lack of communication and understanding of inter- and intra- stakeholders issues generates fear associated with the plans.
- The tone of the energy document is negative. Remember that energy development is driven by demand. Reliance on Holloran's study needs to be clarified. The existing draft (Threat doc) reflects negative bias toward the industry.
- Potential lack of sharing of information between all responsible stakeholders on an ongoing basis.
- Lack of cooperation in collecting information for additional analysis.
- Expressed fear that the rate of development of the energy resource will outpace our ability to understand the impacts.

Data Assembly and Synthesis

The following pages give a detailed discussion of the background for the oil and natural gas component of the population viability analysis (PVA) conducted in advance of this workshop are reported here in Section VII. Please see the following section for a more detailed discussion of PVA model input, results and interpretation. The discussion here is meant to capture the working group's response and dialog following presentation of the model.

Brad Petch (CDOW) presented the data that was used in the *VORTEX* models (see also PVA O&G input write-up). He noted that the models used the demographic effects from 6 studies, the most recent being Holloran's and Lyons' studies, rather than the reduction of the amount of habitat available.

The available data sets used for the modeling effort are:

Holloran Dissertation (2005)
Lyons and Anderson (2003)
C. Hagen (1999)
Braun et. Al (2002).
Remington & Braun (1991)
Meeting notes, North American Wildlife & Nat. Res. Conf.

Holloran's findings:

- Decline of # of males attending leks
- 20% increase in mortality of adult females
- 6.4% increase in mortality of juvenile females
- All of his "control" leks were developed during the study
- Pre- and post-development comparison of all activities. Drilling and production phases compared.

Lyons results:

- 24% decrease in nest initiation due to traffic

"Could the lessons from the ColoWyo coal mining activity be applicable to the effects of natural gas drilling on GrSG?"

Brad looked at the current distribution of wells in the three populations on which the model was applied: North Park, PPR, and NW Colorado. Less impacted populations of Middle Park and White River were not modeled.

Holloran Thresholds:

- Control: < 5 wells in a 2 mile radius of lek.
- High Impact: > 15 wells in a 2 mile radius of the lek.

Brad changed the minimum threshold from 5 to 8 wells within 2 miles of the lek to reflect existing conditions in North Park. Note: Tony Apa's study in Axial Basin shows that to include 80% of nesting females, the distance from the lek of capture needs to include a 4 mile radius. Only one GrSG population in CO is already at the minimum threshold.

The minerals subcommittee chose to model 3 levels of development within each population from the following levels: 250, 1000, 5000, or 20,000 of additional wells. The lower 3 levels were used to model NP, while NW CO and PPR were modeled w/ the upper 3 levels of development. Wells were randomly distributed across the landscape within GRSG occupied habitat, but only the well sites that fell within the 2 mile buffer of active leks were considered to impact the grouse population.

The assumption was that all wells currently active plus all the wells drilled in the 50 year buildout remained active and resulted in a permanent loss of habitat.

Some in the group had problems using the data from Holloran's study in Colorado – it is more appropriate to use the research that have already been developed for Colorado populations of GrSG. Brad pointed out that the GrSG studies and the GuSG plan do not include data for evaluation of potential impacts from oil & gas development or local drilling/development projections.

In addition, others noted that the current PVA model presents an unfair picture of the potential impacts of drilling on GrSG.

Fact: some populations of GrSG are migratory while others remain on basically the same terrain year-round. Within populations there is variation of migration distances. Birds migrate up to 60 miles in WY. Often we do not have data on migration distances. Need to adapt recommendations to statewide plan. E.g. flexible enough to allow for population specific needs. Population size may affect migration. O&G literature says birds might move away. Note: Tony A. is also observing huge dispersal distances for juvenile birds in his studies in Moffat County.

Possible data set: ColoWyo has developed habitat off the mine site as mitigation, plus they have also reclaimed habitat on the mine itself. Note: minimum SG use has been documented on reclaimed sites to date. Sharp-tailed grouse have been documented as using reclaimed sites substantially.

Assumptions on the distribution of wells – North Park is already over the minimum threshold of 5 wells per lek. Although 15 wells/lek is the threshold for heavy development, it is unlikely that 100 wells/lek has the same impact as 15, but the model conservatively underestimates the impacts of the very high scenarios (20,000 wells projected into the population).

It is also possible to determine a K value for wells – that can be determined for the gas field by the "spacing order" which is available on the web on the COGCC site. Minimum thresholds may already be met in existing well situation.

Holloran does not differentiate between 10 wells on one pad or 10 wells on 10 pads. Both equal 10 wells per lek. You could have one pad within a lek buffer and be considered a heavy impact. In this respect, this is not a conservative analysis.

The additional wells modeled in PVA at 250, 1000, 5000 and 20,000 levels are almost logarithmic. The assumption is that all wells are drilled in GrSG habitat, that only those that fell within the two-mile radius have an impact on the grouse, and that the heavy impacts did not occur until the average density exceeded 15 wells/lek.

Missing data: the spatial relationship of active leks to active drilling vs. producing wells.

Information on North Park drilling activity: Many factors influence impacts on grouse. A lot of the older oil wells are on small pads and have been in production for decades. Many of these old oil wells are within the two-mile radius of leks that are still active. The proposed well drilling for natural gas will be deeper and require bigger pads than oil wells. Some of the newer technology uses solar panels for recording and transmission of data from the wells and electrical lines to gas fields (instead of gas generators). This reduces the noise and traffic normally associated with gas or oil production. Interim reclamation is also improving current development. Holloran might not have this data. Use NP data to analyze bird trends during production activities. North Park has a good lek count data set; also there are producing wells within the 2 mile radius of active leks.

In the PPR population, the randomization of well locations does not mimic the reality that drilling will occur in almost the identical areas used by GrSG (e.g. on ridgelines). Note: This is another way PVA model is conservative in estimating impacts of development in PPR.

The assumption is that the pace and scale of development will be greater than it is now, we need to consider the additional impacts of this acceleration.

The current PVA model assumes that all current and future (randomly distributed) wells will remain active for the entire 50 years of the simulation. Holloran's data is considered worst case scenario, but we are in that place now.

Data needs: we don't have the effects sorted out and there is no 'test of causes', i.e. Holloran measured effects but did not tie those effects to causes). Noise, well density w/ respect to leks or @ other times of year is incorporated into the model by default. Need seasonal breakout & migratory vs. non-migratory.

Stephen F. noted that in Moffat County (LSFO), the RFD projects about 3100 wells over the next 15-20 years (the life of the RMP). He said we should base our model inputs on actual data, eg. the RFD, not speculation. Phil noted the simulations in the PVA go out to 50 years but can be used to see results for each year, if desired.

Lets not keep using Holloran's study – use local plans instead. In this analysis, Holloran's data was used to describe effects of drilling activity observed during his study; since there are no data available in Colorado that addresses the impacts of energy development. Tony Apa's GRSG data were used as baseline information for the PVA model.

There may be no impacts up to a point. May be able to calculate high frequency of drilling based on well spacing. Increase in mortality of 20% is a huge change in demographics.

Brad's take-home message: don't delay needed action waiting for model (or data availablilty) improvement!

The working group then developed the following Basic Agreements:

- There will be future energy development and that the pace is increasing in some areas. This future development could occur on both public and private lands.
- Planning and mitigation measures will be needed to offset impacts to Greater Sage Grouse as a result of energy development.
- The goal is to get buyoff of the plan by all stakeholders on a regional basis. (We recognize that not all stakeholders are at the table or are involved with implementation of mitigation.)

Issue 1: Monitoring, Management and Mitigation		
Facts	**Assumptions**	**Information Gaps**
Lek locations		Locations of existing mitigation opportunities
How much sagebrush is too much? What stages or arrangements of sagebrush provide good habitat?	We will have data to back this up.	How long does it take for mitigation to provide suitable habitat? (site & ecological type dependant) What facts are known about successional progress? (at specific locations or by ecological type)
	What is the status of ownership (federal, state, local vs. private) of mineral rights under GrSG habitats?	Are there restrictions/benefits to doing directional drilling? (cost factors/geologic/topographic)
		Is there data associated with this mitigative measure (directional drilling) with respect to benefits to SG?
		Data is needed to help determine or predict economic feasibility
		What is the minimum or ideal patch size for GrSG?
		Are there opportunities to minimize the footprint of energy development on the habitat?
		What is the current state of fragmentation of GrSG habitat?
		How often are stipulations or conditions of approval related to SG being implemented at the APD level? Are the current stipulations and conditions of

	approval on APD's effective/adequate? What is the rate of compliance with stips and conditions on the ground by industry? (In WR BLM, compliance is almost non-existent, no people to enforce) Threats write-up needs to reflect a more complete array of oil shale techniques. How effective are incentives for industry to modify development on existing leases? – use Pinedale/Jonah data Are there alternatives to the radial buffer approach? (use local topography & vegetation conditions to define the geometry) Utilization and refining of existing vegetation mapping for better understanding of encroachment on GrSG habitat.

Data Sources Include: CDOW, NRCS range site information, BLM, Personal interviews w/ landowners, Industry, 2005 Aerial photography, State, USGS, BLM offices w/ APDs, Counties, Connelly et.al.

Issue 2: Research and Modeling		
Facts	**Assumptions**	**Information Gaps**
	The resolution of the data may not show cause and effect. Need to look at case studies. 3050 *wells* in RFD for NW Colorado (LSFO)	Info on oil wells in North Park (locations, status, proximity to leks, wells/pad etc.) What has the grouse response been to the oil development activity in NP or in other populations. Data on past surface mine sites and whether GrSG have used or will reuse these sites. Are any of these disturbed areas associated with former leks? Date/map the infrastructure assoc. with the mining or drilling activity w/in GRSG habitat. Research on effectiveness of mitigation

Issue 3: Policy and Guidelines		
Facts	**Assumptions**	**Information Gaps**
		How up to date are current RMPs concerning grouse & associated conservation measures? Need to inventory other federal, state, local and Local Working Group plans for consideration of GrSG needs What are these stipulations and where do they apply? How do birds react with stipulations in place? Are there adequate stipulations in place to protect grouse habitat? Is conditional application of stipulations (COAs) applied appropriately? Are the stipulations being enforced and complied with? Are special use permit approval processes adequate? Are the guidelines flexible enough to accommodate emerging industry technologies? Exceptions, modifications, waivers, inconsistencies in stipulations -all raise flags. Are there jurisdicitional conflicts? Policy varies county by county on permitting of activities.

Data Sources include: RMP's (BLM), Counties, COGCC, SLB, Div. of Minerals and Geology, Municipalities, USFWS, MOU's between state agencies, NEPA, DOW comments on policies & application, MOU's w/ agencies and states.

Issue 4: Communication		
Facts	**Assumptions**	**Information Gaps**
There is proprietary information which can cause informational gaps		Gaps between agencies
There are statutory restrictions on sharing info (FACA)		Gaps between counties and agencies
		Gaps between companies (industry)

Management Goals and Strategies

Issue: Monitoring/Mitigation/Management

Overall goal statement: Restore/reclaim habitats to standards needed for Sage Grouse subgoals (i.e. that meet the needs of Greater Sage Grouse)

1. Develop a valid monitoring plan to assess impacts of energy development on Greater Sage Grouse
2. Develop a valid monitoring plan to assess habitat restoration measure success w/ respect to Sage Grouse. (dfn: restore to original condition).
3. Develop a monitoring plan for reclamation activities to meet Sage Grouse needs. (dfn: rebuild damage on site)
4. Develop an adaptive management plan that includes monitoring.
5. Consider incorporating appropriate portions of the NW plan [Note: some of the goal statements in the NW local plan (read by Marianna) could be incorporated into/considered for the list of goals for the statewide plan relating to Energy Development]
6. Look for incentives to industry that will accomplish positive results for Greater Sage Grouse.
7. Have an adaptive approach to regulations for industry over time based on monitoring results (i.e. moving drill pads more than 200 meters to benefit the bird)
8. Develop and implement a framework that encourages voluntary participation in Greater Sage Grouse conservation. (possibly #1 goal)
9. Assure a consultative process during project approval that allows for incorporation of most current data and technology available.

The working group recognized a series of goal statements from the Northwest Local Plan that were thought to be applicable to the Statewide Plan (text in brackets added by energy working group):

1. Minimize SG habitat & population loss to oil and gas [energy development] activities while ensuring continued development.

2. Reduce fragmentation of Sage Grouse habitat by oil and gas [energy] development activities.
3. Minimize disturbance to Sage Grouse associated with oil and gas [energy] development.
4. Reduce cumulative impacts of oil and gas [energy] development.
5. Minimize area impacted & duration of impact on sage grouse populations & habitat from surface mining and from above-ground facilities of underground mines.

The working group first ranked the goals under Monitoring, Management and Mitigation, then decided to add a goal of "Increase funding to monitor populations of Greater Sage Grouse in Colorado". The group then ranked the goals under Research and Modeling, then Guidelines and Policy. After reviewing the draft goals under Communication, the consensus was to defer the discussion of the goals under this issue to the Expanded Steering Committee.

To work completely thru an issue-goal-strategy scenario, the group then compared the top issues under Monitoring/Management/Mitigation with Research/Modeling, and Guidelines/Policy, and ranked those to determine which were the top priority to completely flesh out.

After attempting to complete the goal and strategy worksheets, it quickly became apparent that the group would not finish with even one of the Issue areas. The working group facilitator polled the group and the consensus was a desire to meet again face to face, after a subgroup of the expanded Steering Committee has time to sort out, attempt to link issues, goals and strategies (actions), and send that document back to the Energy workgroup for study. Brad Petch informed the group that an attempt would be made complete to the synthesis of information within this working group and meet once again in late August, 2006 to further the discussions.

Issue 1:

<u>Goal 1.1</u>

Reduce spatial and temporal influence /footprint of oil and gas development in both occupied and suitable unoccupied GRSG habitat

Action 1.1.1

Look for and implement incentives to commerce that will accomplish positive results for GrSG.

Responsible parties: BLM, Industry, Counties, CDOW, COGCC
Timeline: Develop framework-incentive package(s) by mid-2007; Immediate when plan approved
Collaborators: Landowners, industry, state agencies, public
Results: Have info from biologists that the measure will have pos. Results on grouse. That companies have used the incentive package(s)
Consequences of no action: The habitat will not be improved, the potential for federal listing increases. Industry will not be motivated to cooperate. Lack of responsibility to an incentive will result in prescriptive measures.
Obstacles: Inconsistency across jurisdictional boundaries; lack of flexibility; time frames for Documentation and permitting
Note: tie initiation of incentive package to initiation of monitoring

Action 1.1.2

Develop a list of BMPs to reduce overall post-construction footprints of energy development. [Obtain a strategy from industry of the smallest practical size of footprint in GRSG habitat. Reduce long-term footprint of facilities to the smallest practical space in GrSG habitat.].

Responsible parties: CDOW Energy Liaison
Timeline: Immediate, before the final draft of statewide plan

Collaborators: COGCC, USFS, Counties, industry, CDMG, general public, environmental community

Results: Meeting of stakeholders to develop list of BMPs

Note: pre-construction issues need to be dealth with in other goal/action statements. BMPs are found in http://www.blm.gov/bmp

Appendix I:
Additional Working Group Discussion Materials

The following material was put together by the working group during the workshop but was not worked through in greater detail. Discussion of this material will be an important component of the August 2006 follow-up meeting of the working group.

OIL AND GAS DEVELOPMENT, MINERAL EXTRACTION, ENERGY DEVELOPMENT

1. Minimize sage grouse habitat loss to oil, gas, mining, and energy development activities while ensuring continued development.
2. Reduce fragmentation of sage grouse habitat by oil, gas, mining, and energy development activities.
3. Minimize disturbance to sage grouse associated with oil, gas, mining, and energy development.
4. Reduce cumulative impacts of oil, gas, mining, and energy development.

1. <u>Monitoring, Mitigation, and Management</u> may not be adequate to maintain, restore, or reclaim Sage Grouse habitat and populations to standards needed for Sage Grouse

A. Goals
   i. Develop an adaptive management plan that includes monitoring. (19)
      a. How do birds react to stipulations?
      b. Are the stipulations adequate?
      c. Are the stipulations appropriate?
      d. Look for incentives to commerce that will accomplish positive results for SG.
      e. Have adaptive approach to regulations for industry over time based on monitoring results, such as moving drill pads to benefit bird
      f. Locations of existing mitigation opportunities.
      g. How long for mitigation to provide suitable habitat (type dependant, location dependency).
      h. Determine the sufficient minimum patch size for SG, as it relates to fragmentation.
      i. What is the current state of fragmentation? Utilize 2005 aerial photography from USGS (or state).
      j. Is there follow up data on compliance?
      k. Pinedale and Jonah data on effectiveness of incentives for drilling on existing sites.
      l. Utilization and refining of existing vegetation mapping for a better understanding of encroachment on SG habitat. Sources include BLM.

m. Use early and effective reclamation techniques, including interim reclamation, to speed return of disturbed areas to use by grouse. (may require multiple reclamation efforts)
n. Practice reclamation techniques that speed recovery of pre-existing vegetation. (e.g. brush-beating of sage brush for site clearance, retention of topsoil with native seed)
o. Cooperate with county weed programs to control noxious weed infestations associated with oil and gas development disturbances.
p. Minimize width of field surface roads. Avoid engineered and graveled roads when possible to reduce the footprint.
q. Reduce daily visits to well pads and road travel to the extent possible in sage grouse habitat.
r. Utilize well telemetry when practical to reduce daily visits to wells.
s. Share sage grouse data with industry to allow planning to reduce impacts.
t. Structure reclamation soil profiling and re-vegetation seed mixes to create high quality sage grouse habitat as quickly post mining as possible.
u. Conduct effective enhancements to adjacent or nearby habitats to maintain sage grouse population numbers.
v. Complete mitigation measures prior to mine site development or expansion where possible to minimize sage grouse population disruption.

ii. Develop and implement a framework that encourages voluntary participation in SG conservation. (17)
a. Are the stipulations appropriate?
b. Look for incentives to commerce that will accomplish positive results for SG.
c. Have adaptive approach to regulations for industry over time based on monitoring results, such as moving drill pads to benefit bird.
d. Determine the sufficient minimum patch size for SG, as it relates to fragmentation.
e. Needs to reflect more complete array of oil shale techniques.
f. Pinedale and Jonah data on effectiveness of incentives for drilling on existing sites.
g. Utilization and refining of existing vegetation mapping for a better understanding of encroachment on SG habitat. Sources include BLM.
h. Cooperate with county weed programs to control noxious weed infestations associated with oil and gas development disturbances.
i. Share sage grouse data with industry to allow planning to reduce impacts.
j. Conduct effective enhancements to adjacent or nearby habitats to maintain sage grouse population numbers.
k. Complete mitigation measures prior to mine site development or expansion where possible to minimize sage grouse population disruption.

iii. Reduce the spatial and temporal influence / footprint of oil and gas development in both occupied and suitable unoccupied Sage grouse habitat. (16)
a. Look for incentives to commerce that will accomplish positive results for SG. (16)
b. Develop a list of BMPs to reduce overall post-construction footprints of energy development. [Obtain a strategy from industry of the smallest practical size of footprint in GRSG habitat. Reduce long-term footprint of facilities to the smallest practical space in GrSG habitat. (13)
c. Have adaptive approach to regulations for industry over time based on monitoring results, such as moving drill pads to benefit bird. (6)
d. In collaboration with the operator, site, and design oil and gas facilities to maximize opportunities for the application of interim and long term Sage grouse oriented reclamation. (5)

e. Encourage operators to participate with long term financial commitments in reclamation design, compliance, and monitoring. (5)
f. Practice reclamation techniques that speed recovery of pre-existing vegetation. (e.g. brush-beating of sage brush for site clearance, retention of topsoil with native seed) (3)
g. Conduct effective enhancements to adjacent or nearby habitats to maintain sage grouse population numbers. (3)
h. Cluster development of roads, pipelines, electric lines and other facilities and use existing, combined corridors where possible. (3)
i. Use directional drilling where biologically significant habitats are involved, to minimize impact to grouse habitat, if such techniques are technically feasible and cost effective.
j. Minimize pad size and other facilities to the extent possible, consistent with safety. (Where directional drilling is utilized, larger pads are needed for multiple wells.)
k. Locations of existing mitigation opportunities. (1)
l. Determine the sufficient minimum patch size for SG, as it relates to fragmentation. (2)
m. What is the current state of fragmentation? Utilize 2005 aerial photography from USGS (or state). (2)
n. Share sage grouse data with industry to allow planning to reduce impacts. (2)
o. Cooperate with county weed programs to control noxious weed infestations associated with oil and gas development disturbances. (1)
p. Plan and construct roads to minimize duplication. (1)
q. Is there follow up data on compliance? (0)
r. Utilization and refining of existing vegetation mapping for a better understanding of encroachment on SG habitat. Sources include BLM and Ed Hollowed. (0)
s. Use early and effective reclamation techniques, including interim reclamation, to speed return of disturbed areas to use by grouse. (may require multiple reclamation efforts). (0)
t. Utilize reclamation seed mixes consisting of native bunchgrasses, forbs and appropriate subspecies of big sagebrush. (0)
u. Avoid aggressive, non-native grasses (e.g. intermediate wheatgrass, pubescent wheatgrass, crested wheatgrass, smooth brome, etc) in reclamation seed mixes. (0)
v. Minimize width of field surface roads. Avoid engineered and graveled roads when possible to reduce the footprint. (0)
w. Reduce daily visits to well pads and road travel to the extent possible in sage grouse habitat. (0)
x. Utilize well telemetry when practical to reduce daily visits to wells. (0)
y. Structure reclamation soil profiling and re-vegetation seed mixes to create high quality sage grouse habitat as quickly post mining as possible. (0)
z. Complete mitigation measures prior to mine site development or expansion where possible to minimize sage grouse population disruption. (0)

iv. Develop a valid monitoring plan to assess impacts from energy development on SG. (15)
v. Minimize the area impacted and duration of impact on the sage grouse populations and habitat from surface mining and from above ground facilities of underground mines.
vi. Develop a valid monitoring plan to assess habitat restoration (repair or enhancement of habitat) measure success with respect to SG. (5)
vii. Evaluate alternatives to radial buffer approach, such as incorporating local topography conditions for defining geometry. (2)
viii. Develop monitoring plan for reclamation (restore to previous use) activities. (1)

ix. Assure a consultative process in project approval that incorporates most current data and technology available. (1)
x. Determine the factors (cost/benefit, geologic, topographic) associated with directional drilling. (1)
xi. Consider NW Local Plan Goals. (0)
xii. Measure of implementation of stipulations and/or conditions of approval with respect to SG. (0)
    a. Data associated with this mitigative measure for SG.
    b. Data need for economic feasibility.

B. Pool of Strategies to Work From
i. How do birds react to stipulations?
ii. Are the stipulations adequate?
iii. Are the stipulations appropriate?
iv. Look for incentives to commerce that will accomplish positive results for SG.
v. *****Have adaptive approach to regulations for industry over time based on monitoring results.
    a. Moving drill pads to benefit bird.
vi. Locations of existing mitigation opportunities.
vii. How long for mitigation to provide suitable habitat (type dependant, location dependency).
viii. Determine the sufficient minimum patch size for SG, as it relates to fragmentation.
ix. What is the current state of fragmentation? Utilize 2005 aerial photography from USGS (or state).
x. Is there follow up data on compliance?
xi. Needs to reflect more complete array of oil shale techniques.
xii. Pinedale and Jonah data on effectiveness of incentives for drilling on existing sites.
xiii. Utilization and refining of existing vegetation mapping for a better understanding of encroachment on SG habitat. Sources include BLM.
xiv. How much sage brush is too much? Stages of sage brush – habitat? Source includes Connelly et all.
xv. Inventory of ownership of minerals in SG habitat on federal, state and county lands. Ownership include BLM, States, and Counties.
xvi. NW Strategies
    i. Use early and effective reclamation techniques, including interim reclamation, to speed return of disturbed areas to use by grouse. (may require multiple reclamation efforts)
    j. Reduce long-term footprint of facilities to the smallest practical space.
    k. Utilize reclamation seed mixes consisting of native bunchgrasses, forbs and appropriate subspecies of big sagebrush.
    l. Practice reclamation techniques that speed recovery of pre-existing vegetation. (e.g. brush-beating of sage brush for site clearance, retention of topsoil with native seed)
    m. Avoid aggressive, non-native grasses (e.g. intermediate wheatgrass, pubescent wheatgrass, crested wheatgrass, smooth brome, etc) in reclamation seed mixes.
    n. Cooperate with county weed programs to control noxious weed infestations associated with oil and gas development disturbances.
    o. Minimize width of field surface roads. Avoid engineered and graveled roads when possible to reduce the footprint.
    p. Reduce daily visits to well pads and road travel to the extent possible in sage grouse habitat.
    q. Utilize well telemetry when practical to reduce daily visits to wells.
    r. Share sage grouse data with industry to allow planning to reduce impacts.

s. Structure reclamation soil profiling and re-vegetation seed mixes to create high quality sage grouse habitat as quickly post mining as possible.
t. Conduct effective enhancements to adjacent or nearby habitats to maintain sage grouse population numbers.
u. Complete mitigation measures prior to mine site development or expansion where possible to minimize sage grouse population disruption.

2. **<u>Current research and modeling does not provide an adequate understanding of the oil, gas, mining and energy development impacts on GRSG in Colorado.</u>**

A. Goals
- i. Increase funding for research. (18)
- ii. While developing additional Colorado specific research, use the best available and applicable information to expand the extent and enhance the utility of habitats available for sage grouse. (17)
- iii. Determine the effectiveness of mitigation through research. (15)
- iv. Determine how much energy development a population can withstand. (13)
- v. Have existing research evaluated. (8)
  - a. Have existing research peer reviewed.
- vi. Have research establish casual relationships to help with formulation of real solutions. (2)
- vii. Improve understanding and acceptance of research and modeling. (2)
- viii. Address issue of insufficient duration of current research data sets. (0)
  - a. Acknowledge affect on planning
  - b. Design and implement research program so that duration of data becomes sufficient.
- ix. Include in modeling scenarios and impact assessment 1) reclamation; 2) long term changes; 3) various stages of development. (0)

B. Strategies
- i. Information on oil wells in North Park
- ii. Grouse information ties to changes in oil activity
- iii. Data on past surface disturbance areas and whether SG have "reclaimed" area, or on top of former lek.
- iv. Infrastructure mapped and dated with respect to habitat (historical and new).
- v. Share information from this meeting with the research currently being conducted in the Piceance Basin.
- vi. NW Strategies
  - a. Study, monitor and attempt to quantify, impacts to sage grouse from oil and gas development.
  - b. Evaluate need for near-site and/or off-site mitigation to maintain sage grouse populations during oil and gas development and production.
  - c. Evaluate the effectiveness of the mitigation actions.
  - d. Share sage grouse data with industry to allow planning to reduce impacts.
  - e. Determine whether sage grouse will move to mitigation areas as mine sites develop in active habitat.

3. **<u>Policy and Guidelines</u>**

A. Goals
- i. Accommodate adaptive management where appropriate. (13)
- ii. Ensure resource management plans provisions for SG habitat are up to date. (9)
- iii. Obtain land use considerations for SG in counties that have SG. (7)
  - a. Encourage counties to consider SG conservation plans (local work group and statewide) when planning land use, and when processing land use permits.

b. Present information about SG to counties on an ongoing basis.

iv. Clarify what constitutes meaningful mitigation. (6)

v. Ensure conditions and stipulations for leases and permits are enforced and complied with. (6)

vi. Require (or secure) monitoring plans for project. (3)

vii. Make guidelines applicable to variety of site-specific situations. (1)

B. Strategies

i. Inventory SG provisions in Resource Management Plans (RMP)

ii. Evaluate existence and adequacy of plans are in place for federal, state, local, and local working group.

iii. Clarify stipulations and where they apply.

iv. NW Strategies

a. Plan and construct roads to minimize duplication

a. Cluster development of roads, pipelines, electric lines and other facilities and use existing, combined corridors where possible.

b. Avoid breeding/nesting season (refer to local conservation plans) construction and drilling when possible nesting? in sage grouse habitat.

c. Limit breeding season (refer to local conservation plans) activities near active sage grouse leks to portions of the day after 9:00 a.m. and before 4:00 p.m.

d. Gate field service roads or otherwise limit regular public access on field service roads, consistent with landowner wishes and direction.

e. Reduce noise impacts from compressor stations by locating stations and at least 2500 feet away from leks or by decibel reduction equipment.

f. Upon indications that substantial drilling may occur, a plan that evaluates impacts to sage grouse from entire field development would be preferable to individual well analysis. (where possible)

g. Limit facility footprint in sage grouse habitat to that necessary for safe and effective mining.

Bold and italicized will be further review by the team.

4. Communication

A. Goals

i. Present data so that they are accepted by people in general, especially among stakeholders.

ii. Include recommendations that are responsive to private property owner's concerns.

iii. Recognize need for energy production.

iv. Improve information sharing among stakeholders and between stakeholders and agencies.

v. Promptly and frequently update information for better understanding of impacts.

B. Strategies

i. Bridge gaps between agencies

ii. Bridge gaps counties and agencies

iii. Bridge gaps between commercial companies

iv. Bridge gaps between companies and agencies

* - Goal or Strategy?

Appendix II:
Requests for Future Energy PVA Modeling Efforts

These are actions that the group would like to have applied to the PVA modeling effort:

- Measure possible impacts outside the two-mile radius that are reflected inside the 2-mile circle
- Evaluate migration distances of populations and correlate to population size effects
- Use oil/gas literature about GrSG movements associated with development
- Gather data from industry where development is going to occur.
- Go to ColoWyo for data on migration and reclamation
- Evaluate for possible change the assumption that: 10 wells per pad = 10 wells per lek vs. 10 wells on 10 pads = 10 wells per lek.
- Measure the relationship of active leks to active drilling vs. active leks and producing wells. (the NP example)
- Get data from Kent Crowder on the lek usage in NP
- Identify possible important variables for energy impacts on GrSG like:
    - Pad size – small vs. large
    - Reclamation
    - Length of time from production, drilling
    - Power use at the site – electric vs. gas vs. solar (relates to noise and traffic)
    - Length of time since cessation of drilling, time in production
    - Depth of well – shallow vs. deep
- Use the continued monitoring of NP leks that are located near oil producing facilites. NP has a good continuous data set of lek counts.
- Try to establish causal relationships through more research
- Run the model for Moffat Co. with about 3100 wells. The result of this modeling effort can also be used in the draft NW local plan.
- Don't delay needed action(s) while waiting for model improvements
- Assume that the pace and scale of development will be greater in the future and run PVA model with these higher rates.

Greater Sage Grouse in Colorado
Statewide Conservation Planning Workshop

9 – 11 May 2006
Steamboat Springs, Colorado

WORKSHOP REPORT

Section VII

Colorado Greater Sage Grouse Population Viability Analysis Report

Population Viability Analysis for the Greater Sage Grouse (*Centrocercus urophasianus*) in Colorado

Philip Miller, Conservation Breeding Specialist Group
and
Colorado Greater Sage Grouse Conservation Plan Steering Committee Members

Introduction

Dependent exclusively on sagebrush ecosystems that define the ecology of much of western North America, the Greater Sage Grouse (*Centrocercus urophasianus*) was once distributed across twelve states of the western United States and three provinces of Canada. Greater sage-grouse currently occupy 700,000 km^2, or 56%, of their potential pre-settlement range, which once covered approximately 1,200,000 km^2 (Connelly et al. 2004). The species is now lost from Nebraska and Alberta, and other peripheral populations are at increasing risk of extirpation. As a result of these declines, petitions have been filed to list the species under the United States Endangered Species Act.

In Colorado, Greater Sage Grouse occupy significant tracts of sagebrush habitat in the northwestern region of the state. Authors of the Colorado Statewide Conservation Plan have identified six largely discrete regions where birds are found and have formed local working groups of concerned citizens, researchers, and managers dedicated to developing grouse conservation strategies at the local level. As in many other western states, there is concern over a variety of human activities – new housing development, oil and natural gas exploration, livestock grazing, surface mining, and hunting – that may unintentionally result in significant negative impacts to local Sage Grouse populations. These impacts might possibly destabilize the integrity of the sagebrush habitat or the populations themselves to an extent where the risk of local extinction is greatly increased. Therefore, it is critical that the potential impact of these activities is evaluated using sound scientific methodologies, and the results of these analyses are incorporated into the evolving statewide species conservation strategies.

Population viability analysis, or PVA, can be an extremely useful tool for investigating current and future risk of Colorado Greater Sage Grouse population decline or extinction. The need for and consequences of alternative management strategies can be modeled to suggest which practices may be the most effective in managing Sage Grouse populations in its wild habitat. *VORTEX*, a simulation software package written for population viability analysis, was used here as a vehicle to study the interaction of a number of Greater Sage Grouse life history and population parameters, to explore which demographic parameters may be the most sensitive to alternative management practices, and to test the effects of selected management scenarios.

The *VORTEX* package is a simulation of the effects of a number of different natural and human-mediated forces – some, by definition, acting unpredictably from year to year – on the health and integrity of wildlife populations. *VORTEX* models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or random variables that follow specified distributions. The package simulates a population by recreating the essential series of events that describe the typical life cycles of sexually reproducing organisms.

PVA methodologies such as the *VORTEX* system are not intended to give absolute and accurate "answers" for what the future will bring for a given wildlife species or population. This limitation arises simply from two fundamental facts about the natural world: it is inherently unpredictable in its detailed behavior; and we will never fully understand its precise mechanics. Consequently, many researchers have cautioned against the exclusive use of absolute results from a PVA in order to promote specific management actions for threatened populations (e.g., Ludwig 1999; Beissinger and McCullough 2002; Reed et al. 2002; Ellner et al. 2002; Lotts et al. 2004). Instead, the true value of an analysis of this type lies in the assembly and critical analysis of the available information on the species and its ecology, and in the ability to compare the quantitative metrics of population performance that emerge from a suite of simulations, with each simulation representing a specific scenario and its inherent assumptions about the available data and a proposed method of population and/or landscape management. Interpretation of this type of output depends strongly upon our knowledge of Greater Sage Grouse biology in its habitat, the environmental conditions affecting the species, and possible future changes in these conditions.

The *VORTEX* system for conducting population viability analysis is a flexible and accessible tool that can be adapted to a wide variety of species types and life histories as the situation warrants. The program has been used around the world in both teaching and research applications and is a trusted method for assisting in the definition of practical wildlife management methodologies. For a more detailed explanation of *VORTEX* and its use in population viability analysis, refer to Appendix I, Lacy (2000) and Miller and Lacy (2003).

Specifically, we were interested in using this preliminary analysis to address the following questions:

- Can we build a series of simulation models with sufficient detail and precision that can accurately describe the dynamics of Greater Sage Grouse populations distributed across Colorado?
- What are the primary demographic factors that drive growth of Greater Sage Grouse populations in Colorado?
- How vulnerable are small, fragmented populations of Greater Sage Grouse in Colorado to extinction under current management conditions? How small must a population become to increase its risk of extinction to an unacceptable level?
- What are the predicted impacts of current and potential future levels of housing development on selected Greater Sage Grouse populations in Colorado?
- What are the predicted impacts of current and potential future levels of mining and other surface activities on selected Greater Sage Grouse populations in Colorado?
- What are the predicted impacts of current and potential future levels of petroleum and natural gas development on selected Greater Sage Grouse populations in Colorado?
- What are the predicted impacts of current and potential future levels of hunting on selected Greater Sage Grouse populations in Colorado?
- Can reproductive mitigation improve the viability of Greater Sage Grouse populations in Colorado in the face of other anthropogenic processes?

Baseline Input Parameters for Stochastic Population Viability Simulations

Much of the data discussed below are gleaned from Zablen et al. (2003), the radio telemetry studies on Greater Sage Grouse of Hausleitner (2003 MS thesis) and Thompson (unpublished) in Moffat County, Colorado and Peterson (1980) in North Park, Colorado.

Breeding System: The Greater Sage Grouse is a polygynous lek-breeding species. In *VORTEX*, a set of adult females are therefore randomly selected each year to breed with a given male. Breeding success of adult males within a give year is often dependent on the success of that male in the previous year. This was not specifically simulated in this analysis as this aspect of the breeding biology is unlikely to have a noticeable demographic impact on future population performance.

Age of First Reproduction: *VORTEX* considers the age of first reproduction as the age at which the first clutch of eggs is laid, not simply the onset of sexual maturity. Female Sage Grouse can lay their first clutch at one year of age, while males are much more likely to be two years old at the time of egg-laying. Because of the very low probability of breeding success among yearling males, we elected to ignore this possibility in our models.

Age of Reproductive Senescence: In its simplest form, *VORTEX* assumes that animals can reproduce (at the normal rate) throughout their adult life. There are no real data available on senescence in Sage Grouse, so we made a reasonable estimate of the maximum age possible for this species as 10 years. In reality, surpassing this age in our models is unlikely given observed mortality rates (see below).

Offspring Production: Based on the depth of our knowledge of Sage Grouse life history, we have defined reproduction in these models as the production of newly-hatched chicks by a given female, roughly early May – June. Field data have been collected on the rates of nest initiation and success among both yearling and adult females. Of those that are initially unsuccessful in nesting, additional data exist on the rates of renesting success. With these data in hand, we can calculate the proportion of females that successfully reproduce in a given year through the following equation:

P(♀) = [(first nest initiation)(first nest success)] +
[(first nest initiation)(first nest NO success)(second nest initiation)(second nest success)]

Radio telemetry data from Hausleitner (2003) and Thompson (unpublished) in Moffat County allow us to derive estimates of these important parameters:

	Nest initiation	Nest success	Renest initiation	Renest success
Adults	0.93	0.50	0.16	0.75
Yearlings	0.83	0.39	0.22	0.57

Taken together, these data means that, on average, 38.7% of Greater Sage Grouse yearlings successfully reproduce in a given year, and 52.1% of adults are likewise successful. These results were combined in an equation used within *VORTEX* to describe the relationship between the average percentage of adult females breeding each year and their age.

Annual environmental variation in female reproductive success is modeled in *VORTEX* by specifying a standard deviation (SD) for the proportion of adult females that successfully lay a clutch of eggs within a given year. Wing receipt data from Greater Sage Grouse populations suggests that annual variability in reproductive success among yearling females is about 8%, while slightly lower among older birds (SD = 6%).

The maximum number of eggs per clutch has been set at 9, based on data collected by Griner (1939) in Greater Sage Grouse populations in eastern Utah. Given that an adult female lays a clutch of eggs, the distribution of clutch size was set as follows:

Number of eggs	%
1	1.0
2	1.0
3	1.0
4	1.0
5	5.5
6	27.3
7	35.0
8	25.0
9	3.2

This distribution yields an average clutch size of 6.75 eggs. The overall population-level sex ratio among eggs is assumed to be 50%.

Density-Dependent Reproduction: *VORTEX* can model density dependence with an equation that specifies the proportion of adult females that reproduce as a function of the total population size. In addition to including a more typical reduction in breeding in high-density populations, the user can also model an Allee effect: a decrease in the proportion of females that bread at low population density due, for example, to difficulty in finding mates that are widely dispersed across the landscape.

While a significant source of debate among species experts, there are no current field data to support density dependence in reproduction in Greater Sage Grouse populations. Consequently, this option was not included in the models presented here.

Male Breeding Pool: In many species, some adult males may be socially restricted from breeding despite being physiologically capable. This can be modeled in *VORTEX* by specifying a portion of the total pool of adult males that may be considered “available” for breeding each year. Observational data suggests that as few as 10% of the adult males are actually participating in the displays on leks within a given population segment, and this value was used in our baseline population analysis. Other researchers think this value may be much higher, approaching as high as 33%.

Mortality: *VORTEX* defines mortality as the annual rate of age-specific death from year x to $x + 1$; in the language of life-table analysis, this is equivalent to $q(x)$. Juvenile rates were composed of data estimated from hatching to 1 September (NW Colorado: Thompson, unpublished), then 1 September to 30 March (Idaho: Beck et al., in press). Yearling and adult rates are largely based on data collected in North Park by Zablan et al. (2003), with additional data provided by Hausleitner (2003).

Age Class	% Mortality (SD)	
	Females	Males
0 – 1	75.7 (5.0)	74.5 (5.0)
1 – 2	24.0 (4.0)	36.5 (3.0)
2 - +	42.0 (4.0)	63.0 (1.0)

Inbreeding Depression: *VORTEX* includes the ability to model the detrimental effects of inbreeding, most directly through reduced survival of offspring through their first year. Because of the complete absence of information on the effects of inbreeding on the demography of Greater Sage Grouse, the group concluded that this option should not be included in our models.

Initial Population Size: A total of six discrete populations of Greater Sage Grouse were considered in this analysis. These populations are listed below, with their estimated numbers based on observed spring breeding counts of males on leks and a presumed 2:1 female:male ratio.

Population	Breeding Males*	Total Population
Piceance / Parachute / Roan	186	1,104
Meeker / White River	28	153
North Park	1,234	6,731
Middle Park	290	1,581
North Eagle / South Routt	104	567
Eagle	11	60
Routt	93	507
Northwest Colorado	2,387	13,023
Zone 1	153	834
Zone 2	28	153
Zone 3A	534	2,913
Zone 3B	625	3,408
Zone 3C	139	759
Zone 4A	217	1,185
Zone 4B	76	414
Zone 5	294	1,605
Zone 6	304	1,659
Zone 7	17	93

* Average value, 2001 - 2005
** Total N = (0.55)(Breeding males) + 2(0.55)(Breeding males)

Note that the North Eagle / South Routt and Northwest Colorado regions are actually composed of metapopulations – that is, aggregates of subpopulations that are linked together through differential rates of dispersal. See below for a detailed discussion of additional metapopulation parameters.

VORTEX distributes the specified initial population among age-sex classes according to a stable age distribution that is characteristic of the mortality and reproductive schedules described previously.

Carrying Capacity: The carrying capacity, K, for a given habitat patch defines an upper limit for the population size, above which additional mortality is imposed randomly across all age classes in order to return the population to the value set for K.

The estimation of a carrying capacity is a very difficult process. The approach taken in this analysis involved identifying the most reasonable estimated high male lek count in a given region and, by applying the same transformation used to calculate current population size, determine total local carrying capacity. These results are given in the table below.

Population	Max. Breeding Males*	Total K
Piceance / Parachute / Roan	285	1554
Meeker / White River	--	300
North Park	1521	8296
Middle Park	327	1784
North Eagle / South Routt	307	1673
Eagle	79	429
Routt	228	1244
Northwest Colorado	2,387	18,170
Zone 1	268	1462
Zone 2	129	704
Zone 3A	570	3109
Zone 3B	667	3638
Zone 3C	153	835
Zone 4A	486	2651
Zone 4B	--	414
Zone 5	565	3082
Zone 6	400	2182
Zone 7	--	93

Metapopulation Parameters: For the North Eagle / South Routt and Northwest Colorado populations, additional data on dispersal was required. Field observations indicate that dispersing birds are predominantly composed of yearlings; as a result, we limited dispersal to only those birds aged 1 year. Moreover, while a small percentage of dispersing birds are observed to be male, the model assumes that only females disperse.

Largely in order to achieve a higher degree of model realism with respect to overall metapopulation dynamics, we derived a conditional function that limited the amount of dispersal into populations that were already approaching a given habitat's carrying capacity. Specifically, we prohibited dispersal into a given population when the recipient population was at least 80% saturated; in other words, under conditions when $N \geq 0.8K$.

Rates of dispersal – defined in *VORTEX* as the probability (expressed as a percentage) of an individual moving from one population to another, are given in the table below. Note that the rates between any two populations are not constrained to be symmetric, based on the available data. Source populations are listed as rows, while columns designate recipient populations.

Zone	1	2	3A	3B	3C	4A	4B	5	6	7
1	87	10	0	0	0	0	0	0	1	2
2	3	77	6	5	0	0	0	5	3	1
3A	1	2	69	10	10	0	0	5	3	0
3B	0	3	10	62	10	10	0	5	0	0
3C	0	1	15	15	60	0	4	5	0	0
4A	0	0	0	15	5	75	5	0	0	0
4B	0	0	0	0	3	3	93	1	0	0
5	0	3	5	5	5	0	3	74	5	0
6	1	3	3	0	0	0	0	3	87	3
7	1	1	0	0	0	0	0	0	1	97

Iterations and Years of Projection: All population projections (scenarios) were simulated 500 times. Each projection extends to 50 years, with demographic information obtained at annual intervals. All simulations were conducted using *VORTEX* version 9.60 (March 2006).

Table 1 below summarizes the baseline input dataset upon which all subsequent *VORTEX* models are based.

Table 1. Demographic input parameters for the baseline *VORTEX* Colorado Greater Sage Grouse models. See accompanying text for more information.

Model Input Parameter	Baseline Value
Breeding System	Polygynous
Age of first reproduction (♀ / ♂)	1 / 2
Maximum age of reproduction	10
Annual % adult females reproducing	38.7 (Yrl) / 52.1% (Ad)
Density dependent reproduction?	No
Maximum clutch size	9
Mean clutch size†	6.75
Overall offspring sex ratio	0.5
Adult males in breeding pool	10%
% annual mortality, ♀ / ♂ (SD)	
0 – 1	75.7 / 74.5 (5.0)
1 – 2	24.0 / 36.5 (3.0)
2 – +	42.0 / 63.0 (4.0 / 1.0)
Initial population size / carrying capacity	
Parachute / Piceance / Roan	1,104 / 1,554
Meeker / White River	153 / 300
North Park	6,731 / 8,296
Middle Park	1,581 / 1,784
North Eagle / South Routt	567 / 1,673
Eagle	60 / 429
Routt	507 / 1,244
Northwest Colorado	13,023 / 18,170
Zone 1	834 / 1,462
Zone 2	153 / 704
Zone 3A	2,913 / 3,109
Zone 3B	3,408 / 3,638
Zone 3C	759 / 835
Zone 4A	1,185 / 2,651
Zone 4B	414 / 414
Zone 5	1,605 / 3,082
Zone 6	1,659 / 2,182
Zone 7	93 / 93

† Exact probability distribution of individual clutch size specified in input file.

Simulating the Impacts of Human Activity on Sage Grouse Population Dynamics

Once the baseline demographic parameters are established, additional work must be devoted to determining the mechanisms through which specific human activities within Greater Sage Grouse habitat – namely housing development, harvest, oil & natural gas development, surface mining, and mitigation of reproductive success – may influence the bird's population dynamics in the future. Each individual activity is discussed in detail below.

Housing Development
Regions considered: Meeker/White River; Middle Park; North Eagle / South Routt

The primary assumption in our analysis is that the construction of new homes will reduce the amount of suitable sagebrush habitat available to Sage Grouse. This can be modeled in *VORTEX* through a gradual reduction in habitat carrying capacity, K.

Human population projections through 2020, and associated estimates of average household size, were used to estimate the increase in new housing units across each affected region. Additional data on sagebrush habitat distribution were used to estimate the proportion of individual land parcels of different size classes that would occur within habitat considered optimal for Greater Sage Grouse. Using these estimates, two different levels of housing intensity were developed: Level 1, where only land parcels less than 40 acres in size were considered; and Level 2, where parcels up to 320 acres were considered to impact sagebrush habitat.

	% Reduction in K, 50 Years	
Region	**Level 1**	**Level 2**
Meeker / White River	3.4%	23.5%
Middle Park	8.2	31.2
North Eagle / South Routt		
Eagle	8.0	85.2
Routt	6.7	57.3

These reductions in carrying capacity are implemented in *VORTEX* as a linear decline in K over 50 years. For example, a Level 1 reduction in carrying capacity for Middle Park would result in a total reduction in K of 8.2%, from 1784 to 1638.

Harvest
Region considered: North Park

The primary assumption in an analysis of harvest is that such a process will directly impact the mortality rates of affected age-sex classes. Detailed data on harvest composition (based on wing receipts) are available from Jackson County (North Park) dating back to 1970. These data were used in conjunction with high male lek count data in the same area to derive an estimate of the percentage of the total Sage Grouse population that was harvested by hunters during the time period 2000 – 2004. From 2000 to 2003, the average harvest was approximately 3.3% of the estimated total population, while in 2004 the harvest increased dramatically to nearly 15% of the population. Moreover, additional analysis indicates that the average composition of the harvest from 1974 to 1998 does not appear to deviate significantly from the age-sex structure of the wild population. In other words, there appears to be little evidence to suggest a noticeable bias in the age or sex of the birds that are harvested.

Based on these historic data, the potential impacts of long-term additional hunting-based mortality was investigated by adding 1%, 2%, 4%, or 8% mortality to all age-sex classes of Greater Sage Grouse during each year of the simulation. Note that an often vigorous debate exists on the mechanism of hunting mortality in game species such as Greater Sage Grouse. For many species, hunting mortality is typically thought to be *compensatory*; in other words, hunting is a method for removing individuals from a population that would otherwise die from other natural causes, so that the actual hunting mortality does not impose an additional burden on the population. For other species, hunting may largely act in an *additive* fashion, thereby increasing the overall mortality rate of affected cohorts above that observed in an unaffected population. As is the case with most natural phenomenon, the "truth" for Greater Sage Grouse likely falls within these two extremes. The hunting models described here do not by definition ascribe to a specific level of compensation and/or additivity, but instead merely serve as a tool to stimulate discussion of hypotheses and associated assumptions.

Oil and Natural Gas

Regions considered: Northwest, Parachute / Piceance / Roan, North Park

Scientific evaluation of the effects of oil and gas development on Greater Sage Grouse in Colorado does not currently exist. Until such research can be completed, we must rely on the recent studies from Holloran (2005) and Lyon and Anderson (2003) conducted in Wyoming.

Essentially, Holloran identified two levels of demographic impact on Sage Grouse populations in Wyoming, as a function of the density of wells within a 3-km (2-mile) distance from a lek. Holloran (2005) found that male lek attendance was affected by increasing oil and gas development: leks with 5-15 wells within 3km (2 miles) were lightly impacted, while those with >15 wells within 3km were heavily impacted. Since the PVA model assumes that only 10% of males breed, male activity reduction is not likely to strongly influence model performance. However, Holloran also found that annual survival of adult nesting females declined 20.4% (73.4% pretreatment to 53.0% post treatment) in development areas. He also found a 6.4% decline in annual survival (91.8% pretreatment to 85.4% post-treatment) for nesting yearling females. In addition, Lyon and Anderson (2003) found that female nest initiation rates declined in disturbed areas from 89% to 65%, a 24% decline.

In an attempt to estimate oil and gas impacts on Greater Sage Grouse, we increased adult female mortality by 20%, increased yearling female mortality by 6.4%, and decreased nest initiation by 24% where oil and gas development reaches Holloran's heavy impact criteria (>15 wells within 3km). Holloran used leks where well density was >5 as treatment leks. Leks with less than that level of development were used as controls, where impacts were assumed to be minimal. For our analysis, we raised this control level from 5 to 8 wells/lek. Considering only current infrastructure, North Park is already at 8 wells/lek. As North Park populations remain stable, we believe this upward adjustment in the bottom impact threshold is warranted and supported by current trend data in North Park. Impacts at levels of development between the control and 15 wells/lek were considered to be less than those above 15 wells/lek, though intermediate levels of demographic impacts to female sage grouse were not reported by Holloran or Lyons. For development densities between our control level of 8 wells/lek and the high impact threshold of 15 wells/lek, we imposed a gradual increase in demographic impact, applying an annual increment of additional mortality and decreased nest initiation each year until the high threshold was reached. The heavy impact parameters were applied each year once the heavy impact threshold was crossed.

To cover a range of possible scenarios, we evaluated three levels of future development (1000, 5000, 20000 additional wells) in addition to currently active wells. The first two scenarios (250, 1000, 5000) were used for the North Park population, while all three were used for NW Colorado and Piceance / Parachute / Roan. The future development scenarios for each population are intended to represent reasonable low, medium and high levels of potential development over the 50-year life of the PVA model. They do not represent published estimates of development but are selected only to provide a picture of what impacts might be at each level of development. We attempt to keep the scenarios plausible however, by comparing with estimates of foreseeable development for the three areas developed by BLM and others, especially in NW Colorado and Piceance / Parachute / Roan. The medium and high levels in North Park substantially exceed current estimates (~100 wells in the next 20 years). We assumed that existing and new wells would operate through the full life of the model. Holloran (2005) found that existing facilities continued to impact populations after construction, so both existing and potential new wells were combined in each portion of this analysis.

To evaluate development intensity, we randomly plotted wells for each development scenario and then counted the number of wells (current and future) within each 3 km (2mi) lek buffer. These counts were then averaged across each population or zone. Current active wells were plotted in GIS within each of the three target populations. Well placement for the various scenarios was then added to the existing well layer. New wells were randomly placed within greater sage-grouse overall range in each population area in the North Park and Piceance / Parachute / Roan populations. In the Northwest Colorado population, half of the wells were randomly placed in Zones 2 and 3b, both areas with substantial current oil and gas activity. The remaining wells were randomly placed in the remaining Zones, except Zone 7.

For the purposes of this PVA, we assume that the density of new wells will increase linearly over time. We also assumed that Sage Grouse demographic responses will also react linearly over time between the thresholds > 8 wells per lek and >15 wells/lek as described in the table above. The model assumes that impacts of development increase linearly from no impact below the control threshold (8 wells/lek) to the high impact measures once the high threshold is reached (15 wells/lek). That is, no impact is assessed from 0 to 8 wells, annually increasing impacts (heavy impact rates/number of years between control and high threshold) from 9 to 15 wells, and heavy impacts above 15 wells. Therefore, Sage Grouse demographic rates will change linearly over time as well until the critical well density threshold is reached (15 wells/lek). Once the heavy impact development level is reached, heavy impact demographic parameters will continue to be applied throughout the remaining course of the 50-year simulation.

A representative set of “trajectories” for the three demographic rates affected is shown in Figure 1 below, considering only adult female mortality in the Piceance / Parachute / Roan region.

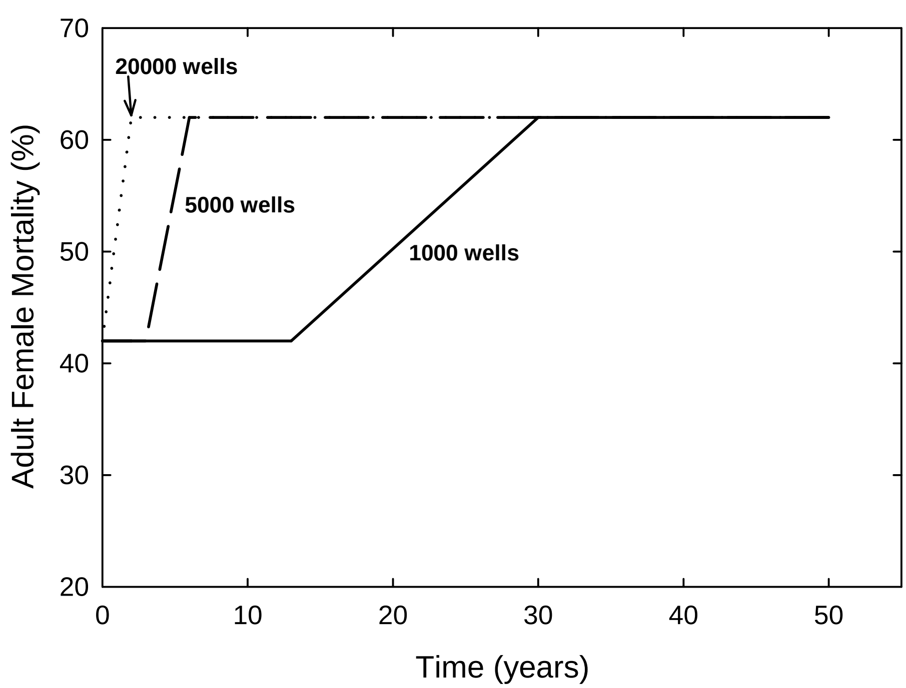


Figure 1. Simulated increase in adult female mortality of Greater Sage Grouse in the Piceance / Parachute / Roan region under alternative scenarios of oil & natural gas well development in the region. As the total number of proposed wells increases, the time required to reach the “critical” threshold density of 15 wells / lek decreases, leading to a more rapid rise in mortality as wells are constructed. See text for additional information.

The year at which each threshold is reached under each development scenario was derived from the GIS well plots for each population and NW Colorado zone. These threshold points are presented in Table 2 below. The body of the table indicates the number of years required to reach the appropriate threshold for each population and development scenario.

Table 2. Time thresholds for impacts from oil and natural gas well development on Greater Sage Grouse population demographics. The first value gives the number of years before an impact begins, while the second value indicates the number of years before maximum impact is reached. "—" indicates that the appropriate impact threshold is not reached within the 50-year span of the PVA model. See text for additional information on model parameterization.

	Proposed Well Density		
Region	1000	5000	20000
North Park	1 / 20	1 / 4	
Parachute / Piceance / Roan	13 / 30	3 / 6	1 / 2
Northwest		25 / 50	6 / 13
1	— / —	30 / —	8 / 20
2	— / —	15 / 30	4 / 8
3A	— / —	40 / —	10 / 20
3B	5 / 30	10 / 30	3 / 8
3C	— / —	20 / 50	5 / 13
4A	— / —	40 / —	10 / 20
4B	— / —	45 / —	11 / 20
5	— / —	40 / —	10 / 20
6	— / —	40 / —	10 / 20
7			

Surface Mining

Regions considered: Northwest, Middle Park, North Eagle / South Routt, Piceance / Parachute / Roan

As with new housing development, the primary assumption in our analysis here is that surface mining for gravel, oil shale and similar resources will reduce the amount of suitable sagebrush habitat available to Sage Grouse. This can be modeled in *VORTEX* through a gradual reduction in habitat carrying capacity, K.

GIS analysis methods were used to identify Sage Grouse habitat areas that could be targeted for surface mining activities, and linear rates of habitat carrying capacity loss were calculated over the 50-year period of the PVA model. Two levels of activity were considered, with increasing extent of disturbance to Sage Grouse habitat (see table below). Low levels of activity in the Meeker / White River region were initially considered, then removed from the analysis due to their negligible impact. Detailed analysis of the Northwest Colorado region indicates that mining activity is relevant only for zones 3C, 4B, 5, and 6.

Region	% Reduction in K, 50 Years Level 1	Level 2
Middle Park	15.0	26.0
North Eagle / South Routt		
Eagle	17.0	35.0
Routt	17.0	35.0
Piceance / Parachute / Roan	11.0	40.0
Northwest		
3C	6.0	10.0
4B	6.0	10.0
5	6.0	10.0
6	6.0	10.0

Reproductive Success Mitigation

Regions considered: All

In addition to the above anthropogenic activities, our PVA model considers the impact that increasing reproductive success could have on improving Greater Sage Grouse population demographics. Such mitigation activities can include improving habitat quality / availability, population augmentation, or predator mitigation. The choice was made to simulate reproductive mitigation through improving reproductive success, since past research (e.g., Duebbert and Kantrud 1974; Garretson and Rohwer 2001) has demonstrated that such activity can be highly beneficial during the breeding season for waterfowl species. Unfortunately, analogous data do not exist for Greater Sage Grouse, and studies on European species have targeted adult survival.

It is important to consider that "reproductive mitigation" does not by necessity mean "predator control" in the typical sense. Mitigation can also be at least partially achieved through, for example, habitat modifications that make predation on nesting Sage Grouse less likely.

In light of the data cited above, we elected to simulate three different levels of reproductive mitigation by increasing the percentage of breeding-age Greater Sage Grouse that successfully reproduce in a given year by 5%, 10%, or 15%. These values were added to the baseline measures for both yearlings and adults. For example, the baseline value of 38.7% of yearling females breeding was increased to 43.7%, 48.7%, and 53.7%. Reproductive mitigation was simulated in the large majority of models that included one or more human activities in order to evaluate its utility as a management action that could possibly ameliorate the negative impact of other activities on the landscape.

Results of Baseline Simulations

Results reported for selected modeling scenarios include:

$\underline{r_s}$ (SD) – The mean rate of stochastic population growth or decline (standard deviation) demonstrated by the simulated populations, averaged across years and iterations, for all simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity.

$\underline{P(E)_{50}}$ – Probability of population extinction after 50 years, determined by the proportion of 500 iterations within that given scenario that have gone extinct within the given time frame. "Extinction" is defined in the *VORTEX* model as the lack of either sex.

$\underline{N_{50}}$ (SD) – Mean (standard deviation) population size at the end of the simulation, averaged across all simulated populations, including those that are extinct.

$\underline{GD_{50}}$ – The gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity.

Model Validation Through Retrospective Population Analysis

An important component of population viability analysis involves testing our simulation model against historical population census data. In this approach, we set the model's initial population size with a value based on historical data and then project the model forward to the present day, comparing the predicted trajectory with the real trajectory determined from field census counts. A reasonable fit between the observed and predicted curves gives considerable credibility to the simulation's mechanics and, therefore, instills much more confidence in the relative results from models that predict future responses of Greater Sage Grouse populations to human activities on the landscape.

The results of these retrospective analyses for each population are shown in Figure 2. With the exception of the Meeker / White River population, all other simulation models appear to accurately predict the true population census within a reasonable degree of uncertainty. Given this general degree of accuracy, the disparity between predicted population size and field census counts in the Meeker / White River analysis is likely not an error in the simulation model but instead probably reflects the small number of leks included in the field census, the difficulty in conducting detailed studies in the area, and the short time period over which the census was conducted. Therefore, the overall conclusion from this retrospective analysis is that our simulation model of Colorado Greater Sage Grouse population dynamics can be used with acceptable confidence in predicting the relative outcomes of alternative management scenarios for the species.

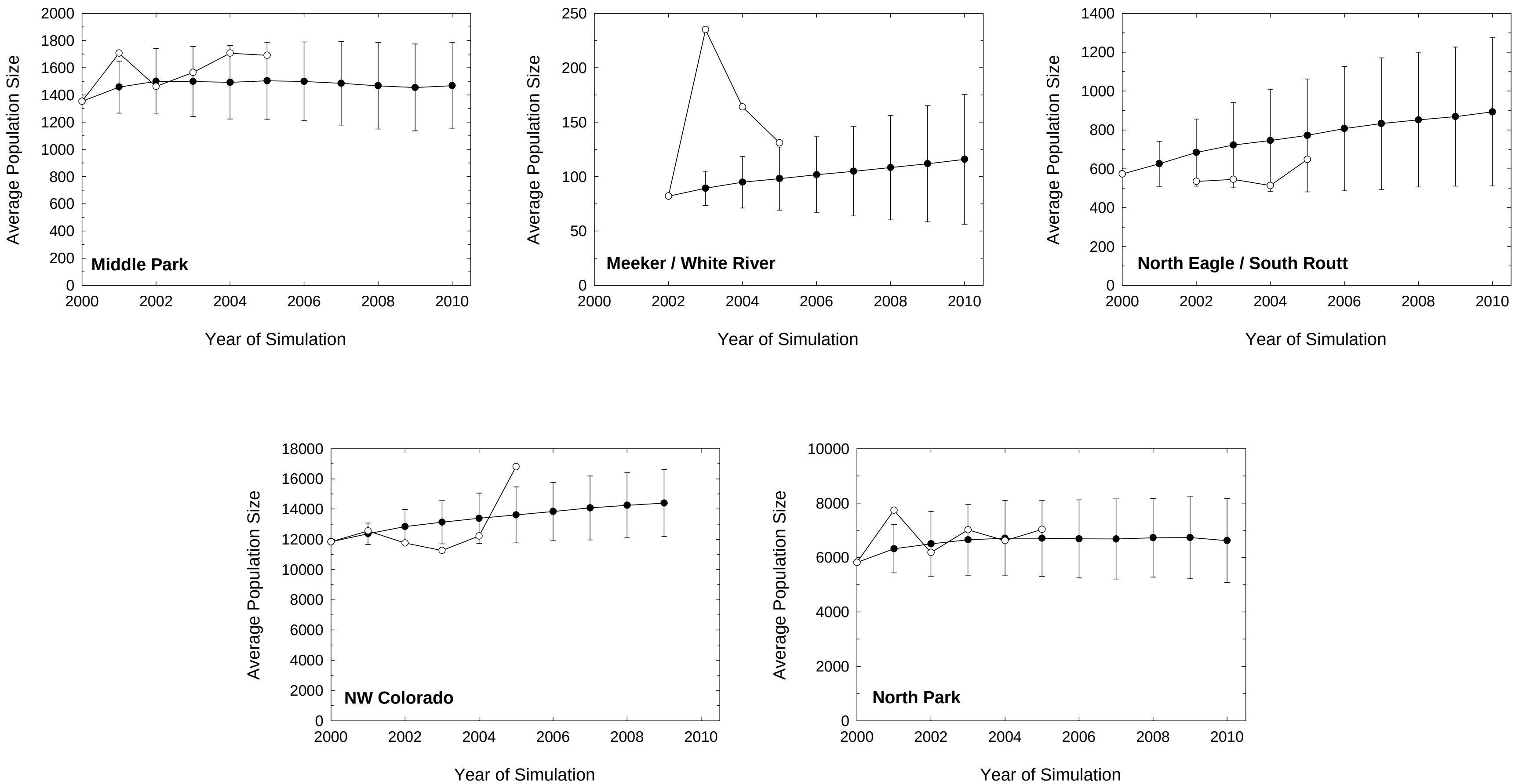


Figure 2. Retrospective projections for simulated Greater Sage Grouse populations in Colorado. Filled symbols indicate population sizes predicted using the PVA platform *Vortex*, while open symbols give "true" population size estimates derived from field counts. Analysis of the Piceance / Parachute / Roan population is not included here as field census data do not exist. See accompanying text for additional details on model construction and interpretation.

Demographic Sensitivity Analysis

During the development of the baseline input dataset, it quickly became apparent that a number of demographic characteristics of Greater Sage Grouse populations were being estimated with varying levels of uncertainty. This type of measurement uncertainty, which is distinctly different from the annual variability in demographic rates due to extrinsic environmental stochasticity and other factors, impairs our ability to generate precise predictions of population dynamics with any degree of confidence. Nevertheless, an analysis of the sensitivity of our models to this measurement uncertainty can be an invaluable aid in identifying priorities for detailed research and/or management projects targeting specific elements of the species' population biology and ecology.

To conduct this demographic sensitivity analysis, we identify a selected set of parameters from Table 1 whose estimate we see as considerably uncertain. We then develop proportional minimum and maximum values for these parameters (see Table 3).

Table 3. Uncertain input parameters and their stated ranges for use in demographic sensitivity analysis for the Colorado population of Greater Sage Grouse. Highlighted rows indicate those demographic parameters that show the highest sensitivity, *S*, as listed in the far right-hand column of the table. See accompanying text for more information.

		Estimate		
Model Parameter	Minimum	Baseline	Maximum	*S*
Maximum Age	9	10	11	-0.01269
% Yearling Females Reproducing	34.83	38.7	42.57	-0.11957
% Adult Females Reproducing	46.89	52.1	57.31	-0.27038
Clutch Size	6.08	6.75	7.43	-0.39531
% Female Chick Mortality	68.13	75.7	83.27	1.273304
% Male Chick Mortality	67.05	74.5	81.95	-0.00098
% Yearling Female Mortality	21.6	24.0	26.4	0.080039
% Yearling Male Mortality	32.85	36.5	40.15	0.000976
% Adult Female Mortality	37.8	42.0	46.2	0.253294
% Adult Male Mortality	56.7	63.0	69.3	0.006833

For each of these parameters we construct two simulations, with a given parameter set at its prescribed minimum or maximum value, with all other parameters remaining at their baseline value. With the ten parameters identified above, and recognizing that the aggregate set of baseline values constitute our single baseline model, the table above allows us to construct a total of 20 additional, alternative models whose performance (defined, for example, in terms of average population growth rate) can be compared to that of our starting baseline model.

For the entire suite of sensitivity analysis models, we will consider a generic population of 6,700 individuals and a carrying capacity of 13,500 individuals. This population is large enough to be relatively immune from excessive demographic uncertainty that is characteristic of small populations. Furthermore, carrying capacity is large enough to allow for significant population growth and to observe proper demographic dynamics.

The proportional sensitivity of a given simulation model, S, is given by

$$S = [(\lambda_{Min} - \lambda_{Max}) / (0.2^* \lambda_{Base})]$$

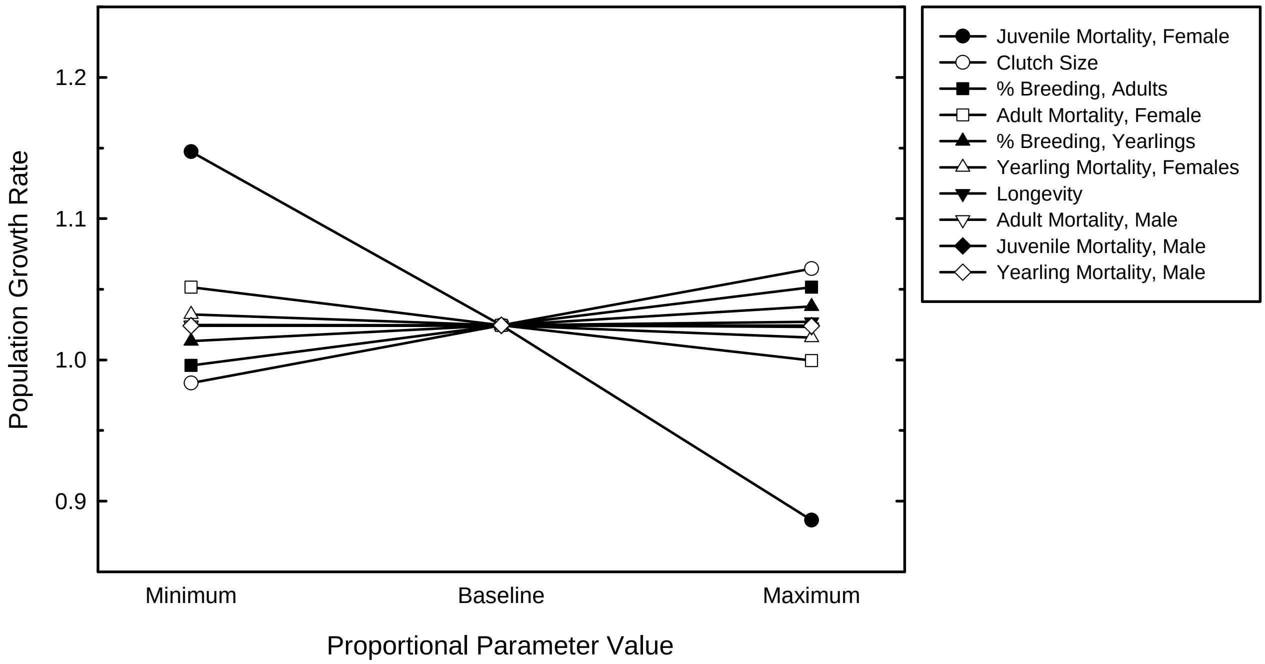
Where $\lambda = e^r$ is the annual rate of population growth calculated from the simulation and subscripts *Min*, *Max* and *Base* refer to simulations that include the minimum, maximum, and baseline values of the appropriate parameter, respectively. Using this formulation, model parameters with large S values show strong differences in λ when values are manipulated (modified from Heppell et al., 2000).

The results of the sensitivity analysis are shown in tabular form in Table 4 and graphically in Figure 3. Those lines with the steepest slope – namely, juvenile (chick) female mortality, clutch size, and adult female mortality – show the greatest degree of response in terms of population growth rate to changes in those parameters and, hence, the greatest sensitivity. These parameters can then be targeted in subsequent field activities for more detailed research and / or demographic management.

Table 4. Greater Sage Grouse PVA. Output from demographic sensitivity analysis models. See text for additional information on model construction and parameterization.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Baseline	0.024 (0.134)	0.000	10181 (3044)	0.9926
Maximum Age – Minimum	0.024 (0.135)	0.000	10230 (3218)	0.9923
Maximum Age – Maximum	0.027 (0.135)	0.000	10505 (2874)	0.9929
% Yearlings Breeding – Minimum	0.013 (0.136)	0.000	8987 (3578)	0.9914
% Yearlings Breeding – Maximum	0.037 (0.136)	0.000	11412 (2361)	0.9932
% Adult Females Breeding – Minimum	-0.004 (0.136)	0.000	5913 (3598)	0.9865
% Adult Females Breeding – Maximum	0.050 (0.135)	0.000	12077 (1837)	0.9940
Litter Size – Minimum	-0.017 (0.133)	0.000	3822 (2927)	0.9828
Litter Size – Maximum	0.063 (0.139)	0.000	112360 (1646)	0.9940
Juvenile Female Mortality – Minimum	0.138 (0.134)	0.000	13310 (564.8)	0.9933
Juvenile Female Mortality – Maximum	-0.120 (0.175)	0.226	41 (73)	0.7415
Juvenile Male Mortality – Minimum	0.024 (0.126)	0.000	10289 (3012)	0.9933
Juvenile Male Mortality – Maximum	0.024 (0.147)	0.000	10172 (3095)	0.9909
Yearling Female Mortality – Minimum	0.032 (0.136)	0.000	11132 (2625)	0.9929
Yearling Female Mortality – Maximum	0.016 (0.137)	0.000	9149 (3472)	0.9917
Yearling Male Mortality – Minimum	0.024 (0.134)	0.000	10291 (3029)	0.9928
Yearling Male Mortality – Maximum	0.024 (0.137)	0.000	10126 (3169)	0.9922
Adult Female Mortality – Minimum	0.050 (0.134)	0.000	12077 (1826)	0.9940
Adult Female Mortality – Maximum	0.000 (0.136)	0.000	6420 (3707)	0.9880
Adult Male Mortality – Minimum	0.024 (0.132)	0.000	10365 (3135)	0.9932
Adult Male Mortality – Maximum	0.023 (0.139)	0.000	10198 (3116)	0.9915

Figure 3. Demographic sensitivity analysis of a generic Colorado Greater Sage Grouse population. Those curves with the steepest slope indicate the model parameters with the greatest overall sensitivity. See accompanying text for additional information on model construction.



Risk Analysis I: Impacts of Habitat – Centric Activities (Housing, Surface Mining etc.) on Greater Sage Grouse Population Dynamics

Table 5 and Figure 4 show the combined results of the housing and surface activities analysis for the affected populations: Middle Park, Meeker / White River, North Eagle / South Routt, and Piceance / Parachute / Roan. All four regions show some degree of Greater Sage Grouse population decline in the presence of thee activities, with the lowest level seen in Meeker / White River and the greatest level of decline in North Eagle / South Routt. In Middle Park, the relative contributions of housing and surface mining to population decline appear to be roughly equal as evidenced by the gradual increase in the magnitude of the decline from scenarios in which both housing and surface activities are at a low level (H1 – M1) to when both are at a high level (H2 – M2). On the other hand, in the North Eagle / South Routt region the impacts of housing appear to be more severe since the high-level H2 housing scenarios show a more precipitous population decline. Interestingly, this appears to be at least partly linked to the more rapid decline seen in the much smaller Eagle subpopulation, which then contributes to the overall greater instability of the larger metapopulation. In addition, the high-level housing scenarios included a significant rate of habitat decline, with more than 85% of available Greater Sage Grouse habitat being lost over the time period of the simulation. This magnitude of decline, when combined with the small population sizes and their inherent demographic instability, works to put the larger metapopulation at a marked risk of extinction if conditions of habitat alteration reach predicted levels.

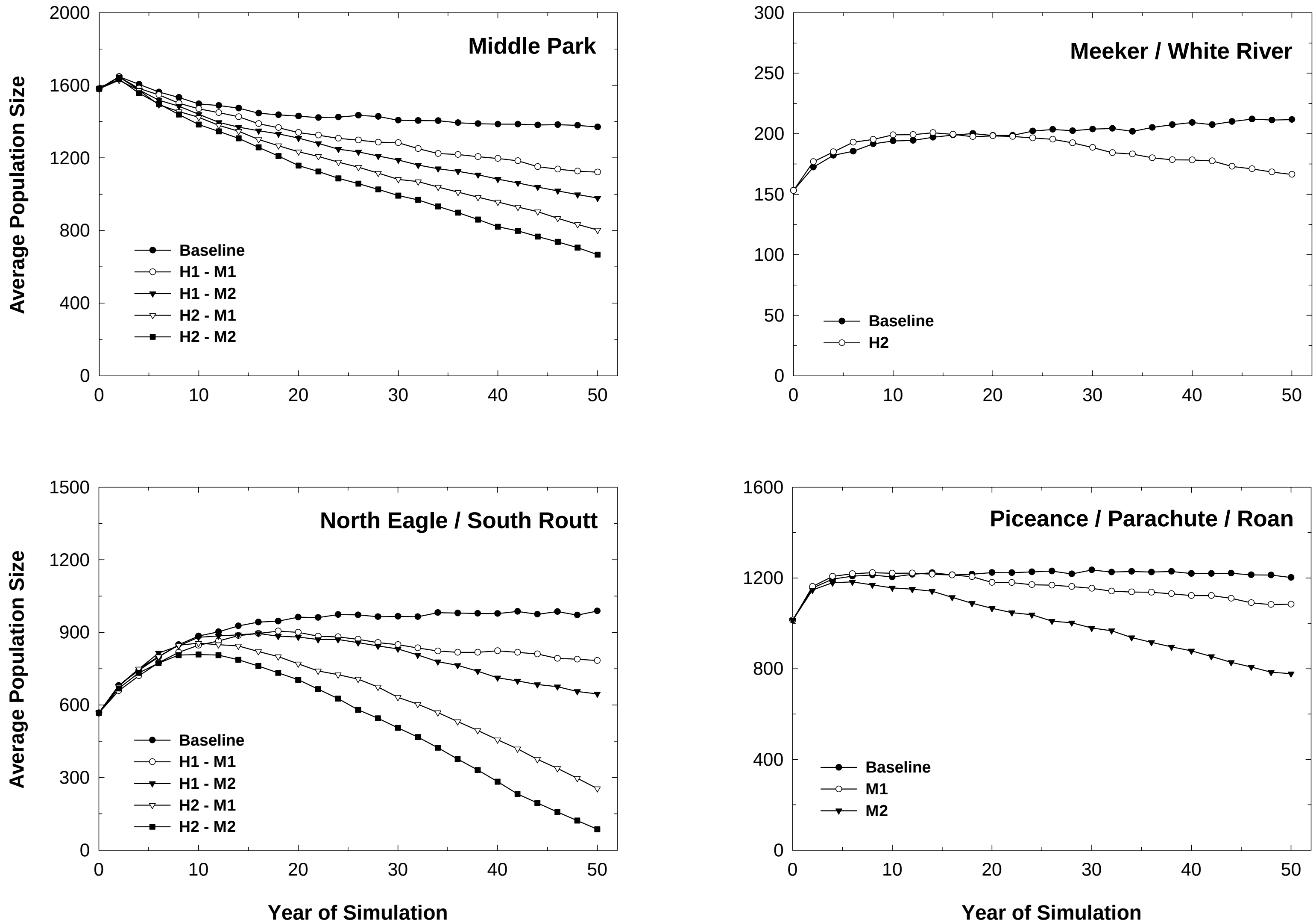
The extent of sagebrush habitat loss was so small in the Northwest Colorado region as to be essentially negligible. As a result, this activity had no measurable impact on the predicted dynamics of a simulated NW population. These results are not graphically depicted here.

Table 5. Greater Sage Grouse PVA. Output from analysis of habitat – centric activities models. See text for additional information on model construction and parameterization.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Middle Park				
Baseline	0.022 (0.138)	0.000	1370 (400)	0.9531
Housing 1 – Mining 1	0.025 (0.139)	0.000	1122 (273)	0.9502
Housing 1 – Mining 2	0.025 (0.139)	0.000	979 (214)	0.9462
Housing 2 – Mining 1	0.023 (0.139)	0.000	802 (175)	0.9427
Housing 2 – Mining 2	0.023 (0.140)	0.000	667 (121)	0.9366
Meeker / White River				
Baseline	0.019 (0.160)	0.016	208 (83)	0.6619
Housing 2	0.021 (0.160)	0.022	198 (84)	0.6718
North Eagle / South Routt				
Baseline	0.031 (0.167)	0.000	988 (471)	0.8980
Housing 1 – Mining 1	0.030 (0.168)	0.000	276 (55)	0.8156
Housing 1 – Mining 2	0.031 (0.168)	0.000	646 (261)	0.8921
Housing 2 – Mining 1	0.030 (0.172)	0.000	255 (82)	0.8217
Housing 2 – Mining 2	0.024 (0.177)	0.014	87 (19)	0.7854
Piceance / Parachute / Roan				
Baseline	0.025 (0.139)	0.000	1202 (342)	0.9422
Mining 1	0.025 (0.139)	0.000	1084 (296)	0.9404
Mining 2	0.023 (0.141)	0.000	778 (176)	0.9329

It may be important to note that the overall risks of population extinction under these habitat modification scenarios are perhaps an underestimate of the true risks. All of our modeling scenarios do not include significant levels of density dependence in either reproduction or mortality, other than the rather harsh "truncation" form of density dependence imposed when a simulated population exceeds the stated carrying capacity. The decision to exclude it from the modeling effort was based on the fact that specific data on the mode of action of density dependence is not available for Greater Sage Grouse. In these models, population growth continues at a relative constant average rate until K is exceeded, at which time individuals from the population are randomly removed across all age-sex classes until the population returns to a value at or slightly below K. In other words, the growth rate can remain high, even when the population is at K and the population has been reduced to relatively small numbers through the activity of something like housing development or surface mining activities. Some biologists may argue a contrary view – where the underlying intrinsic population growth declines to near 0.0 when the population reaches carrying capacity. This reduction in growth can lead to accompanying increases in demographic instability over time, especially when the population has been reduced to a small remnant as we are seeing in the North Eagle / South Routt complex. Reduced average growth rates and instability in these rates can conspire to increase risk of further population decline and perhaps even extinction. Therefore, the absence of density dependence in this system may result in an artificially high level of apparent stability and, consequently, population security. This characteristic of our simulations may perhaps be investigated in more detail and evaluated for its robustness at a later date. In the meantime, we can conclude that the reduction of available sagebrush habitat through housing development and surface mining activities can greatly reduce the size of associated Greater Sage Grouse populations.

Figure 4. Average projected size of simulated Greater Sage Grouse populations in the presence of habitat – centric human activities (housing development, surface mining etc.). Numerical designations “1” and “2” refer to low or high levels of development intensity, respectively, as described in the section on model inputs. See accompanying text for additional information on model construction and results.



Risk Analysis II: Impacts of Oil and Natural Gas Development on Greater Sage Grouse Population Dynamics

The results of our analysis of oil and natural gas development, and its impact on local populations of Greater Sage Grouse, are depicted in Table 6 and Figure 5. In all three regions where such development is either currently underway or to begin soon, our simulations suggest that the impact may be severe on the future viability of nearby Greater Sage Grouse populations. The onset of development leads to strongly negative population growth, rapid population decline and, in all cases but one (lower levels of development in Northwest Colorado), nearly certain extinction of local Grouse populations within 50 years.

This rather dramatic result is clearly the result of imposing strong demographic consequences on Greater Sage Grouse populations that live and breed near current or proposed oil and natural gas development areas. The data of Holloran (2005) indicate a marked reduction in survival and breeding success of Greater Sage Grouse in close proximity to oil and natural gas development areas; these data have been used essentially unmodified in this analysis, and clearly represent an unsustainable situation.

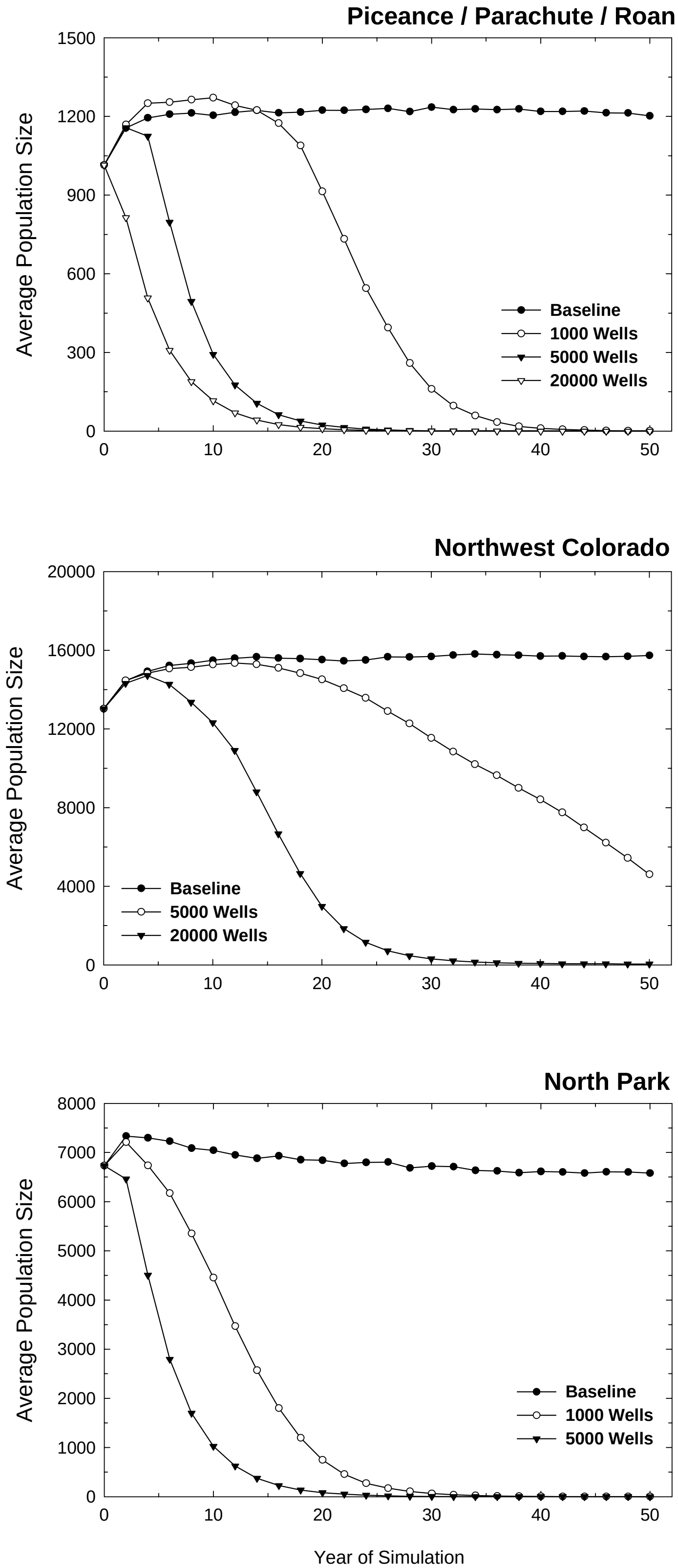
Table 6. Greater Sage Grouse PVA. Output from oil and natural gas analysis models. See text for additional information on model construction and parameterization.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Piceance / Parachute / Roan				
Baseline	0.025 (0.139)	0.000	1202 (342)	0.9422
1000 Wells	-0.120 (0.245)	0.907	1 (2)	0.4616
5000 Wells	-0.220 (0.260)	1.000	—	—
20000 Wells	-0.260 (0.257)	1.000	—	—
Northwest Colorado				
Baseline	0.030 (0.081)	0.000	15739 (1872)	0.9956
5000 Wells	-0.011 (0.089)	0.000	4604 (1798)	0.9925
20000 Wells	-0.011 (0.163)	0.072	48 (29)	0.5142
North Park				
Baseline	0.025 (0.135)	0.000	6582 (1794)	0.9903
1000 Wells	-0.191 (0.230)	0.988	1 (1)	0.4636
5000 Wells	-0.252 (0.238)	1.000	—	—

It is possible that the "raw" data presented in Holloran (2005) represent a worst-case scenario with respect to local Greater Sage Grouse population viability, for two primary reasons:

1. The natural gas fields Holloran studied were in the most intense development phase, where activity is at its highest and, consequently, impacts on local Grouse populations may be most severe. Such development lasts a finite period of time – perhaps only 5 to 10 years – before the field transitions into a production phase where activity is reduced and subsequent impacts on local Grouse populations may actually decline. The simulations presented here effectively assume that this development phase remains in effect throughout the 50-year duration of the simulation – thereby possibly over-estimating the long-term impact of the well field on Sage Grouse dynamics.

Figure 5. Average projected size of simulated Greater Sage Grouse populations in the presence of oil and natural gas development in selected regions of Colorado. See accompanying text for more information on model construction and results.



2. Through environmental conditions beyond his control, Holloran actually collected data on the impacts of oil and natural gas field development on Greater Sage Grouse during a period of marked drought. While the detailed mechanisms of drought's impact on local Grouse populations is not fully understood, it is possible that the measured effects in the presence of oil and natural gas development were compounded by the coincident drought – thereby leading to an overestimate of the true impacts of well-field development on local Grouse populations.

Because of these potential complicating and confounding factors, the PVA analyses presented here may be seen as preliminary and perhaps subject to refinement at a later date. Nevertheless it is important to recognize that our models target adult female breeding success and mortality as those parameters that are likely to be affected by oil and natural gas development – precisely those demographic parameters that appear to be primary drivers of population growth as determined in the sensitivity analysis. Therefore, while the exact degree of impact is unknown at the present time, it remains quite likely that this type of activity, with its direct impacts on Sage Grouse demographic rates, can have a much more severe impact on the stability and future viability of local Sage Grouse populations than those activities such as housing development that we believe act solely to reduce the quantity and/or quality of available sagebrush habitat.

Risk Analysis III: Impacts of Local Harvest through Hunting on Greater Sage Grouse Population Dynamics

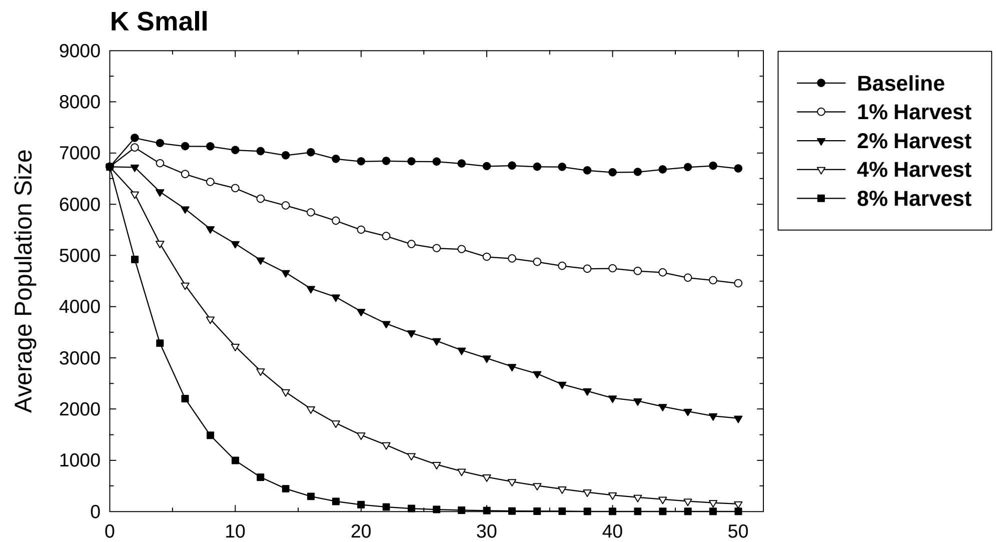
Table 7 and Figure 6 present the results of our harvest analysis on a simulated North Park population of Greater Sage Grouse. Note that even the imposition of an additional 1% increase in mortality across all age-sex classes can lead to a qualitative change in the growth character of our simulated population – from one that increases at approximately 2.5% per year to one that declines at 0.1 to 0.2% per year.

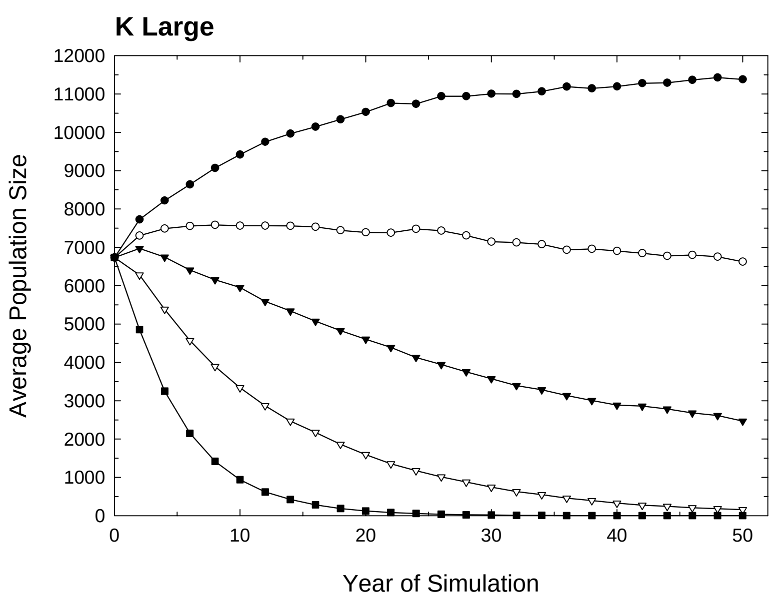
Table 7. Greater Sage Grouse PVA. Output from North park harvest models. See text for additional information on model construction and parameterization.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
K Small				
Baseline	0.026 (0.136)	0.000	6697 (1634)	0.9903
1% Harvest	-0.001 (0.139)	0.000	4454 (2253)	0.9855
2% Harvest	-0.030 (0.143)	0.000	1820 (1482)	0.9700
4% Harvest	-0.089 (0.163)	0.030	147 (242)	00.8253
8% Harvest	-0.225 (0.233)	0.996	1 (1)	0.1814
K Large				
Baseline	0.024 (0.135)	0.000	11379 (3272)	0.9929
1% Harvest	-0.002 (0.139)	0.000	6624 (4140)	0.9876
2% Harvest	-0.029 (0.144)	0.000	2467 (2649)	0.9718
4% Harvest	-0.089 (0.164)	0.032	156 (208	0.8286
8% Harvest	-0.224 (0.236)	0.994	1 (1)	0.5887

It is clear from these analyses that even a seemingly small increase in mortality – if applied equally to all age-sex classes at the same time – can have dramatic effects on the growth potential and long-term viability of affected populations.

Figure 6. Average projected size of simulated North park Greater Sage Grouse populations under different levels of harvest. Harvest is defined here as the identified percentage increase in annual mortality rates across all age classes of both sexes. The top panel shows population projections in the presence of a restrictive carrying capacity, set as 8300 individuals, while the bottom panel shows the same projections when that restrictive carrying capacity is lifted, thereby allowing essentially unrestricted population growth throughout the duration of the simulation. See accompanying text for more information on model construction and results.





It may be argued that the marked declines in population size seen in all harvest scenarios is at least partially caused by the restrictions imposed by the addition of a carrying capacity in our North Park population models. This carrying capacity, estimated to be about 8300 individuals, might be low enough to drive populations to decline as they encounter the restriction to grow beyond the ceiling. To further investigate this hypothesis, a second set of models was developed that effectively removed this restrictive ceiling by increasing carrying capacity K from 8300 to 15,000 individuals. As seen in the bottom panel of Figure 6, the removal of this restriction allowed the baseline (unharvested) population to nearly double in size over the 50 years of the simulation. However, the harvested populations showed a nearly identical trajectory in the presence of added mortality: significant decrease in growth potential and, in the most extreme cases, rapid population decline to extinction. Therefore, the imposition of a carrying capacity does not seem to be a major factor in predicting how a simulated Greater Sage Grouse population will respond to additional hunting-based mortality.

A very important assumption in these analyses is that our simulated harvest represents, effectively, 100% additive mortality on top on natural mortality acting on the population. In other words, we are assuming that all those birds that are removed from the population through harvest would have otherwise survived during the year, and many of them would have reproduced. We are therefore simulating the most extreme harvest scenario, in contrast to one where there is some level of compensatory mortality that would serve to reduce the overall magnitude of added mortality on the population. There is considerable controversy on the degree of compensatory v. additive mortality in game species such as Greater Sage Grouse (see Johnson and Braun 1999 for a review of this topic); while the controversy rages, the analyses presented here provide more general cautionary insights into the sensitivity of Sage Grouse populations to slight increases in mortality rates – particular of juvenile and adult females.

Risk Analysis IV: An Assessment of Increasing Reproductive Success Through Reproductive Mitigation as a Greater Sage Grouse Management Tool

The results of our reproductive mitigation models are shown in Table 8 and Figure 7. The efficacy of reproductive mitigation as a management tool for Greater Sage Grouse depends on the primary type of human activity that takes place within Sage Grouse habitat, and on the underlying growth dynamics of the Grouse populations. For example, in Middle Park where housing and surface activities are of primary concern, and the current population is already thought to be close to its habitat carrying capacity, reproductive mitigation appears to have relatively little overall impact. This is because, as we have learned before, housing development and surface mining activities act to reduce carrying capacities, while leaving the underlying Greater Sage Grouse population demography unchanged (in the absence of density-dependent phenomena). The increase in reproductive success through various mitigation activities only serves to hasten the approach of the simulated population to carrying capacity, after which time the population's trajectory is constrained by the gradual decrease in available habitat.

In contrast, consider the case of Meeker / White River where the population has an opportunity to grow to a carrying capacity that is currently rather large compared to today's population size. In this instance, an increase in reproductive success through mitigation activities can have a dramatic effect on the growth potential of the simulated Greater Sage Grouse population. Over the first 20 years of the simulation, the population can increase in size by as much as about 50% compared to the baseline trajectory, in the absence of housing development and reproductive mitigation. At later stages of the simulation, the model's growth potential is ultimately constrained by the gradual reduction in habitat carrying capacity – but reproductive mitigation models still show final population sizes that are at least as large as the baseline model. Under these conditions, reproductive mitigation can have a considerable impact potential.

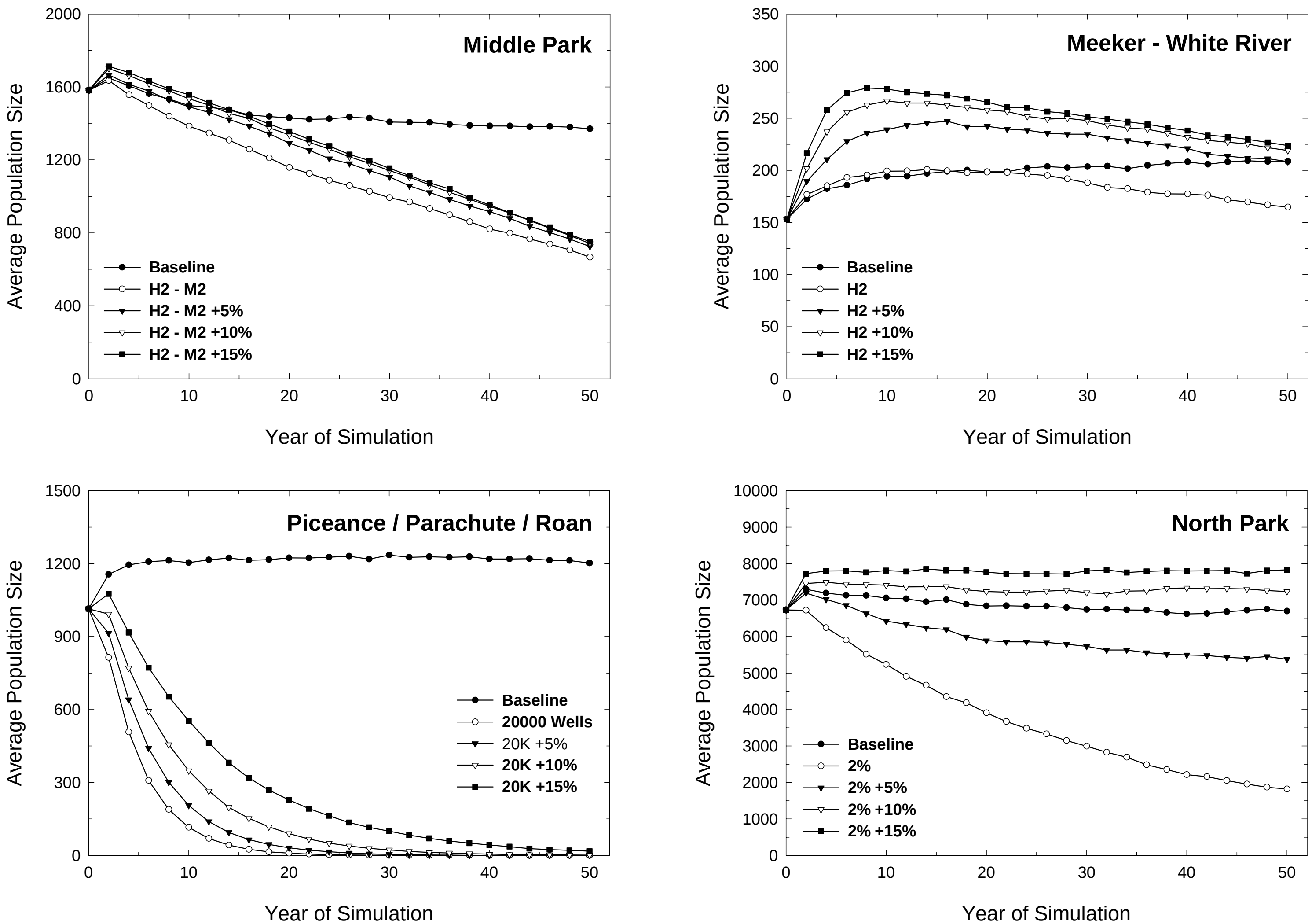
When reproductive mitigation is assessed in the context of our current assumptions around the impacts of oil and natural gas development, the situation remains much less optimistic. As exemplified by the Piceance / Parachute / Roan example given in Table 6 and Figure 7, the increase in reproductive success achieved through mitigation does not sufficiently compensate for the significant declines in survival and breeding success that results from oil and natural gas development. Overall population sizes may be considerably higher in the early stages of the simulation, particularly under assumed conditions of strong reproductive mitigation, but the general trend in population trend remains strongly negative, with high extinction risks by the end of the 50-year simulation.

Table 8. Greater Sage Grouse PVA. Output from analysis of reproductive mitigation models. “H2” and “M2” refer to high levels of habitat loss through housing and surface mining activities, respectively, in Middle Park and Meeker / White River. “20000 Wells” refers to a given level of oil and natural gas activity in the Piceance / Parachute / Roan region, and “2%” in North Park refers to specific level of harvest mortality through hunting. Reproductive mitigation is simulated through a 5%, 10% or 15% increase in the number of yearling and adult females that breed in a given year. See text for additional information on model construction and results.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Middle Park				
Baseline	0.022 (0.138)	0.000	1370 (400)	0.9351
Housing 2 – Mining 2	0.023 (0.140)	0.000	667 (121)	0.9366
Housing 1 – Mining 2 +5%	0.064 (0.140)	0.000	725 (71)	0.9410
Housing 2 – Mining 1 +10%	0.103 (0.140)	0.000	741 (50)	0.9408
Housing 2 – Mining 2 +15%	0.140 (0.142)	0.000	752 (38)	0.9374
Meeker / White River				
Baseline	0.019 (0.160)	0.016	208 (83)	0.6619
Housing 2	0.020 (0.162)	0.010	165 (62)	0.6347
Housing 2 +5%	0.061 (0.153)	0.000	208 (32)	0.6937
Housing 2 +10%	0.099 (0.154)	0.000	219 (22)	0.7024
Housing 2 +15%	0.139 (0.153)	0.000	224 (16)	0.7007
Piceance / Parachute / Roan				
Base line	0.025 (0.139)	0.000	1202 (342)	0.9422
20000 Wells	-0.260 (0.257)	1.000	—	—
20000 Wells +5%	-0.204 (0.251)	0.998	1 (2)	0.5559
20000 Wells +10%	-0.152 (0.243)	0.916	1 (5)	0.3953
20000 Wells +15%	-0.107 (0.216)	0.530	17 (44)	0.5612
North Park				
Baseline	0.026 (0.136)	0.000	6697 (1634)	0.9903
2%	-0.030 (0.143)	0.000	1820 (1482)	0.9700
2% +5%	0.010 (0.145)	0.000	5379 (2208)	0.9870
2% +10%	0.048 (0.145)	0.000	7237 (1306)	0.9903
2% +15%	0.084 (0.148)	0.000	7829 (825)	0.9907

The effects of reproductive mitigation can be much more pronounced under moderate levels of harvest mortality, as demonstrated in North Park in Table 8 and Figure 7. When reproductive mitigation is strong, the population can grow to a level that is larger than that predicted in the baseline model where harvest is absent. Even under low levels of reproductive mitigation, the final size of the harvested population is nearly three times that of a population where reproductive mitigation is absent. Of course, under conditions of higher harvest mortality, the benefits gained from reproductive mitigation are not as pronounced. The practice of reproductive mitigation, however, is shown here to have significant potential to improve the viability of Greater Sage Grouse populations in the presence of certain types of detrimental human activities on the landscape.

Figure 7. Average projected size of simulated Greater Sage Grouse populations in the presence of region-specific human activities and with varying levels of reproductive mitigation. “H2” and “M2” refer to high levels of habitat loss through housing and surface mining activities, respectively, in Middle Park and Meeker / White River. “20000 Wells” refers to a given level of oil and natural gas activity in the Piceance / Parachute / Roan region, and “2%” in North Park refers to specific level of harvest mortality through hunting. Reproductive mitigation is simulated through a 5%, 10% or 15% increase in the number of yearling and adult females that breed in a given year. See accompanying text for additional information on model construction and results



Future Directions for Additional Analysis

Density dependence in demographic rates

The inclusion of density dependence in survival and/or reproduction in Greater Sage Grouse could possibly alter some of the qualitative results of the PVA models discussed in this document, in particular the analysis of housing development and surface mining activities where habitat loss is considerable and Greater Sage Grouse populations soon occupy saturated sagebrush habitats. While there is scant evidence to suggest that strong density dependence is operating to modulate demographic rates in Greater Sage Grouse, the controversy remains vigorous. Additional modeling, including some form of density dependent demographics, could be initiated to demonstrate its effects and stimulate more thoughtful discussion on its mode of operation and intensity.

Revised oil and natural gas scenarios

Because of the issues in model parameterization discussed herein, we feel that the oil and natural gas development models presented in this document may overestimate the long-term impact of this activity on nearby Greater Sage Grouse populations. Efforts are currently underway to thoroughly assess these models for their realism and to modify them accordingly so that we can come up with a more rigorous analysis of the impact of this activity on the landscape.

Impacts of disease

West Nile virus (WNV) is clearly a disease of great concern to Grouse biologists in North America, but the data needed to rigorously evaluate its potential impact is lacking. *VORTEX* can, by itself, simulate fairly complex disease dynamics and their impacts on wildlife population demography. However, we have chosen to delete this option from our current analyses. The Conservation Breeding Specialist Group has also developed *OUTBREAK*, a much more sophisticated simulation model of wildlife disease epidemiology, that can be of tremendous value in studying disease processes in threatened wildlife populations. Future Greater Sage Grouse modeling efforts could be devoted to a deeper evaluation of WNV and its possible affects.

Conclusions

We may conclude our analysis of Greater Sage Grouse population viability by returning to the original set of questions that provided the foundation for our study.

- *Can we build a series of simulation models with sufficient detail and precision that can accurately describe the dynamics of Greater Sage Grouse populations distributed across Colorado?*

  Our retrospective demographic analysis indicates that we are indeed capable of building such models. It is extremely important to remember, however, that reliance on the absolute outcome predicted by any one modeling scenario must always be interpreted with extreme caution due to the inherent uncertainty in model input parameterization. A comparative analysis between models, in which a single factor (or at most two factors) is studied while all other input parameters are held constant, provides a much more robust environment in which alternative management scenarios can be evaluated for their effectiveness in increasing the viability of the target species.

- *What are the primary demographic factors that drive growth of Greater Sage Grouse populations in Colorado?*

  Our demographic sensitivity analysis indicates that models of Greater Sage Grouse population dynamics are most sensitive to variability in female juvenile (chick) survival, the proportion of females that successfully reproduce per year, and clutch size per successful female.

- *How vulnerable are small, fragmented populations of Greater Sage Grouse in Colorado to extinction under current management conditions? How small must a population become to increase its risk of extinction to an unacceptable level?*

  A formal analysis of this question is not yet part of this larger modeling effort; consequently, this question has yet to be fully determined The analyses presented here, however, provide some preliminary insight into this issue. For example, the rather small Meeker / White River population has an intrinsically higher risk of population decline and extinction even under conditions of equivalent underlying demographic rates used as model input. The higher levels of instability we see are directly tied to the smaller size of this population and the resulting higher levels of annual random variation in survival and reproductive rates. Overall, the relatively low levels of environmental variability included in these PVA models leads to a comparatively higher level of population stability and, by extension, a lower probability of population extinction.

- *What are the predicted impacts of current and potential future levels of housing development on selected Greater Sage Grouse populations in Colorado?*

  This activity, manifest largely through reductions in available sagebrush habitat, appears to have comparatively minor impact on the long-term demographic viability of Greater Sage Grouse populations in Colorado as long as underlying population demographic rates remain robust. However, the reduced population sizes that result from the gradual erosion of available habitat cannot be ignored and, in combination with other anthropogenic factors, could lead to longer-term increases in risk of population decline.

- *What are the predicted impacts of current and potential future levels of mining and other surface activities on selected Greater Sage Grouse populations in Colorado?*

  This activity, manifest largely through reductions in available sagebrush habitat, appears to have comparatively minor impact on the long-term demographic viability of Greater Sage Grouse populations in Colorado as long as underlying population demographic rates remain robust. However, the reduced population sizes that result from the gradual erosion of available habitat cannot be ignored and, in combination with other anthropogenic factors, could lead to longer-term increases in risk of population decline.

- *What are the predicted impacts of current and potential future levels of petroleum and natural gas development on selected Greater Sage Grouse populations in Colorado?*

  Oil and natural gas development, manifest through direct impacts on demographic performance of individual birds, may have major and severe consequences for Greater Sage Grouse populations in Colorado. This conclusion is based on models that use data from research studies on Greater Sage Grouse in nearby habitats. Consequently, it is important to thoroughly and critically review this available literature and to determine the applicability of these biological studies to Colorado's Greater Sage Grouse populations.

- *What are the predicted impacts of current and potential future levels of hunting on selected Greater Sage Grouse populations in Colorado?*

  Through field-based evaluations of population status, current levels of Greater Sage Grouse harvest in North Park appear sustainable. However, our analyses presented here provide evidence to suggest that even relatively low levels of additional harvest mortality – if sustained for long periods of time (i.e., one to two decades) can lead to marked increases in the risk of significant population decline. A more complete understanding of the demographic consequences of harvest, such as the degree of compensation that acts in a harvested Greater Sage Grouse population, is recommended before specific adjustments to harvest quotas are made.

- *Can reproductive mitigation improve the viability of Greater Sage Grouse populations in Colorado in the face of other anthropogenic processes?*

  Improving reproductive success through alternative mitigation activities could possibly lead to significant increases in Greater Sage Grouse demographic performance. However, these benefits can only be realized under certain conditions, particularly where specific human activities appear to directly affect population demographic rates to a relatively small degree. In other cases, the observed benefits do not appear to offset the declines in performance brought about by human activities on the landscape.

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Appendix I:
Revised Analysis of Oil and Natural Gas Development

Introduction

As discussed on pages 20 – 21 of this document, certain elements of the viability analyses pertaining to the impacts of oil and natural gas development were seen as perhaps oversimplified and, therefore, worthy of revision in subsequent modeling efforts. Consequently, in consultation with members of the Colorado Greater Sage Grouse Conservation Plan Steering Committee and after review of the original PVA work by participants in the May 2006 Conservation Planning workshop in Steamboat Springs, Colorado, the decision was made to conduct additional simulations of the impact of oil and natural gas on Greater Sage Grouse populations in the Piceance / Parachute / Roan and Northwest Colorado regions.

These additional analyses were specifically designed to help us address the following questions:

- How would the demographic behavior of our simulated populations of Greater Sage Grouse change in response to direct mitigation of oil and natural gas development at and/or near the site of the well pad itself?
- To what extent will the demographic behavior of our simulated populations of Greater Sage Grouse change if we assume a less severe direct impact of oil and natural gas development, even in the absence of mitigation?

We focused on the Piceance / Parachute / Roan and Northwest Colorado regions as they effectively represented what we believe to be, on a comparative scale, high-intensity and low-intensity development scenarios, respectively.

Description of Modified Input Parameters

As displayed graphically in Figure 1 of this document (page 10), we originally assumed that once the maximum level of demographic disturbance due to well-field development was reached, this high level of disturbance would persist throughout the duration of the simulation. This demographic profile is repeated specifically for adult female mortality in (A) of Figure I – 1. However, it was recognized that a shift in activity from well-field development to production, in conjunction with a concerted effort in well-field reclamation by responsible authorities, could lead to a reduction in demographic disturbance in nearby Greater Sage Grouse populations. This recognition was then simulated through a more complex description of those demographic variables thought to be most acutely impacted by this activity, namely, yearling and adult female breeding success (% birds successfully breeding in a given year), and yearling and adult female mortality rates.

In order to describe these more complex demographic profiles, we have derived the following parameters that describe the general trajectories of breeding success and mortality over the duration of the simulations:

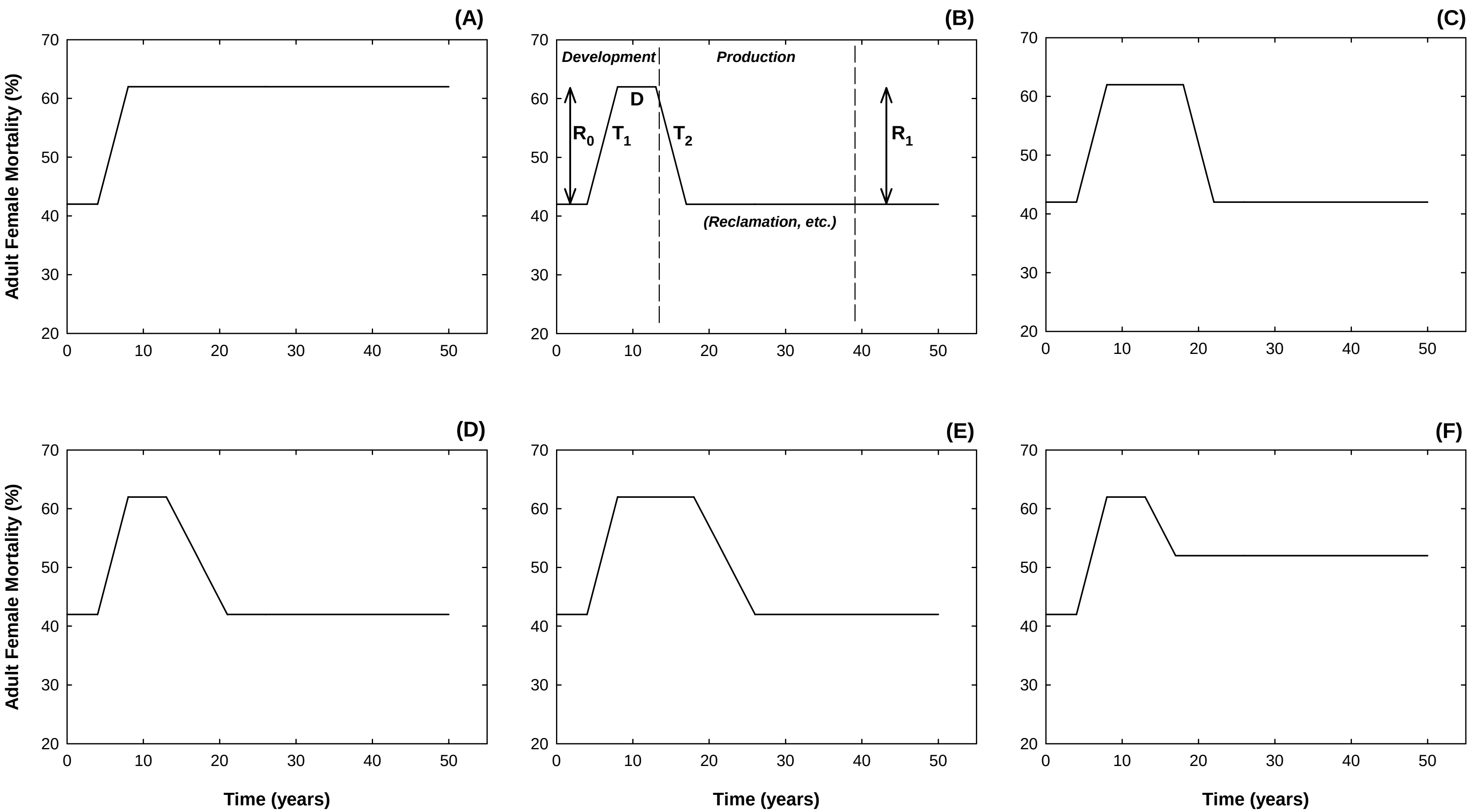


Figure I - 1. Generalized adult female mortality profiles associated with different mitigation scenarios in analyses of oil and natural gas impacts on Greater Sage Grouse populations in the Piceance / Parachute / Roan region of Colorado. In (A), mitigation is absent so the maximum impacts of well development persist through the duration of the simulation. In (B), well development leads to a mortality increase to the maximum impact over time period T_1 (4 years), over which time the well density increases from 24 to 50 wells/2-mile radius of an active lek. The maximum impact persists for duration D (5 years), after which time the shift to well production and associated landscape reclamation lead to a reduction in impact over time period T_2 (4 years). Finally, the mortality rate declines by magnitude R_1, in this case equivalent to the original magnitude R_0, representing the onset of well development. (C) $T_1 = T_2 = 4$ years; $D = 10$ years. (D) $T_1 = 4$ years, $D = 5$ years, $T_2 = 8$ yeas. (E) $T_1 = 4$ years, $D = 10$ years, $T_2 = 8$ years. (B) through (E) are repeated as in (F), with only partial demographic recovery following reclamation as $R_1 = 0.5R_0$. See accompanying text for more details.

R_0 The magnitude of change in the specified demographic variable following the onset of well-field development;
T_1 The time period over which the specified demographic variable changes following the onset of well-field development;
D The duration of time that the demographic disturbance is at a maximum, i.e., when well-field development is most intense;
T_2 The time period over which the specified demographic variable changes (rebounds) following the shift in activity from well-field development to well-field production;
R_1 The magnitude of change (rebound) in the specified demographic variable following the shift in activity from well-field development to well-field production.

In all initial simulations, we assume that well-field development results in an increase in demographic disturbance directly in accordance with the data from Holloran (2005). This is portrayed in Figure I – 1 by an increase in adult female mortality from the pre-development rate of 42% to the maximum rate of 62% – just as we assumed in our initial analyses presented on pages 20 – 21. Therefore, R_0 = 20%. In all Piceance / Parachute / Roan simulations, we have estimated that a total of 16,000 wells (2,000 pads, 8 wells/pad) will be developed over the next decade. Moreover, we now assume that the beginning of demographic disturbance occurs when the well-pad density reaches 1 pad/km^2 within a 2-mile radius of an active lek, and reaches its maximum when the density reaches 2 pads/km^2 within the same radius. This translates into upper and lower disturbance triggers of 24 and 50 wells/lek, respectively. These new triggers are rather different from the thresholds identified in earlier PVA work (8 and 15 wells/lek; see page 10), but are considered to be considerably more realistic and defensible.

Based on this assessment, we assume that the onset of demographic disturbance from this development begins at year 4 and reaches its maximum level at year 8; therefore, T_1 is set at 4 years. Duration D is plausibly set at either 5 or 10 years in order to explore the sensitivity of our models to variation in this variable. Return time T_2 is either set to the initial period T_1 or, more pessimistically, set to $2T_1$ to simulate a more difficult and longer effort required to mitigate well-field development in the shift to production. Finally, a repeated set of simulations was developed where we assume that the extent of demographic recovery is reduced due to difficulties in returning the well-field landscape to a more undisturbed setting. More specifically, we assume that $R_1 = 0.5R_0$.

Upon inspection of Figure I – 1, we can see that (B) represents a "best-case" scenario – where duration D is short, return time T_2 is also short, and demographic recovery is full ($R_1 = R_0$). On the other end of the spectrum, (E) represents a "worst-case" scenario where duration and return times are long. Even more pessimistic is the corresponding scenario combining (E) and (F) – where duration and return times are long and recovery is only partial. It is particularly interesting in this analysis to try to tease apart the relative contributions of these individual parameters to the demographic performance of an impacted Greater Sage Grouse population. In other words, if well-field mitigation and reclamation is to occur, what would be most beneficial to the long-term viability of associated Sage Grouse populations – minimizing duration D, minimizing return time T_2, or maximizing the extent of demographic recovery R_1? Through a process akin to demographic sensitivity analysis (see page 15), we can begin to shed some light on these questions in the context of designing optimal management strategies that strive for environmental responsibility and economic necessity.

A replicate set of models was constructed in which the pre-mitigation impacts of oil and natural gas development was reduced by 50% relative to the original models constructed directly from Holloran's observations (see page 9, Figure I – 2). Specifically, we increased adult female mortality by 10%, increased yearling female mortality by 3.2%, and decreased nest initiation by 12% when oil and gas development reaches the critical threshold of 50 wells/lek.

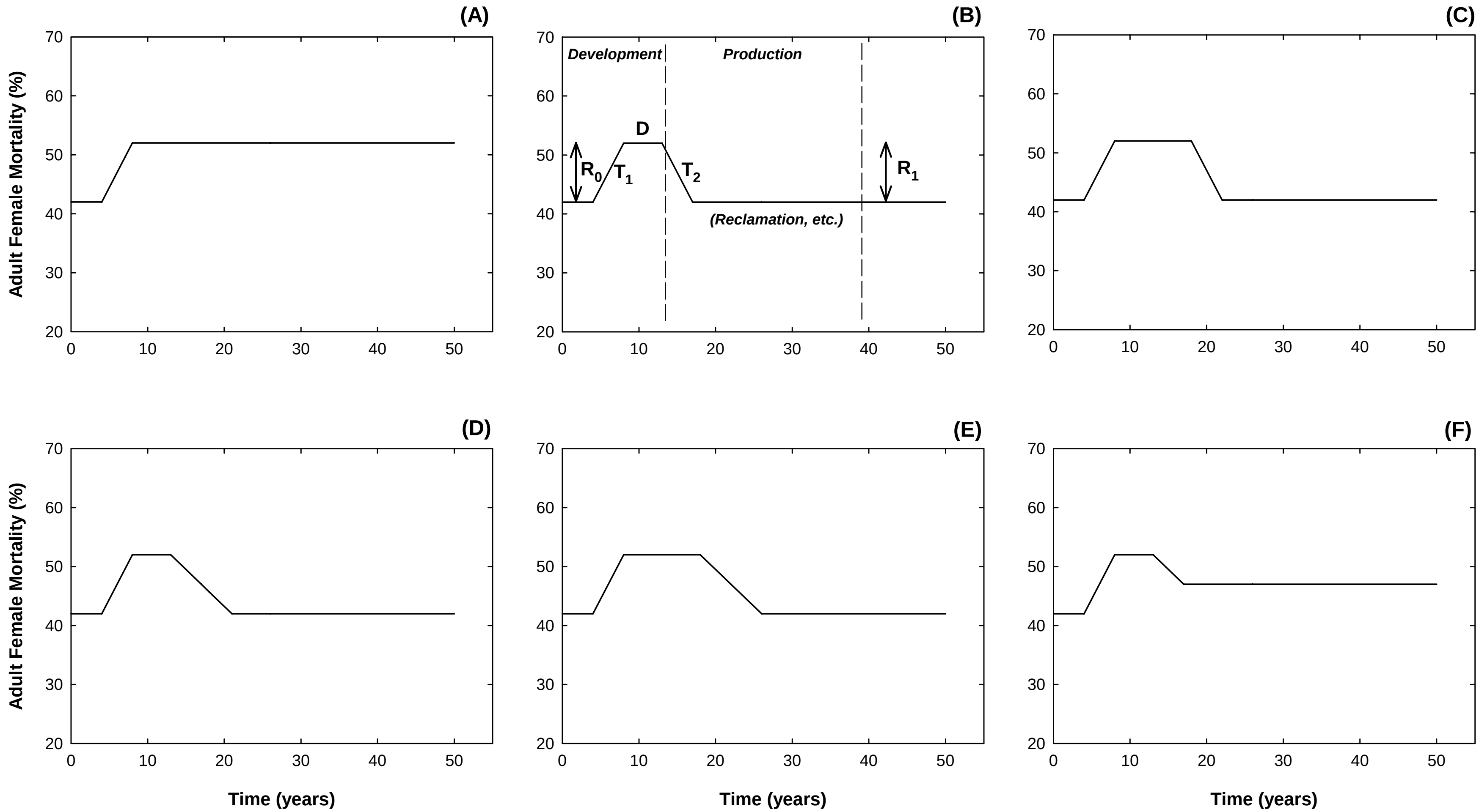


Figure I - 2. Generalized adult female mortality profiles associated with different mitigation scenarios in analyses of oil and natural gas impacts on Greater Sage Grouse populations in the Piceance / Parachute / Roan region of Colorado. In contrast to the graphs given in Figure I – 1, base demographic impacts here are assumed to be 50% lower than those directly observed by Holloran (2005). In (A), mitigation is absent so the maximum impacts of well development persist through the duration of the simulation. In (B), well development leads to a mortality increase to the maximum impact over time period T_1 (4 years), over which time the well density increases from 24 to 50 wells/2-mile radius of an active lek. The maximum impact persists for duration D (5 years), after which time the shift to well production and associated landscape reclamation lead to a reduction in impact over time period T_2 (4 years). Finally, the mortality rate declines by magnitude R_1, in this case equivalent to the original magnitude R_0, representing the onset of well development. (C) $T_1 = T_2 = 4$ years; $D = 10$ years. (D) $T_1 = 4$ years, $D = 5$ years, $T_2 = 8$ yeas. (E) $T_1 = 4$ years, $D = 10$ years, $T_2 = 8$ years. (B) through (E) are repeated as in (F), with only partial demographic recovery following reclamation as $R_1 = 0.5R_0$. See accompanying text for more details.

Oil and natural gas development in the Northwest Colorado metapopulation is expected to be less intense than that currently expected in the Piceance / Parachute / Roan region. Specifically, we assume that 50% of the total level of development will occur in Zones 2 and 3B, lower levels occurring in Zones 3A and 3C, and the remainder taking place in the remaining Zones with the exception of Zone 7 where no activity is assumed to take place. Therefore, we included energy development only in Zones 2, 3A, 3B and 3C. Using the same quantitative triggers as used in PPR, we estimate that the lower well-density threshold will be reached in 26 years for Zones 2 and 3B, and in 44 years for Zones 3A and 3C (Figure I – 3). Maximum thresholds are reached at 50 years (end of the simulation) for Zones 2 and 3B, while the maximum is not reached within this time period for Zones 3A and 3C. Under this assumption, and given the 50-year time period for simulation in this analysis, we do not have the opportunity to investigate well-field mitigation as we did in the Piceance / Parachute / Roan analysis. Nevertheless, the Northwest Colorado scenarios will provide a valuable contrast to the PPR analyses with respect to the impacts of differing levels of development on populations of considerably different sizes.

In addition to investigating well-field mitigation and reclamation, another set of models was developed for both Piceance / Parachute / Roan and NW Colorado that included increasing reproductive success as a complementary tool for Greater Sage Grouse management. As in earlier models, female breeding success was increased in selected models by 5%, 10%, or 15% in accordance with an assumed level of intensity of any of a number of alternative management activities such as improvements in habitat quality / availability, population augmentation, and predator mitigation.

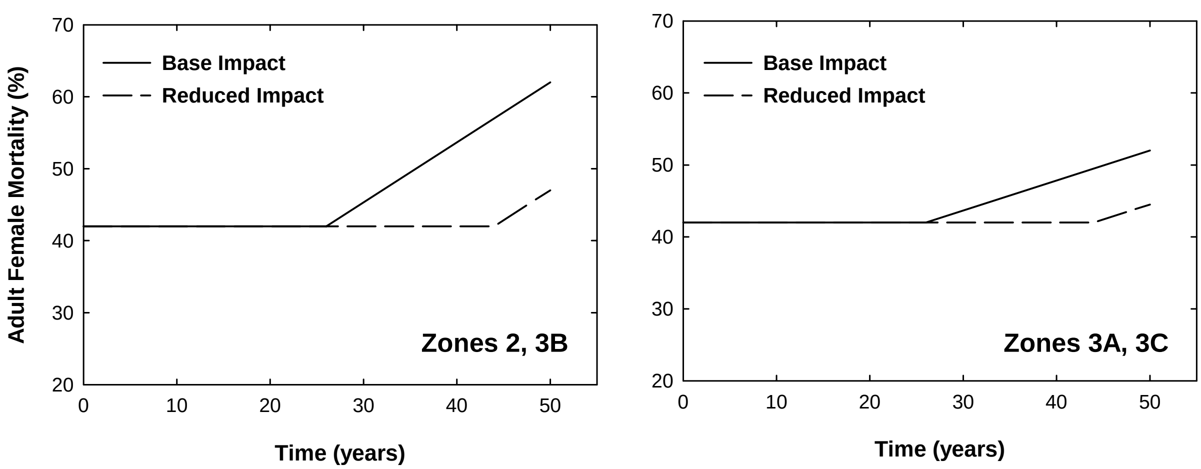


Figure I – 3. Generalized adult female mortality profiles in analyses of oil and natural gas impacts on Greater Sage Grouse populations in selected subpopulations comprising the Northwest Colorado region. Base demographic impacts are assumed to be directly taken from those observed by Holloran (2005), while reduced impacts are 50% less than those reported in Holloran (2005). Note that the maximum demographic disturbance levels seein in the Piceance / Parachute / Roan region are not reached before the end of the 50-year simulation for any NW Colorado Zone, thereby making a detailed analysis of well-field mitigation impractical. See accompanying text for more details.

Results of Revised Analyses

Well-field Mitigation: Piceance / Parachute / Roan

The results of our basic well-field mitigation sensitivity analysis are presented in Table I – 1 and Figures I – 4 and I – 5. As was seen in the original analyses for this region, the simplified treatment of well-field development and production leads to an extremely rapid rate of population decline and extinction within 30 years of the onset of well-field construction. When mitigation and reclamation are included in the simulations, and in particular under the assumption of full demographic recovery through this activity, extinction risks can decline significantly and growth rates (particularly in the time period following the onset of mitigation and reclamation) can become much more robust. For example, under the most optimistic conditions of well-field mitigation and reclamation – D and T_2 low, with full demographic recovery – population growth rates may remain highly negative for the first 15 to 20 years but can rebound to average more than 2.5% for the remaining 30 to 35 years of the simulation.

Figures I – 4 and I – 5 can help us separate the relative contributions of each phase of well-field evolution and mitigation activities to the viability of impacted Greater Sage Grouse populations. The top panel of Figure I – 4 indicates that the largest extent of population recovery as determined by average population size occurs when duration D is low. This effect is seen even more dramatically when we use extinction probability as a measure of population performance (Figure I – 5). The greatest level of impact is demonstrated when the extent of demographic recovery, R_1, is reduced by 50%. Under these conditions, growth rates remain highly negative and extinction probabilities remain very high – even if other aspects of well-field mitigation are pursued aggressively.

Table I - 1. Greater Sage Grouse PVA. Output from initial sensitivity analysis of well-field mitigation options in Piceance / Parachute / Roan region. See Figure I – 1 and text for additional information on model construction and parameterization.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Full Recovery ($R_1 = R_0$)				
No mitigation	-0.205 (0.266)	1.000	—	—
D Low; T_2 Low	-0.033 (0.195)	0.058	374 (385)	0.6956
D High; T_2 Low	-0.081 (0.243)	0.366	112 (196)	0.5485
D Low; T_2 High	-0.049 (0.211)	0.132	233 (304)	0.6181
D High; T_2 High	-0.107 (0.256)	0.542	59 (137)	0.4951
Partial Recovery ($R_1 = 0.5R_0$)				
No mitigation	-0.205 (0.266)	1.000	—	—
D Low; T_2 Low	-0.139 (0.248)	0.838	4 (11)	0.4023
D High; T_2 Low	-0.164 (0.260)	0.924	1 (7)	0.3571
D Low; T_2 High	-0.145 (0.252)	0.852	4 (12)	0.4607
D High; T_2 High	-0.172 (0.263)	0.948	1 (4)	0.3835

Given this information, we may conclude that with respect to maintaining viability of Greater Sage Grouse populations in the presence of oil and natural gas extraction, well-field development and production is most effectively mitigated by, in order of decreasing efficacy,

- Maximizing the extent of Sage Grouse demographic recovery to near levels observed before the onset of well-field development;
- Minimizing the time period of maximum demographic impact;
- Minimizing the time period over which demography recovery is achieved.

The relative feasibility of these activities on the ground is outside the expertise of this author. Nevertheless, it is hoped that this analysis can stimulate discussion among those parties both involved in the undertaking and concerned with the consequences of these activities so that effective protection of nearby Greater Sage Grouse populations can be achieved.

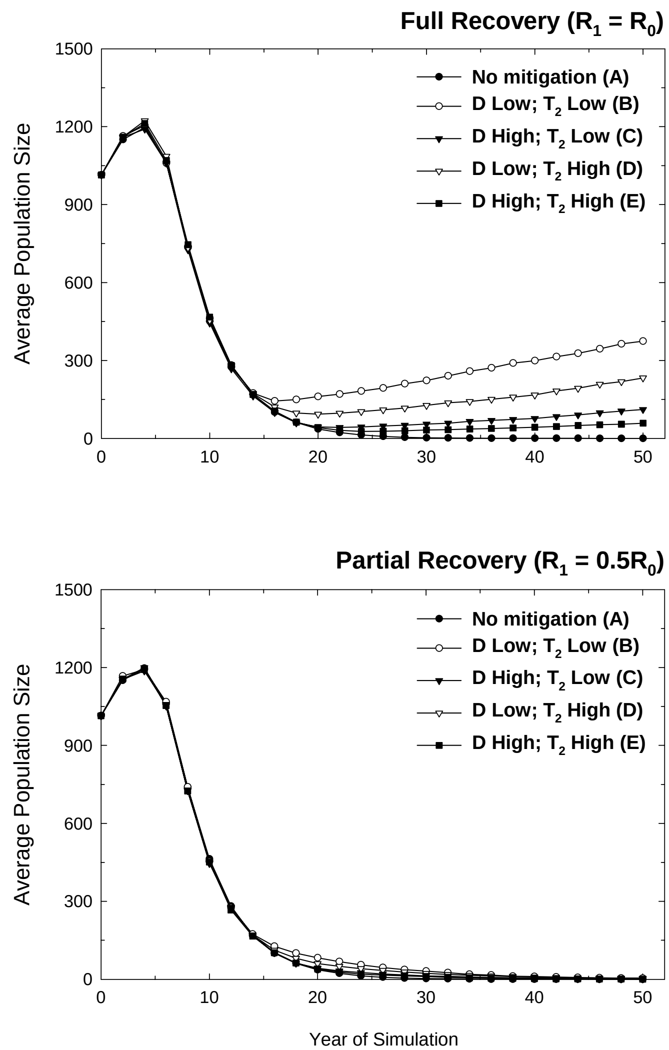


Figure I – 4. Average projected size of simulated Greater Sage Grouse populations in the Piceance / Parachute / Roan region, in the presence of varying levels of oil and natural gas well-field mitigation. Total well development includes the construction of 16,000 wells spread over 2,000 well pads. Labels (B) – (E) refer to profiles identified in Figure I – 1. See Figure I – 1 and text for accompanying information on model construction and parameterization.

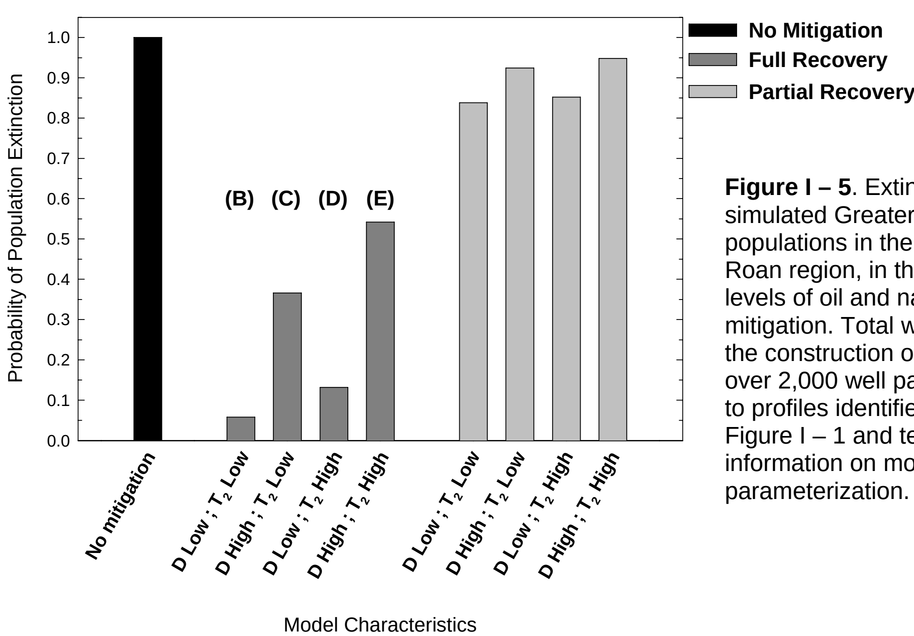


Figure I – 5. Extinction probabilities for simulated Greater Sage Grouse populations in the Piceance / Parachute / Roan region, in the presence of varying levels of oil and natural gas well-field mitigation. Total well development includes the construction of 16,000 wells spread over 2,000 well pads. Labels (B) – (E) refer to profiles identified in Figure I – 1. See Figure I – 1 and text for accompanying information on model construction and parameterization.

Additional Mitigation Activities: Piceance / Parachute / Roan

Table I – 2 and Figure I – 6 shows the combined effects of well-field mitigation / reclamation and additional reproductive mitigation activities as simulated in earlier portions of this document (e.g., page 12). If aggressive well-field mitigation is possible with full demographic recovery, significant increases in growth rate can be achieved with as little as 5% increase in Greater Sage Grouse reproductive success through additional mitigation (Figure I – 6A). If well-field mitigation is less aggressive, larger increases in reproductive success through additional mitigation are required to offset the impacts of well-field disturbance. At the other end of the well-field mitigation spectrum, where only partial demographic recovery is possible, high levels of increased reproductive success are required to offset well-field disturbance (Figure I – 6C, D).

Figure I – 6 shows very explicitly the interactions among the various mitigation activities. When well-field development is extended (*D* increases), the size of the population decreases further and remains at a lower level for a longer period of time. These two processes act to greatly increase the risk of population extinction in the absence of additional mitigation. The additional mitigation activities greatly diminish these risks. Once again, the impact of only partial demographic recovery is clearly demonstrated, as well as the need for aggressive reproductive mitigation in the face of incomplete well-field mitigation.

Table I - 2. Greater Sage Grouse PVA. Output from combined analysis of well-field mitigation and additional mitigation activities in Piceance / Parachute / Roan region. See Figure I – 1 and text for additional model information.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Full Recovery ($R_1 = R_0$)				
D Low; T_2 Low				
+0% Reprod. success	-0.033 (0.195)	0.058	374 (385)	0.6956
+5%	0.018 (0.170)	0.000	1242 (398)	0.8674
+10%	0.059 (0.167)	0.000	1484 (146)	0.9222
+15%	0.096 (0.165)	0.000	1526 (77)	0.9422
D High; T_2 High				
+0% Reprod. success	-0.107 (0.256)	0.542	59 (137)	0.4951
+5%	-0.030 (0.211)	0.106	480 (484)	0.6582
+10%	0.020 (0.186)	0.006	1238 (444)	0.8168
+15%	0.065 (0.176)	0.000	1514 (108)	0.9087
Partial Recovery ($R_1 = 0.5R_0$)				
D Low; T_2 Low				
+0% Reprod. success	-0.139 (0.248)	0.838	4 (11)	0.4023
+5%	-0.078 (0.205)	0.270	47 (67)	0.6240
+10%	-0.026 (0.167)	0.018	358 (351)	0.8061
+15%	0.019 (0.158)	0.000	1091 (433)	0.9118
D High; T_2 High				
+0% Reprod. success	-0.172 (0.263)	0.948	1 (4)	0.3835
+5%	-0.113 (0.239)	0.590	13 (28)	0.4872
+10%	-0.050 (0.195)	0.122	154 (208)	0.6602
+15%	0.001 (0.165)	0.004	769 (483)	0.8502

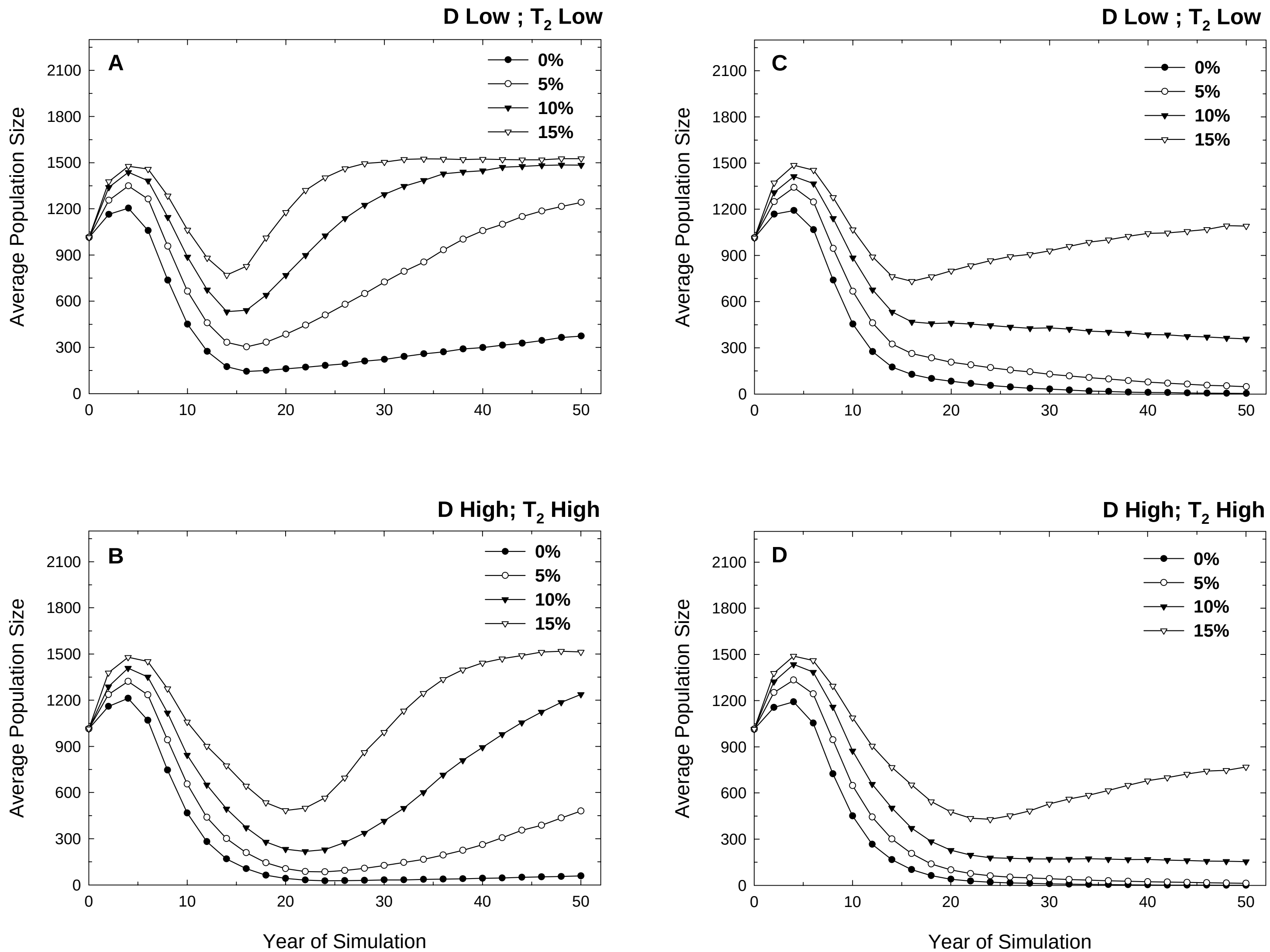


Figure I – 6. Average projected size of simulated Greater Sage Grouse populations in the Piceance / Parachute Roan region in the presence of alternative levels of well-field mitigation and additional levels of reproductive mitigation. Reproductive mitigation is simulated through a 5%, 10% or 15% increase in the number of yearling and adult females that breed in a given year. Left-side panels A and B include full demographic recovery following well-field development, while right-side panels C and D include only partial recovery. See Figure I – 1 and text for accompanying information on model construction and parameterization.

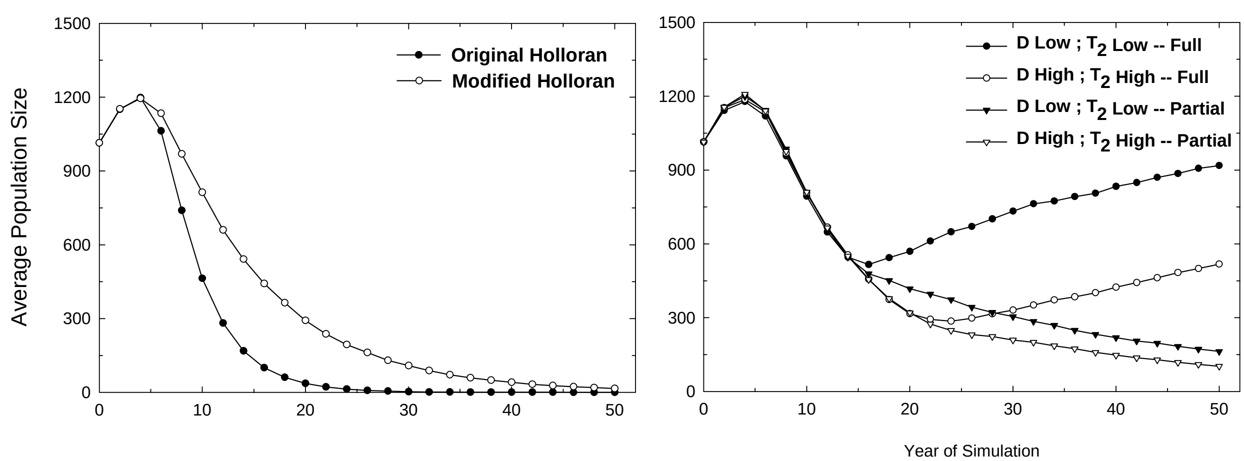
Reducing the Base Impact of Oil and Natural Gas Activities: Piceance / Parachute Roan

Even when the demographic impacts are reduced by 50% from Holloran's (2005) original estimates, the simulated Piceance / Parachute / Roan population is heavily impacted by oil and natural gas development and production (Table I – 3, Figure I – 7). The initial population decline is less severe under the assumption of reduced demographic disturbance, and the population growth rate shows significant improvement over the original simulations, but the underlying growth rate remains highly negative and the ultimate outcome of the simulations are very similar.

Table I - 3. Greater Sage Grouse PVA. Output from sensitivity analysis of well-field mitigation options in Piceance / Parachute / Roan region where the base impacts of well-field development are modified (reduced 50%) from the original analyses using the direct observations of Holloran (2005). See Figure I – 1 and text for additional information on model construction and parameterization.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Original Holloran impact	-0.205 (0.139)	1.000	—	—
Reduced Holloran impact	-0.102 (0.208)	0.478	15 (25)	0.5766
Mitigation Options				
D Low; T_2 Low – Full Recovery	-0.001 (0.151)	0.000	918 (479)	0.8808
D High; T_2 High – Full Recovery	-0.020 (0.163)	0.006	517 (426)	0.7918
D Low; T_2 Low – Partial Recovery	-0.049 (0.167)	0.042	162 (188)	0.7525
D High; T_2 High – Partial Recovery	-0.058 (0.175)	0.080	102 (124)	0.6999

Figure I – 7. Average projected size of simulated Greater Sage Grouse populations in the Piceance / Parachute Roan region under revised assumptions of the base impact of oil and natural gas development as determined by Holloran (2005) (left) and under alternative scenarios of well-field mitigation with the revised base impact levels. See Figure I – 1 and text for accompanying information on model construction and parameterization.



If we assume the base impacts to be set at this reduced level, the benefits of well-field mitigation are enhanced (Table I – 4; Figure I – 7, right panel; compare with trajectories in Figure I - 3). If full demographic recovery is possible through well-field mitigation and reclamation, just a 5% increase in reproductive success through mitigation activities can dramatically increase the growth rate to as high as 0.042, in contrast to a negative growth rate in the absence of reproductive mitigation (Figure I – 8). Even if demographic recovery is only partial, low levels of reproductive mitigation is sufficient to offset the impacts of well-field development. As expected, this enhancement through mitigation is much more effective when the underlying base impact of oil and natural gas development is assumed to be lower than that estimated initially by Holloran (2005).

Table I - 4. Greater Sage Grouse PVA. Output from combined analysis of well-field mitigation and additional reproductive mitigation in Piceance / Parachute / Roan region, under revised assumptions of the base impact of oil and natural gas development as determined by Holloran (2005). See Figure I – 1 and text for additional information on model construction

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Full Recovery ($R_1 = R_0$)				
D Low; T_2 Low				
+0% Reprod. success	-0.001 (0.151)	0.000	918 (479)	0.8808
+5%	0.042 (0.147)	0.000	1413 (210)	0.9383
+10%	0.081 (0.048)	0.000	1500 (116)	0.9488
+15%	0.119 (0.148)	0.000	1519 (91)	0.9504
D High; T_2 High				
+0% Reprod. success	-0.020 (0.163)	0.006	517 (426)	0.7918
+5%	0.024 (0.153)	0.000	1302 (341)	0.9108
+10%	0.065 (0.150)	0.000	1486 (142)	0.9446
+15%	0.104 (0.150)	0.000	1524 (90)	0.9490
Partial Recovery ($R_1 = 0.5R_0$)				
D Low; T_2 Low				
+0% Reprod. success	-0.049 (0.167)	0.042	162 (188)	0.7525
+5%	-0.001 (0.147)	0.000	806 (462)	0.8994
+10%	0.043 (0.145)	0.000	1333 (274)	0.9451
+15%	0.081 (0.145)	0.000	1467 (160)	0.9501
D High; T_2 High				
+0% Reprod. success	-0.058 (0.175)	0.080	102 (124)	0.6999
+5%	-0.011 (0.153)	0.002	613 (433)	0.8680
+10%	0.033 (0.147)	0.000	1292 (323)	0.9357
+15%	0.073 (0.146)	0.000	1467 (152)	0.9487

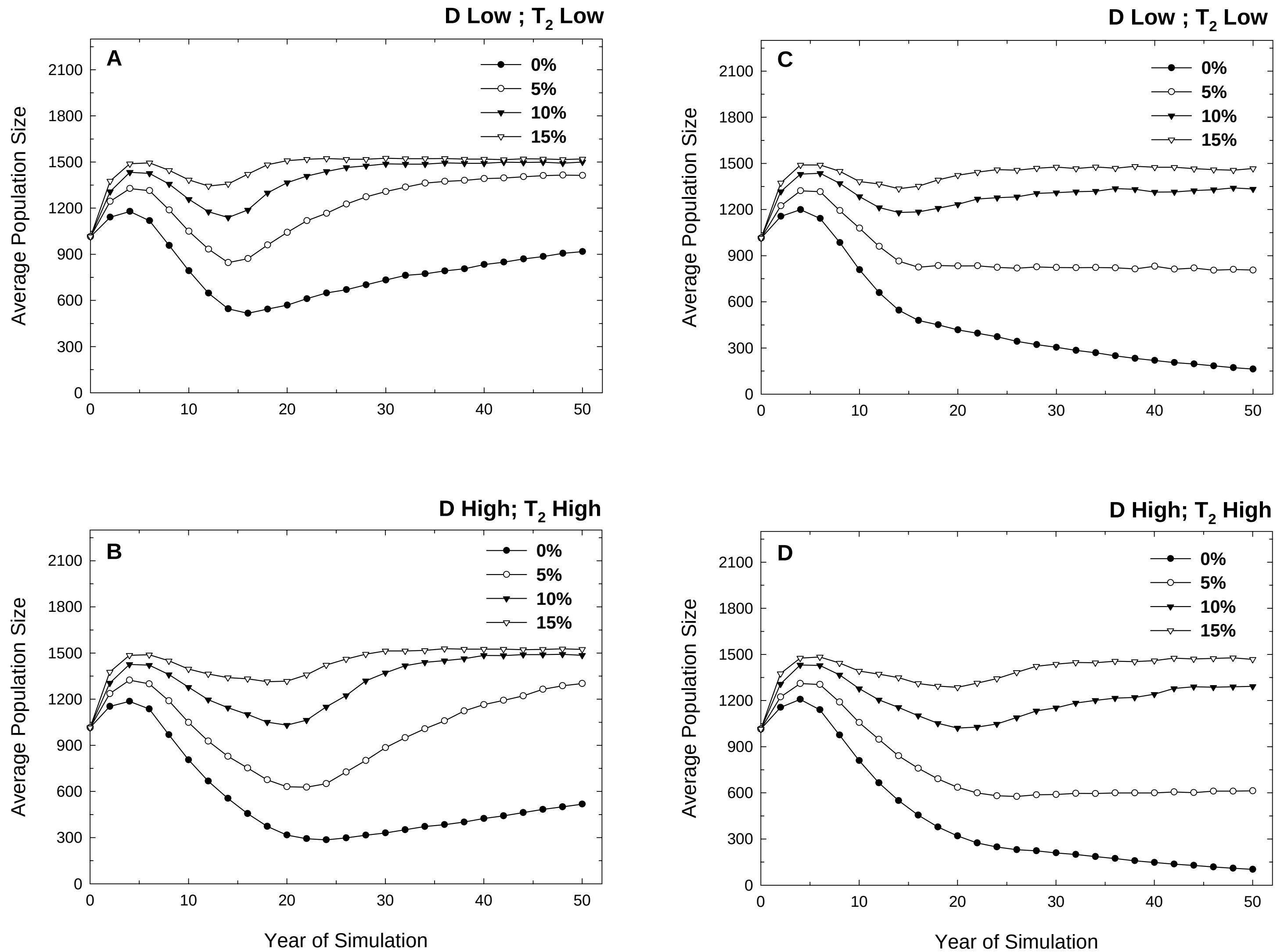


Figure I – 8. Average projected size of simulated Greater Sage Grouse populations in the Piceance / Parachute Roan region in the presence of alternative levels of well-field mitigation and additional levels of reproductive mitigation, under revised assumptions of the base impact of oil and natural gas development as determined by Holloran (2005). Reproductive mitigation is simulated through a 5%, 10% or 15% increase in the number of yearling and adult females that breed in a given year. Left-side panels A and B include full demographic recovery following well-field development, while right-side panels C and D include only partial recovery. See Figure I – 1 and text for accompanying information on model construction and parameterization.

Reducing the Base Impact of Oil and Natural Gas Activities: Northwest Colorado

When oil and natural gas development occurs in selected Zones of the Northwest Colorado region, overall Greater Sage Grouse metapopulation viability is high over the time period of the simulations presented here (Table I – 5, Figure I – 9). The consequences of the delayed onset of demographic disturbance following oil and natural gas development is clear in the Figure, as is the lower overall impact of development under the assumption of a reduced base impact of the activity relative to the data of Holloran (2005). As expected, the consequences of oil and natural gas activity begin to show themselves around year 30 of the simulation, in accordance with the onset of demographic disturbance in Zones 2 and 3B at year 26. While the disturbance does not lead to a measurable risk of metapopulation extinction in the 50-year timeframe of the simulations presented here, population size does indeed decline markedly in the latter portions of the simulation. Oil and natural gas development, activity, it is clear, is predicted to have an impact in this region, with the possibility that the overall Greater Sage Grouse regional population may decline to levels below those currently estimated.

Table I - 5. Greater Sage Grouse PVA. Output from combined analysis of well-field mitigation and additional reproductive mitigation in the Northwest Colorado region, under alternative assumptions of the base impact of oil and natural gas development as determined by Holloran (2005). Population size and extinction probability are given for the entire metapopulation. "Restricted" reproductive mitigation refers to increases in reproductive success in Greater Sage Grouse through mitigation activities in only those Zones that see comparatively high levels of oil and natural gas development activity (specifically, Zones 2, 3A, 3B, and 3C), as opposed to the same levels of increased success realized in all Zones comprising the NW Colorado region. See text for additional information on model construction.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Base Holloran impact				
No well development	0.030 (0.081)	0.000	15824 (1824)	0.9956
10,000 wells	0.016 (0.083)	0.000	10809 (2526)	0.9951
+5% reprod. success	0.056 (0.084)	0.000	14631 (1694)	0.9956
+10%	0.096 (0.085)	0.000	16285 (1096)	0.9956
+5% restricted reprod. success	0.035 (0.085)	0.000	13112 (2213)	0.9955
+10%	0.055 (0.085)	0.000	14630 (1922)	0.9956
Reduced Holloran impact				
No well development	0.030 (0.081)	0.000	15824 (1824)	0.9956
10,000 wells	0.022 (0.082)	0.000	13484 (2384)	0.9954
+5% reprod. success	0.064 (0.082)	0.000	16217 (1300)	0.9958
+10%	0.103 (0.083)	0.000	17136 (827)	0.9959
+5% restricted reprod. success	0.042 (0.083)	0.000	15278 (1813)	0.9957
+10%	0.062 (0.083)	0.000	16179 (1329)	0.9957

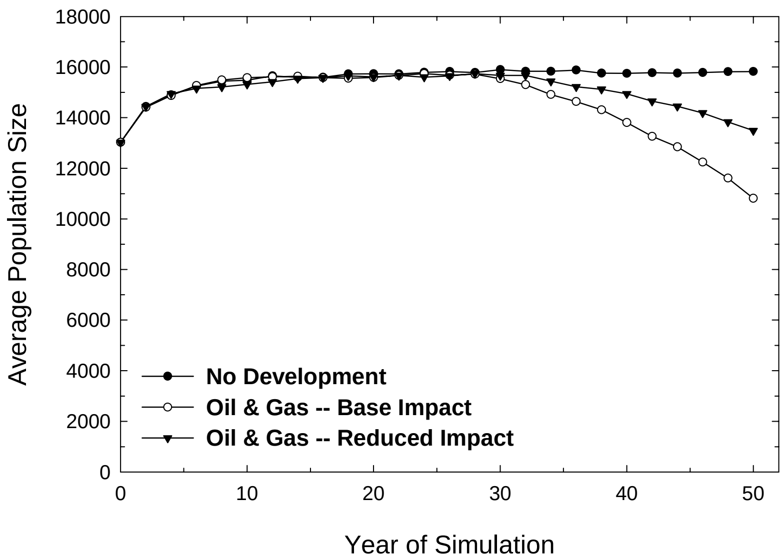


Figure I – 9. Average projected size of simulated Greater Sage Grouse populations in the Northwest Colorado region, under revised assumptions of the base impact of oil and natural gas development as determined by Holloran (2005). See text for additional information on model construction.

An increase in Greater Sage Grouse reproductive success through mitigation activities may be an option to offset the consequences of demographic disturbances brought on by oil and natural gas development in the region. The predicted consequences of this activity are presented in Table I – 5 and Figure I – 10. As in the case of the Piceance / Parachute / Roan analyses, even modest increases in reproductive success through mitigation activities can lead to significant increases in metapopulation growth rate and final population size, even if the base impact of oil and natural gas development as defined by Holloran (2005) is in place (top panel, Figure I – 10). A small set of additional models was constructed that were meant to investigate the efficacy of an increase in Greater Sage Grouse reproductive success over a restricted geographic area – namely, only those Zones where the bulk of regional oil and natural gas development activity is predicted to occur (Zones 2, 3A, 3B, and 3C). In general, a 10% increase in reproductive success across the restricted area is as effective in increasing population size as a 5% increase in reproductive success applied to the entire region. The relative merits of each of these tactics would be necessary in order to more logically determine the most beneficial course of action in planning a reproductive mitigation plan, should one be deemed valuable.

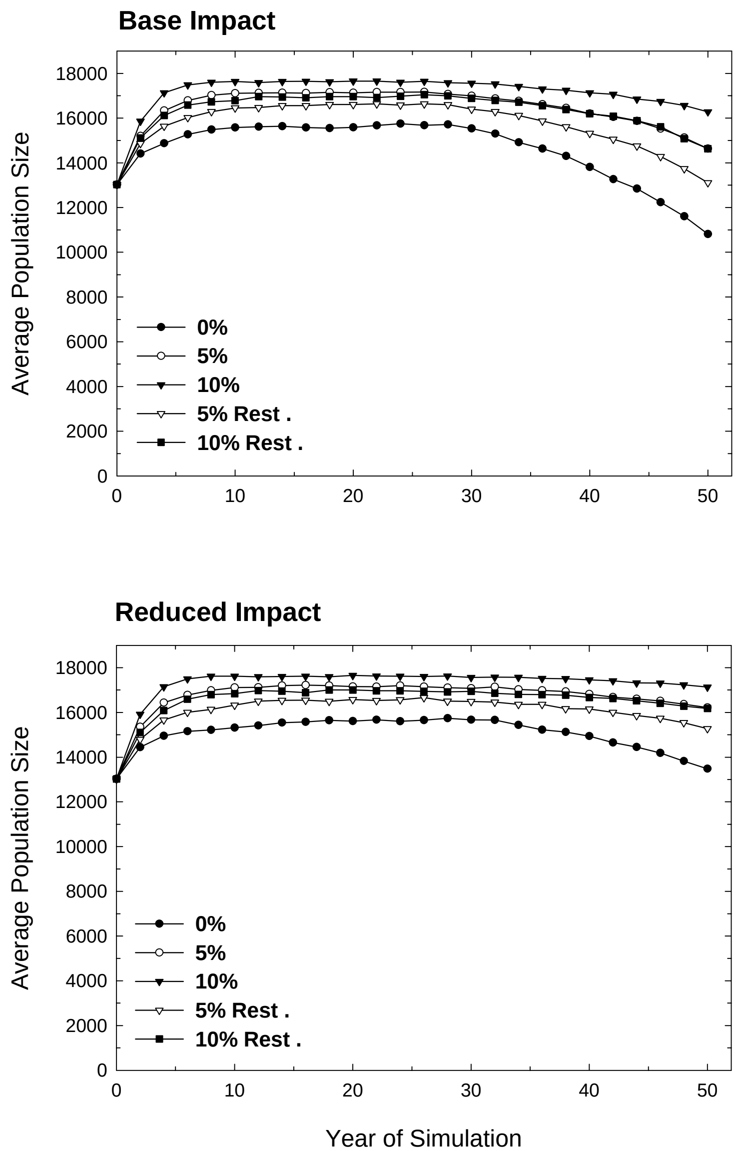


Figure I – 10. Average projected size of simulated Greater Sage Grouse populations in the Northwest Colorado region, under alternative mechanisms of increased reproductive success through mitigation activities and revised assumptions of the base impact of oil and natural gas development as determined by Holloran (2005). “Rest.” mitigation refers to increases in reproductive success through mitigation activities in only those Zones that see comparatively high levels of oil and natural gas development activity (specifically, Zones 2, 3A, 3B, and 3C), as opposed to the same levels of increased success realized in all Zones comprising the NW Colorado region. See text for additional information on model construction.

Conclusions

As before, we conclude our revised analysis by returning to those original questions that guided the development of the scenarios described herein.

- *How would the demographic behavior of our simulated populations of Greater Sage Grouse change in response to direct mitigation of oil and natural gas development at and near the site of the well pad itself?*

  Our analysis of projected oil and natural gas development activity in the Piceance / Parachute / Roan region suggests that well-field mitigation can potentially be effective in reducing the demographic disturbance to Greater Sage Grouse populations occupying nearby sagebrush habitats. These mitigation measures must be conducted aggressively, however, in order for disturbance to be minimized. Most importantly, mortality and reproductive rates must rebound to as close to their original rates as practical as the field shifts to a production phase and reclamation of the surrounding habitats is undertaken. Secondarily, the duration of maximum well-field related disturbance must be minimized.

  The degree to which additional mitigation measures – such as increased reproductive success through various mitigation activities – must be undertaken is closely related to the intensity of well-field mitigation. Under conditions of aggressive well-field mitigation, lower levels of reproductive mitigation may be required to further increase the long-term viability of nearby Sage Grouse populations.

- *To what extent will the demographic behavior of our simulated populations of Greater Sage Grouse change if we assume a less severe direct impact of oil and natural gas development, even in the absence of mitigation?*

  Our analyses indicate that even if the impacts on Greater Sage Grouse demography are reduced in magnitude by 50%, the extent of demographic disturbance of oil and natural gas development is sufficient to cause significant population decline soon after development begins. However, this lower overall demographic impact means that given levels of both well-field mitigation and increases in reproductive success through mitigation can have much greater benefit to the long-term viability of impacted Grouse populations. Consequently, a more thorough understanding of the detailed demographic impacts of oil and natural gas development in Colorado is critical to the formulation of a specific well-field mitigation strategy.

Appendix II:
Population Viability Analysis and Simulation Modeling

Phil Miller
Conservation Breeding Specialist Group (IUCN / SSC)

Introduction

Thousands of species and populations of animals and plants around the world are threatened with extinction within the coming decades. For the vast majority of these groups of organisms, this threat is the direct result of human activity. The particular types of activity, and the ways in which they impact wildlife populations, are often complex in both cause and consequence; as a result, the techniques we must use to analyze their effects often seem to be complex as well. But scientists in the field of conservation biology have developed extremely useful tools for this purpose that have dramatically improved our ability to conserve the planet's biodiversity.

Conservation biologists involved in recovery planning for a given threatened species usually try to develop a detailed understanding of the processes that put the species at risk, and will then identify the most effective methods to reduce that risk through active management of the species itself and/or the habitat in which it lives. In order to design such a program, we must engage in some sort of predictive process: we must gather information on the detailed characteristics of proposed alternative management strategies and somehow predict how the threatened species will respond in the future. A strategy that is predicted to reduce the risk by the greatest amount – and typically does so with the least amount of financial and/or sociological burden – is chosen as a central feature of the recovery plan.

But how does one predict the future? Is it realistically possible to perform such a feat in our fast-paced world of incredibly rapid and often unpredictable technological, cultural, and biological growth? How are such predictions best used in wildlife conservation? The answers to these questions emerge from an understanding of what has been called "the flagship industry" of conservation biology: Population Viability Analysis, or PVA. And most methods for conducting PVA are merely extensions of tools we all use in our everyday lives.

The Basics of PVA

To appreciate the science and application of PVA to wildlife conservation, we first must learn a little bit about population biology. Biologists will usually describe the performance of a population by describing its demography, or simply the numerical depiction of the rates of birth and death in a group of animals or plants from one year to the next. Simply speaking, if the birth rate exceeds the death rate, a population is expected to increase in size over time. If the reverse is true, our population will decline. The overall rate of population growth is therefore a rather good descriptor of its relative security: positive population growth suggests some level of demographic health, while negative growth indicates that some external process is interfering with the normal population function and pushing it into an unstable state.

This relatively simple picture is, however, made a lot more complicated by an inescapable fact: wildlife population demographic rates fluctuate unpredictably over time. So if we observe that 50% of our total population of adult females produces offspring in a given year, it is almost certain that more or less than 50% of our adult females will reproduce in the following year. And the same can be said for most all other demographic rates: survival of offspring and adults, the numbers of offspring born, and the offspring sex ratio will almost always change from one year to the next in a way that usually defies precise prediction. These variable rates then conspire to make a population's growth rate also change unpredictably from year to year. When wildlife populations are very large – if we consider seemingly endless herds of wildebeest on the savannahs of Africa, for example – this random annual fluctuation in population growth is of little to no consequence for the future health and stability of the population. However, theoretical and practical study of population biology has taught us that populations that are already small in size, often defined in terms of tens to a few hundred individuals, are affected by these fluctuations to a much greater extent – and the long-term impact of these fluctuations is always negative. Therefore, a wildlife population that has been reduced in numbers will become even smaller through this fundamental principle of wildlife biology. Furthermore, our understanding of this process provides an important backdrop to considerations of the impact of human activities that may, on the surface, appear relatively benign to larger and more stable wildlife populations. This self-reinforcing feedback loop, first coined the "extinction vortex" in the mid-1980's, is the cornerstone principle underlying our understanding of the dynamics of wildlife population extinction.

Once wildlife biologists have gone out into the field and collected data on a population's demography and used these data to calculate its current rate of growth (and how this rate may change over time), we now have at our disposal an extremely valuable source of information that can be used to predict the *future* rates of population growth or decline under conditions that may not be so favorable to the wildlife population of interest. For example, consider a population of primates living in a section of largely undisturbed Amazon rain forest that is now opened up to development by logging interests. If this development is to go ahead as planned, what will be the impact of this activity on the animals themselves, and the trees on which they depend for food and shelter? And what kinds of alternative development strategies might reduce the risk of primate population decline and extinction? To try to answer this question, we need two additional sets of information: 1) a comprehensive description of the proposed forest development plan (how will it occur, where will it be most intense, for what period of time, etc.) and 2) a detailed understanding of how the proposed activity will impact the primate population's demography (which animals will be most affected, how strongly will they be affected, will animals die outright more frequently or simply fail to reproduce as often, etc.). With this information in hand, we have a vital component in place to begin our PVA.

Next, we need a predictive tool – a sort of crystal ball, if you will, that helps us look into the future. After intensive study over nearly three decades, conservation biologists have settled on the use of computer simulation models as their preferred PVA tool. In general, models are simply any simplified representation of a real system. We use models in all aspects of our lives; for example, road maps are in fact relatively simple (and hopefully very accurate!) 2-dimensional representations of complex 3-dimensional landscapes we use almost every day to get us where we need to go. In addition to making predictions about the future, models are very helpful for us to: (1) extract important trends from complex processes, (2) allow comparisons among different types of systems, and (3) facilitate analysis of processes acting on a system.

Recent advances in computer technology have allowed us to create very complex models of the demographic processes that define wildlife population growth. But at their core, these models attempt to replicate simple biological functions shared by most all wildlife species: individuals are born, some grow to adulthood, most of those that survive mate with individuals of the opposite sex and then give birth to one or more offspring, and they die from any of a wide variety of causes. Each species may have its own special set of circumstances – sea turtles may live to be 150 years old and lay 600 eggs in a single event, while a chimpanzee may give birth to just a single offspring every 4-5 years until the age of 45 – but the fundamental biology is the same. These essential elements of a species' biology can be incorporated into a computer program, and when combined with the basic rules for living and the general characteristics of the population's surrounding habitat, a model is created that can project the demographic behavior of our real observed population for a specified period of time into the future. What's more, these models can explicitly incorporate random fluctuations in rates of birth and death discussed earlier. As a result, the models can be much more realistic in their treatment of the forces that influence population dynamics, and in particular how human activities can interact with these intrinsic forces to put otherwise relatively stable wildlife populations at risk.

Many different software packages exist for the purposes of conducting a PVA. Perhaps the most widely-used of these packages is *VORTEX*, developed by the IUCN Conservation Breeding Specialist Group (CBSG) for use in both applied and educational environments. *VORTEX* has been used by CBSG and other conservation biologists for more than 15 years and has proved to be a very useful tool for helping make more informed decisions in the field of wildlife population management.

Strengths and Limitations of the PVA Approach

When considering the applicability of PVA to a specific issue, it is vitally important to understand those tasks to which PVA is well-suited as well as to understand what the technique is not well-designed to deliver. With this enhanced understanding will also come a more informed public that is better prepared to critically evaluate the results of a PVA and how they are applied to the practical conservation measures proposed for a given species or population.

The dynamics of population extinction are often quite complicated, with numerous processes impact the dynamics in complex and interacting ways. Moreover, we have already come to appreciate the ways in which demographic rates fluctuate unpredictably in wildlife populations, and the data needed to provide estimates of these rates and their annual variability are themselves often uncertain, i.e., subject to observational bias or simple lack of detailed study over relatively longer periods of time. As a result, the elegant mental models or the detailed mathematical equations of even the most gifted conservation biologist are inadequate for capturing the detailed nuances of interacting factors that determine the fate of a wildlife population threatened by human activity. In contrast, simulation models can include as many factors that influence population dynamics as the modeler and the end-user of the model wish to assess. Detailed interactions between processes can also be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes.

PVA models have also been shown to stimulate meaningful discussion among field biologists in the subjects of species biology, methods of data collection and analysis, and the assumptions that underlie the analysis of these data in preparation for their use in model construction. By making the models and their underlying data, algorithms and assumptions explicit to all who learn from them, these discussions become a critical component in the social process of achieving a shared understanding of a threatened species' current status and the biological justification for identifying a particular management strategy as the most effective for species conservation. This additional benefit is most easily recognized when PVA is used in an interactive workshop-type setting, such as the Population and Habitat Viability Assessment (PHVA) workshop designed and implemented by CBSG.

Perhaps the greatest strength of the PVA approach to conservation decision-making is related to what many of its detractors see as its greatest weakness. Because of the inherent uncertainty now known to exist in the long-term demography of wildlife populations (particularly those that are small in size), and because of the difficulties in obtaining precise estimates of demographic rates through extended periods of time collecting data in the field, accurate predictions of the future performance of a threatened wildlife population are effectively impossible to make. Even the most respected PVA practitioner must honestly admit that an accurate prediction of the number of mountain gorillas that will roam the forests on the slopes of the eastern Africa's Virunga Volcanoes in the year 2075, or the number of polar bears that will swim the warming waters above the Arctic Circle when our great-grandchildren grow old, is beyond their reach. But this type of difficulty, recognized across diverse fields of study from climatology to gambling, is nothing new: in fact, the Nobel Prize-winning physicist Niels Bohr once said "Prediction is very difficult, especially when it's about the future." Instead of lamenting this inevitable quirk of the physical world as a fatal flaw in the practice of PVA, we must embrace it and instead use our very cloudy crystal ball for another purpose: to make **relative**, rather than **absolute**, predictions of wildlife population viability in the face of human pressure.

The process of generating relative predictions using the PVA approach is often referred to as sensitivity analysis. In this manner, we can make much more robust predictions about the relative response of a simulated wildlife population to alternate perturbations to its demography. For example, a PVA practitioner may not be able to make accurate predictions about how many individuals of a given species may persist in 50 years in the presence of intense human hunting pressure, but that practitioner can speak with considerably greater confidence about the relative merits of a male-biased hunting strategy compared to the much more severe demographic impact typically imposed by a hunting strategy that prefers females. This type of comparative approach was used very effectively in a PVA for highly threatened populations of tree kangaroos (*Dendrolagus* sp.) living in Papua New Guinea, where adult females are hunted preferentially over their male counterparts. Comparative models showing the strong impacts of such a hunting strategy were part of an important process of conservation planning that led, within a few short weeks after a participatory workshop including a number of local hunters (Bonnaccorso et al., 1998), to the signing of a long-term hunting moratorium for the most critically endangered species in the country, the tenkile or Scott's tree kangaroo (*Dendrolagus scottae*).

PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models often underestimate the threats facing the population, or the total risk these threats collectively impose on the population of interest. To address this limitation, conservation biologists must try to engage a diverse body of experts with knowledge spanning many different fields in an attempt to broaden our understanding of the consequences of interaction between humans and wildlife.

Additionally, models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data and model results periodically, with changes made to the conservation programs as needed (see Lacy and Miller (2002), Nyhus et al. (2002) and Westley and Miller (2003) for more details).

Finally, it is also important to understand that a PVA model by itself does not define the goals of conservation planning of a given species. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used.

Further Reading

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