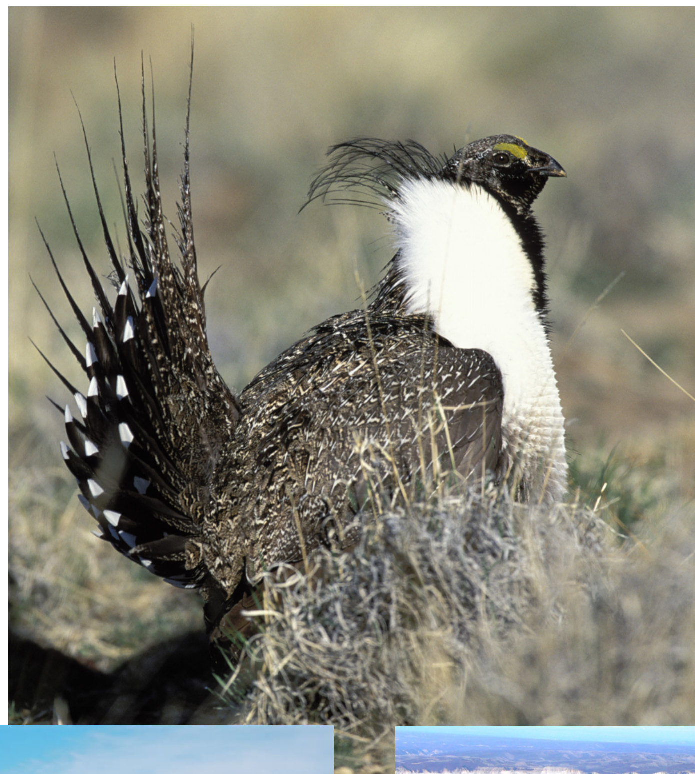
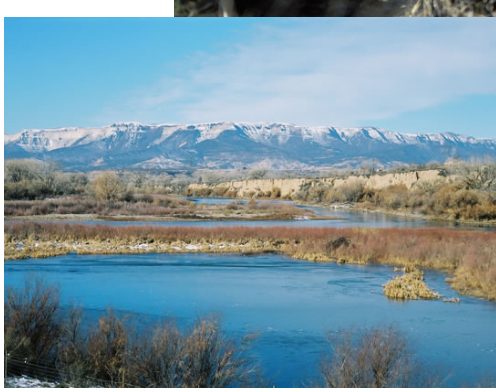
Prepared in cooperation with the U.S. Bureau of Land Management

A Regional Approach to Wildlife Monitoring Related to Energy Exploration and Development in Colorado

By Natasha B. Kotliar, Zachary H. Bowen, Douglas S. Ouren, and Adrian H. Farmer





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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

A Regional Approach to Wildlife Monitoring Related to Energy Exploration and Development in Colorado

By Natasha B. Kotliar, Zachary H. Bowen, Douglas S. Ouren, and Adrian H. Farmer

Executive Summary

The U.S. Bureau of Land Management (BLM) is currently developing a National Monitoring Strategy that will guide efforts to create an efficient and effective process for monitoring land health by BLM. To inform the ongoing development of the national strategy, BLM selected two States (Colorado, Alaska) to serve as focal areas on which to base a flexible framework for developing monitoring programs that evaluate wildlife responses to energy development.

We developed a three-phase monitoring plan to serve as a template and applied it to the design of a monitoring program for the Colorado focal area (White River and Glenwood Springs Field Offices of the BLM). Phase I is a synthesis and assessment of current conditions that capitalizes on existing but under used data sources. A key component is the use of existing habitat and landscape models to evaluate the cumulative effects of surface disturbance. Phase II is the data collection process that uses information provided in Phase I to refine management objectives and provide a linkage to management decisions. The linkage is established through targeted monitoring, adaptive management, and research. Phase III establishes priorities and strategies for regional and national monitoring, and facilitates coordination among other land management agencies and organizations. The three phases are designed to be flexible and complementary.

The monitoring plan guides an iterative process that is performed incrementally, beginning with the highest-priority species and management issues, while building on lessons learned and coordination among administrative levels. The activities associated with each phase can be repeated or updated as new information, data, or tools become available. This allows the development of a monitoring program that expands gradually and allows for rapid implementation.

A demonstration application of the three-phase monitoring plan was conducted for a study area encompassing five BLM field offices in Colorado: White River, Glenwood Springs, Kremmling, Grand Junction, and Little Snake. The overall study area was selected to encompass the primary distribution of sagebrush and greater sage-grouse (*Centrocercus urophasianus*) in Colorado and to provide a larger context for evaluating priority management issues of the White River and Glenwood Springs Field Offices. Within the study area, we selected an additional scale of analysis: the Roan Plateau, an area of increased energy development. We focused our demonstration project on the primary objectives identified by the BLM and other stakeholders: (1) How do we evaluate the cumulative effects of energy development and mitigation activities on species of management interest or concern? (2) How can cumulative effects, including direct and indirect effects, be quantified relative to natural variation? (3) How can we implement compliance and effectiveness monitoring to determine whether lease stipulations are met and restoration/mitigation goals are achieved?

We targeted greater sage-grouse because this species was identified as a monitoring priority for the White River Field Office. We also evaluated landscape-level indices to address fragmentation

resulting from surface disturbance. The primary purpose of this exercise was to highlight the types of analyses and approaches that could be used to evaluate energy development in an application of the three-phase framework. We provide examples of Phase I products that can be used to guide the refinement of management objectives, development of adaptive management and research frameworks, and planning activities in Phase II. Finally, we report on the BLM's National Sage-Grouse Habitat Conservation Strategy as an example of Phase III activities.

The development of an effective monitoring program is a daunting task, and will be difficult to implement by the BLM independently due to the current work load of staff. However, the scientific expertise and experience for developing credible and scientifically sound monitoring programs is available through partners currently involved in assisting other agencies with their monitoring programs [for example, U.S. Geological Survey (USGS), academic institutions, and The Nature Conservancy]. BLM can capitalize on available expertise by partnering with other agencies, which also will help to coordinate activities in Phase III of the monitoring plan.

Background and Objectives

The BLM recently initiated the development of a National Monitoring Strategy to improve the efficiency and effectiveness of the Bureau's inventory, monitoring, and assessment efforts. The goal of this multi-year effort is to develop an integrated data collection and assessment strategy that will be used to inform and guide land management decisions. The monitoring strategy will include protocols for reporting on resource condition and the effectiveness of management actions at the local, regional, and national levels. To guide this effort, an "Energy Team" conducted an evaluation of current monitoring efforts in relation to energy development. The Energy Team comprises several subgroups of experts: wildlife, air, water, and surface disturbance.

As a part of this task, the wildlife subgroup evaluated the existing data collection process and analyses used to inform managers evaluating activities related to energy development and wildlife resources. The subgroup focused the review on information used in Land Use Plans and Environmental Impact Statements. The primary conclusion of the wildlife subgroup was that BLM monitoring generally has focused on monitoring priority habitat and species at the local level (primarily projects and leases), but does not adequately evaluate effects of energy development and management at larger scales (Falise and others, 2005). For example, the BLM monitors greater sage-grouse in relation to wells associated with a particular lease, but does not effectively evaluate the cumulative effects across multiple leases or among field offices. Yet, the BLM is required to evaluate cumulative effects, as mandated by the National Environmental Policy Act (NEPA).

The wildlife subgroup identified several other issues that limited the effectiveness of current monitoring activities (Falise and others, 2005). Frequently, clear monitoring objectives were lacking. Information was incomplete, not analyzed or accessible, or was not used to evaluate or validate decisions or management actions. Inconsistencies in data acquisition, entry, and storage among field offices hindered status and trend analysis at regional scales. Finally, current monitoring does not have a defined link to management and policies because management targets and thresholds have not been clearly defined. The subgroup recommended that a regional monitoring process be developed to address these concerns.

Key Management Questions

To address identified shortcomings of current monitoring, the wildlife subgroup identified four key management questions that should be addressed by the BLM monitoring plan (Falise and others, 2005):

1. What are the conditions and trends of wildlife habitat in basins (such as the Piceance Basin of Colorado) emphasized in the Energy Policy and Conservation Act (http://www.blm.gov/energy/epca)?
2. What are the stressors or agents of change that affect wildlife habitat in these basins?
3. Are applied mitigation and best management practices related to energy development effective in the conservation of wildlife habitat?
4. Are reclamation activities related to energy development accomplishing wildlife and associated habitat objectives as stated in the BLM Activity or Land Use Plans?

The BLM identified two focal areas (Colorado and Alaska) to develop an approach for monitoring the regional effects of energy exploration and development on wildlife species. Each area independently developed a process (hereafter "monitoring plan") for creating a specific monitoring program based on local information needs and priorities. By tailoring the approach for specific management objectives and priorities identified by field offices and stake holders, the monitoring plans developed for each focal area can provide valuable feedback to the BLM for the development of a national monitoring strategy that is responsive to local needs. Here, we report on the monitoring plan developed for the Colorado focal area.

Seven-Step Framework

The BLM required that the monitoring plan incorporate a seven-step framework, adapted from Mulder and others (1999):

1. Specify monitoring goals and objectives.
2. Characterize anthropogenic stressors that affect the parameters of interest.
3. Develop regional questions and conceptual models to describe how, and through what pathways, anthropogenic stressors affect receptors.
4. Suggest indicators to measure the effects of stressors and define information availability and needs.
5. Estimate the sensitivity of indicators to detect change and to guide final indicator choice and sampling design.
6. Describe a process by which management can identify thresholds of change requiring a management response.
7. Identify clear connections between the overall monitoring program and the management decision process.

By using the seven-step framework, the monitoring plans can build on the lessons learned from the successes and limitations of previous monitoring programs by including essential components (Mulder and others, 1999). In addition, it provides a common framework to evaluate the potentially different objectives and resource management issues for each focal area.

BLM Objectives

In addition to the seven-step framework, the following objectives identified by the BLM were used as a guide for the monitoring plan. These objectives were established to ensure that the monitoring plan developed for the focal area will provide information useful to the BLM's national monitoring strategy.

1. Provide a prototype regional monitoring plan for the White River and Glenwood Springs Field Offices of the BLM.
2. Provide BLM with feedback and recommendations based on the experience of developing the monitoring plan and applying it to a specific region.
3. Develop recommendations that will aid the BLM in selecting indicators and adopting appropriate thresholds for management response.
4. Recommend how the product can be integrated within the land use planning process.

Input from BLM Field Offices and Partners

Additional objectives and priorities were discussed at a stakeholder meeting that included approximately 35 representatives from the BLM (field office, State, and national levels), Colorado Division of Wildlife, The Nature Conservancy, and the USGS. The stakeholders identified the highest-priority wildlife management and monitoring questions related to energy development activities, which included the following:

- What is the context for evaluating changes (both anthropogenic and natural)?
- What are the implications of landscape changes for migratory birds, BLM sensitive species, and species of management focus (for example, big game)?
- What are indirect effects of energy development, both local and cumulative?
- How can we evaluate the net loss of effective habitat (both indirect and direct effects of surface disturbance)?
- How can we identify critical habitats (for example, riparian areas and sage-grouse nesting habitat)?
- How can we determine whether management actions are effective or successful in meeting objectives (for example, reclamation, road use, and repeated disturbance)?
- How can we monitor compliance with oil and gas lease stipulations by permit holders?
- How do we implement performance-based mitigation and monitoring?
- How should we monitor invasive species?

Demonstration of Monitoring Plan Application

In addition to developing a monitoring plan, we illustrate how the monitoring plan could be implemented for the focal area. The primary purpose of the demonstration is to provide concrete examples of some of the primary activities of the monitoring plan. We selected a priority species, greater sage-grouse, and relevant management issues to highlight examples of activities for each phase of the management plan. The demonstration project is not intended to be a comprehensive analysis or a completed monitoring program for greater sage-grouse. Rather, it is intended to exemplify the types of analyses, tools, and approaches that could be used to monitor and evaluate the effects of energy development. The maps and graphic summaries included in this report are intended primarily for illustrative purposes; the models were simplified and are not intended for use in planning or analyses.

To illustrate how the monitoring plan could be scaled up or down from the two focal field offices, we selected a larger study area encompassing five Colorado BLM field offices (the focal field offices and Kremmling, Little Snake, and Grand Junction Field Offices; fig. 1). The field offices cover areas of similar size (fig. 2), but there are considerable differences in the cover types (fig. 3).

For a smaller scale of analysis, we selected the Roan Plateau (fig. 1). This area was chosen because it is within the study area and the Piceance Basin, an area of increased exploration and development of energy resources in Colorado. Because the Roan Plateau largely falls within the jurisdiction of the Glenwood Springs Field Office (fig 1), which recently produced an Environmental

Impact Statement and Resource Management Plan for the Roan Plateau, we used this area to illustrate how the monitoring plan could be applied to planning and management activities.

There are many other levels or scales at which analysis and summaries could be performed, depending on the objectives. Our purpose in selecting these scales was to show how the monitoring framework and analysis could be evaluated at several scales and compared across field offices.

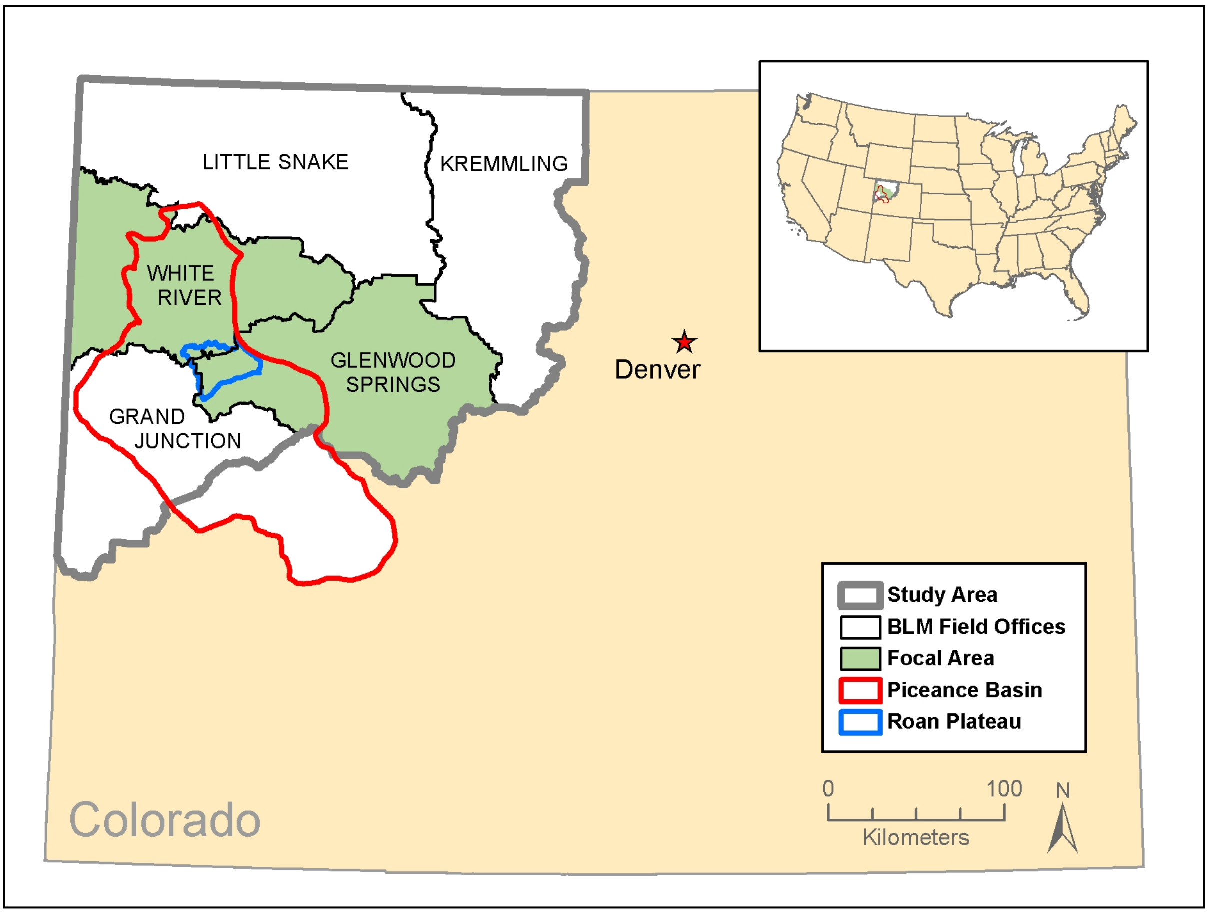

Figure 1. Study area (encompassing five U.S. Bureau of Land Management [BLM] field offices) for the Colorado BLM monitoring plan. White River and Glenwood Springs Field Offices (in green) comprise the focal area. Piceance Basin and Roan Plateau are areas of increased energy development.

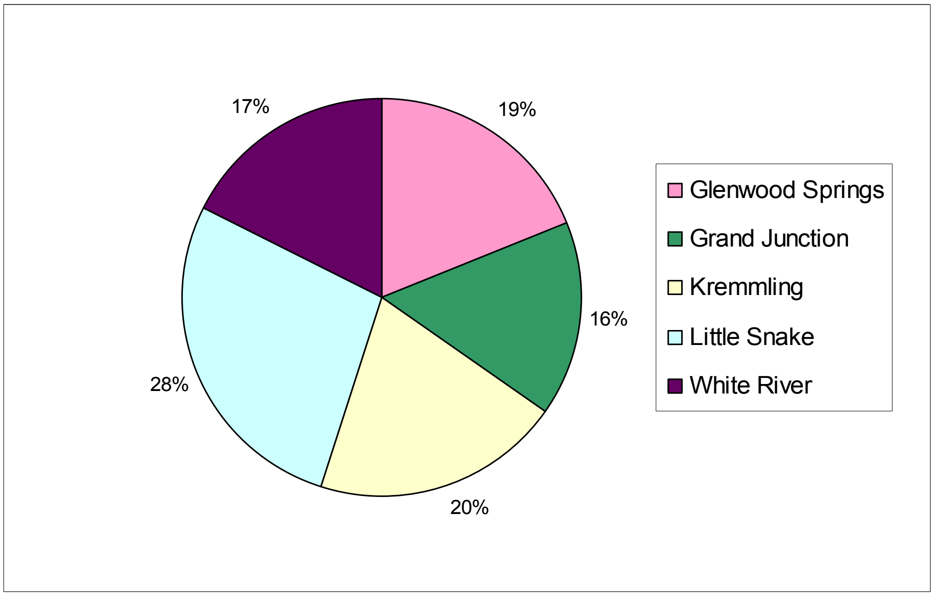

Figure 2. Percent of Colorado study area represented by each U.S. Bureau of Land Management field office.

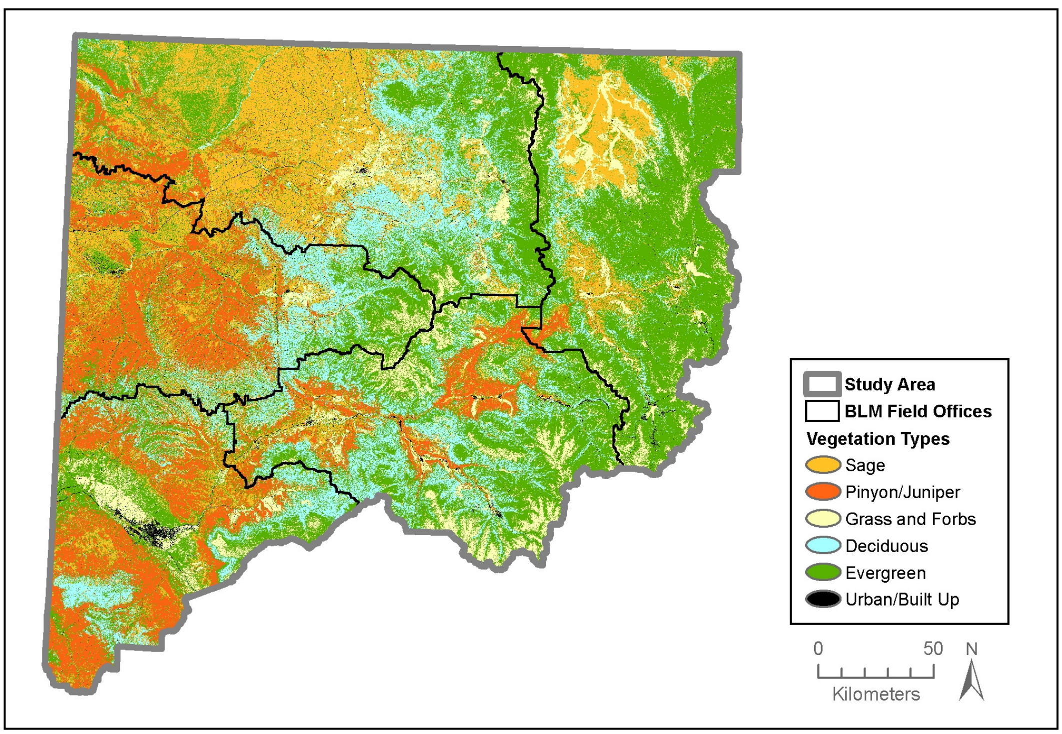

Figure 3. Vegetation map for the study area showing dominant cover classes derived from LANDFIRE vegetation classification. The deciduous cover class includes all woody vegetation (trees and shrubs).

Monitoring Plan Overview

The monitoring plan developed for the Colorado focal area was designed to meet the objectives, criteria, and needs identified by BLM and other stakeholders. The monitoring plan is defined as a process or framework that can be used to guide the development of specific monitoring programs by BLM field offices. Although the priority wildlife management issues for the focal area were used to guide plan development, it was designed with enough flexibility to be applied to other resource management issues (for example, water) and other BLM field offices.

As a part of this effort, we initially reviewed several recently developed monitoring or assessment frameworks (appendix A). In particular, we reviewed frameworks developed for areas that geographically overlap with the BLM focal area. This included Vital Signs monitoring for the Northern Colorado Plateau Network of the National Park Service [NPS (O'Dell and others, 2005)], regional assessments for sagebrush ecosystems—the Great Basin (Wisdom and others, 2005) and Wyoming Basin (Rowland, Leu, and others, 2006) sponsored by the BLM—and status assessments for species of concern and terrestrial ecosystems prepared by Region 2 of the U.S. Forest Service (USFS). A pilot monitoring program for U.S. Fish and Wildlife Service (FWS) refuges was also reviewed. We evaluated the advantages and disadvantages of these frameworks as models for the BLM monitoring plan. Specifically, we considered the objectives, outcomes, and scope of other approaches relative to the BLM's objectives, mandates, and other constraints (funding, staffing, and operating procedures).

In developing the BLM monitoring plan, we relied primarily on the two sagebrush regional assessments (Wisdom and others, 2005; Rowland, Leu, and others, 2006) and the FWS pilot monitoring program. These approaches best fit BLM's objectives and constraints for several reasons. First, the sagebrush regional assessments (Wisdom and others, 2005; Rowland, Leu, and others, 2006) compiled and analyzed the best available information and were completed fairly rapidly (C. Aldridge, oral commun., 2007). Second, the assessments were sponsored by the BLM and specifically designed to meet the information needs of the agency. Third, the regional assessments for sagebrush ecosystems developed comprehensive analyses of species priorities, conducted habitat modeling, and developed landscape indicators in relation to energy development that provided valuable information to guide the development of the monitoring plan. The assessments also provided habitat models and useful guidelines for conducting assessments. Because the Wyoming Basin assessment overlaps a portion of the focal area, it provides information on cumulative effects at larger scales than the focal study area. The focus of the FWS pilot program is adaptive management, which can provide clear links to management decisions, thereby meeting a primary objective of the Wildlife Subgroup. Due to the rapid pace of energy development in the focal area, timely development of a monitoring program that has strong links between management objectives, actions, (for example, mitigation or stipulations relating to energy development), and outcomes (such as the effectiveness of management actions) is paramount.

Three-Phase Approach

To best address the BLM's needs and constraints, we propose an iterative three-phase approach with successive stages building on information and experience gained from earlier stages (figs. 4 and 5). In each iteration of the three-phase approach, monitoring is gradually expanded, beginning with an initial emphasis on greater use of existing data, spatial analysis, and predictive modeling in Phase I, and culminating in an integrated and coordinated program in the third phase. This three-phase approach allows for rapid implementation of a program to assess status and trends at a local or regional level. The scope of the monitoring program expands as objectives are refined or expanded as a result of feedback from an adaptive monitoring framework. Through regional and national coordination, the third phase provides a two-way linkage to the BLM's fledgling national monitoring program.

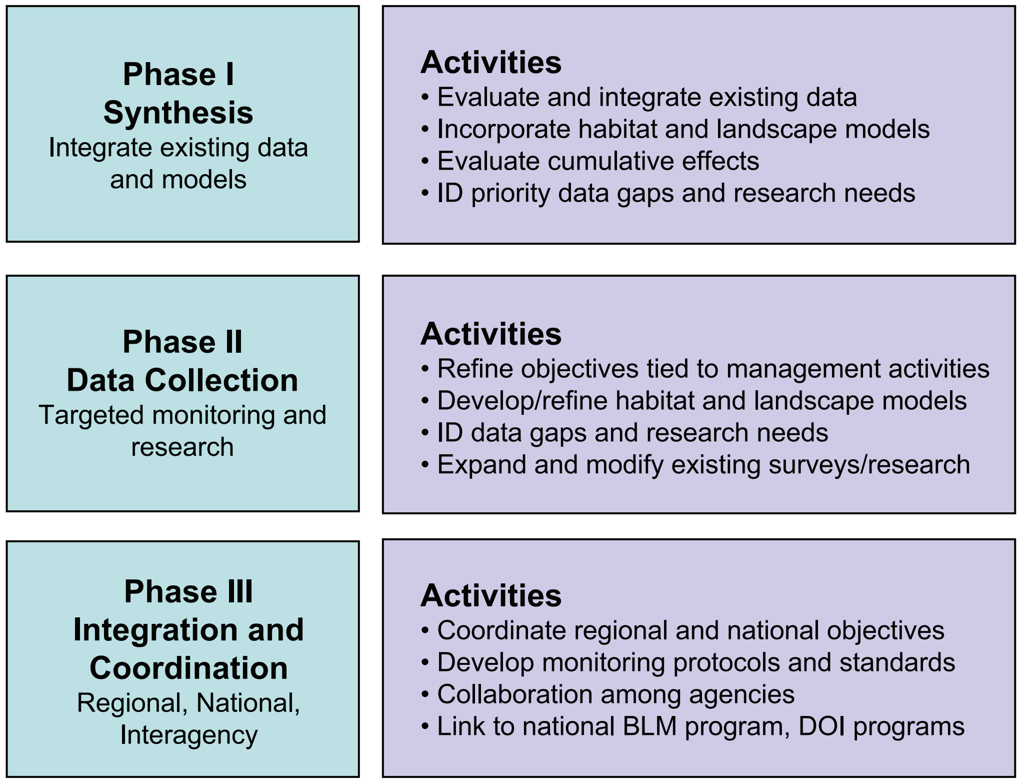

Figure 4. Overview of the three-phase U.S. Bureau of Land Management wildlife monitoring plan developed for the Colorado focus area.

In Phase I, a synthesis is conducted by (1) capitalizing on existing data that currently are not used or are underutilized, (2) incorporating existing habitat models, (3) using spatial analysis and GIS capabilities to address landscape-level cumulative effects of surface disturbance, (4) evaluating legacy data, and (5) identifying critical information gaps that require additional surveys, models, and (or) research. Phase I provides an initial and rapid assessment of the current status and trends of energy development and the cumulative effects on wildlife, as well as an in-depth evaluation of the current state of knowledge and data quality. Compilation of this information is a critical first step in developing a monitoring program. Improved analysis of cumulative effects in Phase I will immediately increase the quality of information available for development of resource management plans, land use plans, lease stipulations, and best management practices related to energy development.

Phase II is the data collection process and relies on information provided in Phase I to refine management objectives and priorities. Based on management objectives, surveys will be refined, expanded, or added to test predictions and assumptions and to address critical information gaps identified in Phase I. This phase provides a linkage to management decisions through targeted monitoring, adaptive management, and research. Additionally, Phase II expands the predictive modeling developed in Phase I by evaluating, modifying, or creating habitat models for priority species. Initially, Phase II will focus on refining existing surveys for the highest-priority species, but will expand to include new surveys in subsequent iterations of the three phases.

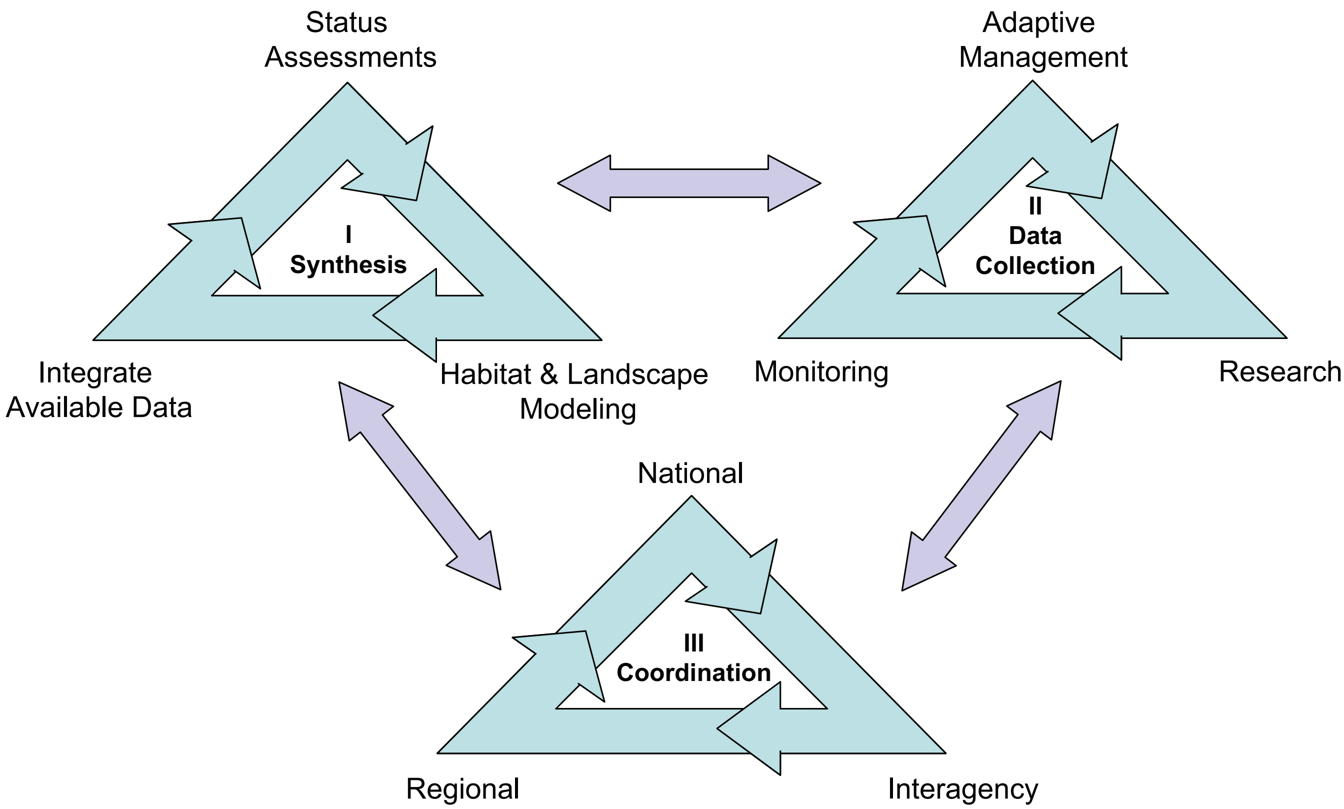

Figure 5. Diagram of the relationship among the three phases of the monitoring plan. The three-phase program is designed to be flexible and iterative. The starting point depends on the objectives, available information, priorities, and strategies. Phases can be implemented in a logical progression or simultaneously. Information obtained from each phase can be used to inform and guide the activities of other phases. Each phase can be repeated as the monitoring program expands or is updated.

Phase III establishes priorities, strategies, and guidelines for monitoring at regional and national levels. This phase is based, in part, on information derived from the application of Phases I and II, which can identify common priorities among several field offices and larger regions. Likewise, national-level coordination is a key part of this process. In addition, collaboration among other land management agencies and organizations (such as FWS, NPS, USFS, State game and fish agencies, and Natural Heritage programs) will improve the efficiency and effectiveness of monitoring programs by reducing duplication of efforts and creating standard monitoring and data management protocols for priority management issues (for example, invasive species) that span multiple jurisdictional boundaries (such as field offices and agencies) to allow for analysis beyond local scales.

Collectively, the three phases are designed to ensure that high-quality information is available to meet the BLM's priority monitoring and evaluation requirements. The seven-step framework (Mulder and others, 1999) guides program development at each phase (table 1). Initial identification of objectives, stressors, conceptual models, and indicators will be achieved in Phase I, but will be refined and expanded in Phases II and III. The primary difference between phases is in the types of activities that are applied to the seven-step framework. By dividing the monitoring plan into three complementary

Table 1. Relationship between seven-step framework (Mulder and others, 1999) and activities associated with each monitoring plan phase.

Seven-step framework	Phase I	Phase II	Phase III
Specify goals	Develop initial goals	Refine/expand goals tied to management options	Coordinate regional, national, and interagency goals
Identify stressors	Identify stressors	Refine/expand stressors to be evaluated	Identify regional/national priority stressors to evaluate
Conceptual models	Develop conceptual models (ecosystem, disturbance, habitat)	Validate/refine models Develop new models Use models to develop adaptive management predictions	Compare and evaluate models
Select indicators	Prioritize indicators	Use predictions to select appropriate indicators Identify priority research and monitoring needs to validate models or address critical monitoring needs	Identify common priority regional/national indicators Identify priority monitoring needs
Sampling design and analysis	Identify and evaluate data available Assessment scales of analysis Assessment design/analysis Priority/focal monitoring sampling design	Evaluate new data sources Forecast effects of management Targeted adaptive management and research design Priority retrospective and baseline monitoring design	Develop standards for monitoring regional and national priority indicators Develop database management and analysis protocols Coordinate research, baseline, and prospective and retrospective monitoring design
Response criteria	Establish condition classes for selected indicators	Refine/establish condition classes for selected indicators	Establish condition classes for selected regional/national indicators
Link to decision making	Develop management targets and management framework	Evaluate and refine management targets and management strategies	Evaluate and refine management targets and management strategies at regional and national levels

phases, the goal is to create an adaptive monitoring process that expands incrementally as knowledge increases (fig. 5). Information that guides the process includes wildlife requirements and ecological system functions, experience in implementing/expanding surveys, and predictions that can be tested in an adaptive monitoring or research framework. This will allow for development of a monitoring program that is not prohibitively complex or unwieldy, yet is scientifically sound and uses the best available information at each stage of development. By gradually expanding and adapting the monitoring program, the likelihood of costly mistakes and delays to implementation will be diminished. The step-wise incorporation into existing BLM protocols will avoid creating unnecessarily complex changes in existing operating procedures that could excessively burden field office personnel or slow implementation.

Guidelines for Implementation

Each phase is designed to be implemented based on the best available information; yet considerable uncertainty will continue to exist. Consequently, each phase, and the monitoring plan as a whole, is an iterative process that is repeated, refined, updated, and expanded as knowledge improves (figs. 5 and 6). Although each phase was designed to build on the preceding phases, there may be activities occurring concurrently. As in the case of the greater sage-grouse, a national conservation program may be under development as the status of local populations is being assessed in Phases I and II. In addition, because each phase follows the same seven-step framework (table 1), there is overlap in the types of activities (for example, modeling) used to achieve the objectives of each phase. The phases are complementary, but the activities associated with each are not necessarily mutually exclusive.

Initially, Phase I will focus on the highest-priority species and landscapes. Other species or resource management issues can be added in future iterations. Status assessments are updated regularly (such as every five years). Likewise, Phase II will initially focus on refinement of existing surveys of priority species (such as greater sage-grouse) to improve the quality of information available for current management and planning activities. Subsequent iterations of the monitoring framework will expand Phase II activities based on guidelines developed in Phase III. Because Phase III can be slow to implement due to the number of stakeholders involved, initial refinement of Phase II activities may proceed prior to full implementation of Phase III. However, to facilitate coordination and efficiency, regional and national guidelines will be developed before large new surveys are initiated.

The iterative process begins with high-priority objectives while allowing for a gradual expansion of monitoring programs with subsequent iterations. This will avoid prohibitive start-up costs and time-consuming background preparation required to implement a complex and comprehensive monitoring program. Thus, a particular program may address only the highest-priority objectives in the initial implementation of the monitoring plan due to funding, time, and knowledge constraints. This approach is designed to allow maximum flexibility to meet a variety of resource management issues but allow the timely implementation of the approach to address pressing information needs.

The monitoring program will be most useful if the process involves coordination and collaboration among field offices within a geographic region. For example, the Wyoming and Great Basin assessments are at scales appropriate for addressing common issues and information needs of several field offices. Initially, assessments of larger regions (for example, the Rocky Mountain Region) may slow the completion of Phases I and II tasks, but may be more appropriate scales for initial Phase III activities. In addition, coordination among disciplines (including wildlife, water, air quality, and energy extraction) is necessary to address conflicting issues and evaluate trade-offs among management actions.

The development of a successful monitoring program is a daunting task, and due to the workload of existing BLM staff, may be achieved more efficiently through partnerships. The scientific expertise and experience in developing credible and scientifically sound monitoring programs are available through partners currently involved in assisting other agencies with their monitoring programs

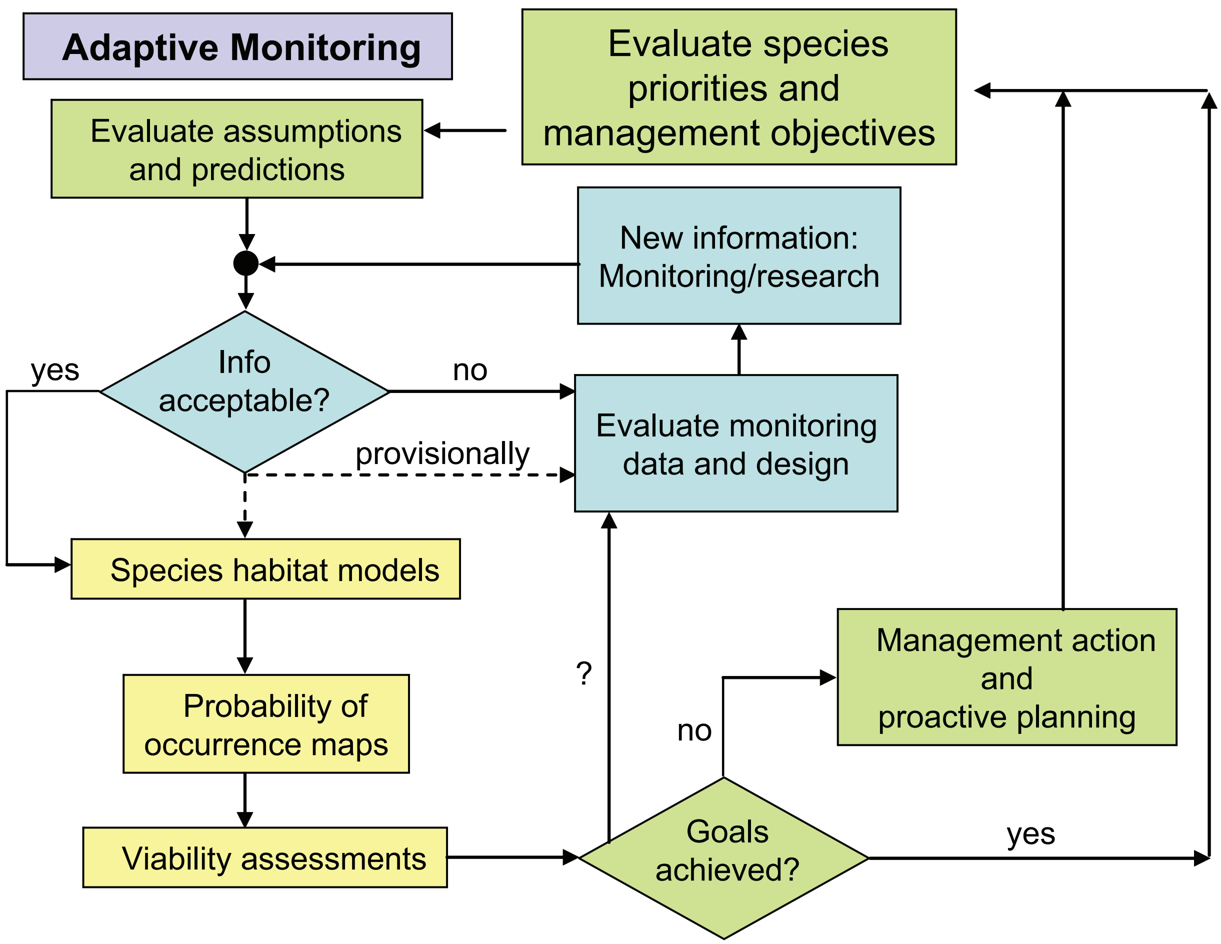

Figure 6. Adaptive monitoring framework illustrated for species-level assessments (adapted from Ringold and others, 2003). A key component of this framework is the development of management goals, actions, and assumptions to be evaluated (green polygons) based on monitoring data and model predictions (yellow rectangles). Management and planning activities will be evaluated if identified goals are not achieved. Information quality and gaps will be evaluated to upgrade the monitoring program (blue polygons).

(including the USGS, academic institutions, and The Nature Conservancy). In particular, expertise in designing surveys that can achieve monitoring goals (such as the ability to detect trends) can help to avoid costly errors. BLM can capitalize on the experience and lessons learned by partnering with other groups, which will also help to coordinate activities in Phase III of the monitoring plan.

Three-Phase Monitoring Plan

We use the seven-step framework to provide more details on the activities associated with each phase. In addition, we discuss how the products of each phase are used to inform the other phases. We also provide examples of products for each phase to illustrate how this approach could be implemented.

Phase I: Synthesize and Integrate Existing Data and Models to Conduct Status Assessments

Overview Phase I

The primary focus of Phase I is to improve the use of existing data in BLM evaluation and planning activities. In particular, this phase is designed to improve the BLM's capabilities to evaluate cumulative effects by including spatial analysis of anthropogenic disturbance into habitat and landscape models. The result will be a set of models that can be used to assess status and trends, as well as forecast future scenarios of energy development and management strategies. A primary product of this phase is the development of regional status assessments for priority species and systems, which are valuable for developing Resource Management Plans, Environmental Impact Statements, lease and permit stipulations, and regional plans. This phase also entails identifying critical information gaps and assumptions that can be addressed by monitoring and research in Phase II, and can help to establish regional and national monitoring priorities in Phase III.

Phase I: Seven-Step Framework

Step 1. Develop, Refine, and Prioritize Initial Monitoring Goals and Priorities

This involves meetings with representatives from all administrative levels of the BLM (field office, State, and national) as well as other stakeholders (such as State game and fish agencies, other Federal agencies, and nongovernmental organizations). Appropriate scales of analysis for each objective will be identified.

Step 2. Identify Key Stressors

This step will be initiated in conjunction with development of monitoring objectives and conceptual models. Priority stressors for assessment in Phase I will be determined.

Step 3. Develop Conceptual Models for Ecosystem Function and Anthropogenic Stressors

The conceptual models identify the major processes and pathways that may be disrupted by anthropogenic stressors and help to ensure that important indicators and confounding factors are considered during the process of prioritizing indicators to monitor.

Step 4. Select and Prioritize Indicators

Indicators will be based on the conceptual and stressor models, as well as high-priority species identified by the BLM. This process will include inputs from State game and fish agencies, and it incorporates priorities established by the FWS, USGS, Partners in Flight, and The Nature Conservancy.

Step 5. Sampling Design and Analysis

This includes several components:

- Compile and evaluate existing data, including legacy data. Existing data will be evaluated for statistical and sampling issues, including survey design, spatial and temporal sampling scales (resolution, grain, and extent), data quality, and sensitivity to population changes and responses to anthropogenic stressors. In particular, the usefulness of legacy data for meeting monitoring objectives will be evaluated.

- Characterize habitats for priority species and quantify landscape condition (figs. 7 and 8). First, existing habitat models for priority species will be evaluated. Species- and landscape-level indicators will be selected based on priorities and conceptual models. The potential for characterizing or modeling historical landscape condition (baseline) for status and trend analysis also will be evaluated.
- Comprehensive status assessments for priority species of concern will be conducted to guide evaluation procedures and management activities. An example of a national-level assessment is the recent conservation assessment for greater sage-grouse and sagebrush habitats (Connelly and others, 2004). Recent regional assessments are the Wyoming and Great Basin assessments (Wisdom and others, 2005; Rowland, Leu, and others, 2006).
- Historic range of variation assessments will be conducted (for example, historical fire regimes for sagebrush cover types; Baker, 2006) to guide management of landscape processes and refinement of indicators of landscape function. Several such assessments were conducted recently by Region 2 of the USFS (Hhttp://www.fs.fed.us/r2/projects/scp/H).
- Identify data gaps for designing surveys and research. Key assumptions, other information gaps, and model predictions will be used to identify and prioritize monitoring and research needs.
- Develop protocols to refine/augment existing surveys based on information priorities.
- Develop a data management framework (including metadata, quality control, and database structure) that facilitates compilation and analysis. The database can be linked to tools for cumulative impact assessments and other analyses. Ideally, the database will be accessible both locally and regionally to allow analyses at scales beyond the level of the field office. Online data entry and processing may facilitate accessibility and analysis.

Step 6. Establish and Integrate Initial Management Targets

This involves assessment of status and trends for priority species and their habitats, landscape condition indices, and the relationship of indicators to Land Health Standards. Management targets will be based on the status and trends of priority species. This activity will be expanded in Phase II.

Development of response criteria will depend on the management objectives for both a particular project area and at larger spatial scales. Currently, there is little empirical information to develop specific response criteria. For these reasons, the development of response criteria is best conducted with inputs from many sources including managers and scientists, and will depend on priorities and expert opinion. Models can help to summarize empirical information and formalize hypotheses into a framework that can aid in the development of condition classes and management targets.

Step 7. Identify Opportunities to Integrate Assessments into Planning and Evaluation

Alternative management activities (including mitigation, setting restoration priorities, and proposed management actions) will be evaluated based on habitat and landscape models. This activity will be expanded in Phase II.

Phase I Demonstration

Step 1. Specify Goals and Objectives

The results of the initial meeting with the BLM White River and Glenwood Springs Field Offices and stakeholders can be summarized by three central management issues related to energy development:

1. How do we evaluate the cumulative effects of energy development and mitigation activities on species of management interest or concern?

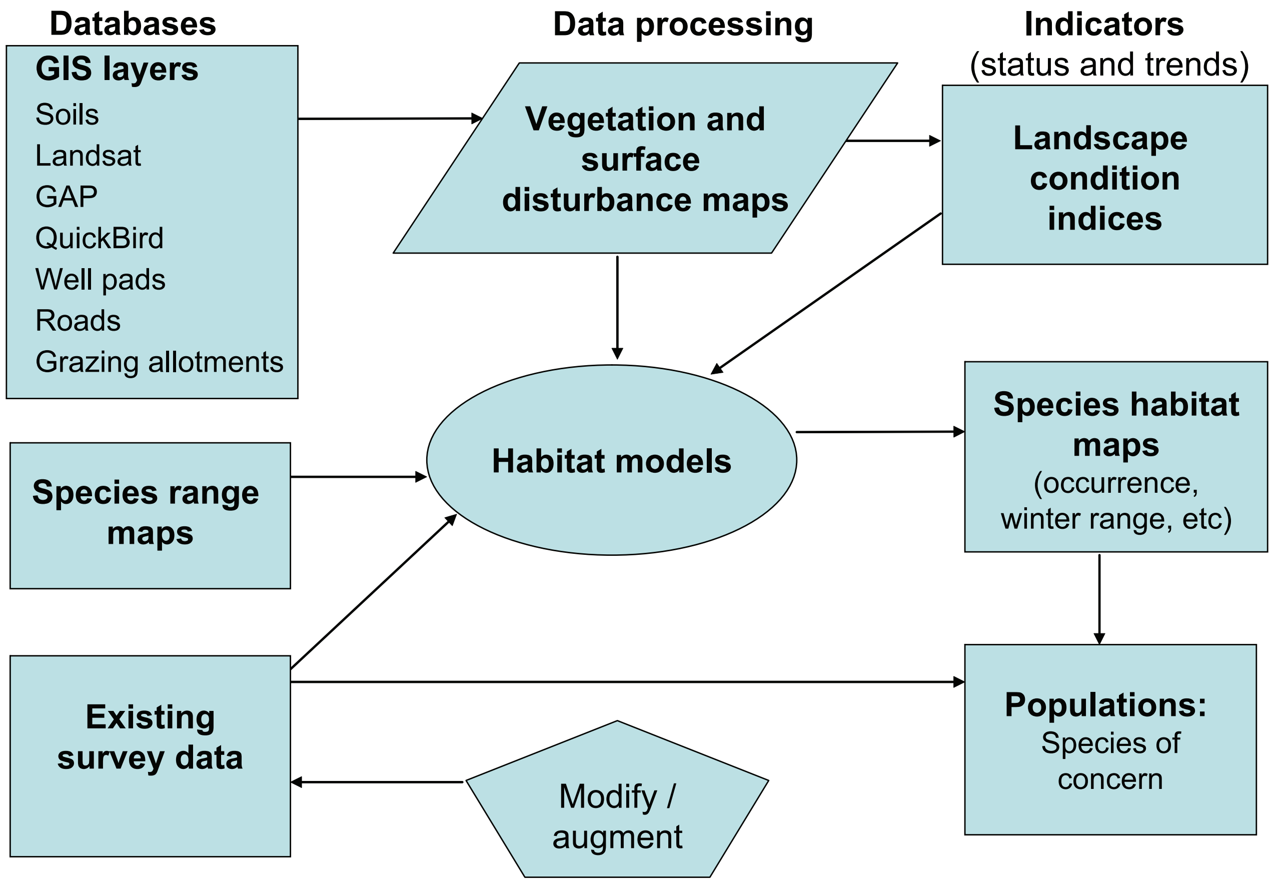

Figure 7. Overview of data input, data processing, and output (indicators) for Phase I activities

2. How can cumulative effects, including direct and indirect effects, be quantified relative to natural variation?
3. How can we implement compliance and effectiveness monitoring (including performance-based) to determine whether stipulations are met and restoration/mitigation goals are achieved?

Cumulative effects can include: (1) cumulative habitat alteration across multiple assessment scales (such as individual projects or areas managed by field offices), (2) indirect effects (for example, increased vehicle disturbance or predation associated with surface disturbances), and (3) spatial attributes of surface disturbance (such as habitat fragmentation and isolation).

Steps 2–3. Develop Conceptual Models and Stressor Models

An ecosystem-level conceptual model was developed for the Northern Colorado Plateau Network of the NPS (Miller, 2005; O'Dell and others, 2005), which overlaps the Colorado focus area. We adapted this conceptual model for the demonstration project. The conceptual model provides a general overview of the dominant ecological processes and pathways that drive ecosystem changes and can help to ensure that critical agents of change and potentially confounding factors are considered (fig. 9). Because the objective of the monitoring program is wildlife habitat and energy development, we developed a stressor model for the wildlife portion of the overall model (fig. 10). These two conceptual models provide the context for evaluating and identifying the primary impacts of road stressors on

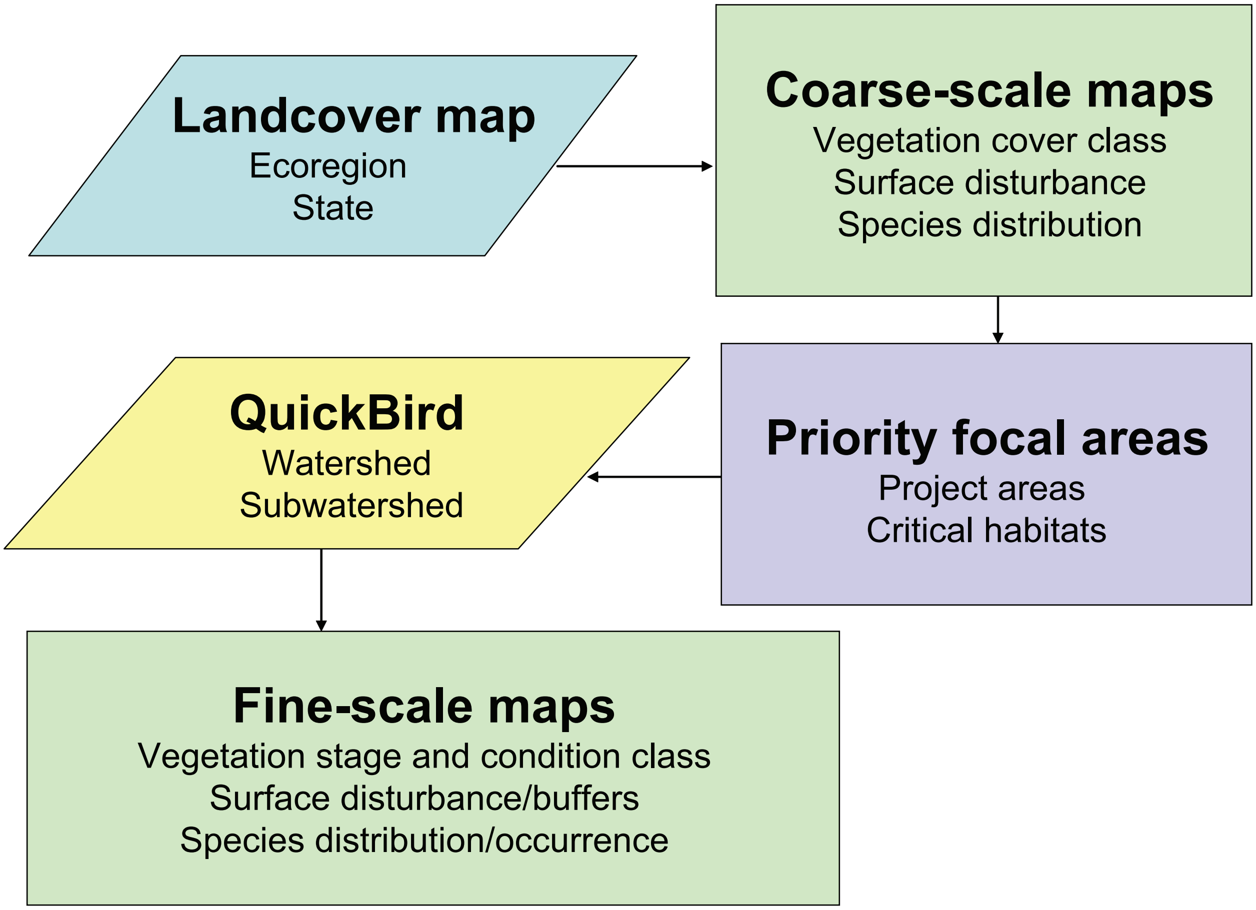

Figure 8. Illustration of a multi-scale approach to landscape and habitat assessments. Coarse-scale vegetation maps (such as, 30-m resolution Landcover maps derived from Landsat imagery) allow analysis at larger spatial scales (State, ecoregions, and national). Finer-scaled maps (such as, 1-m resolution derived from QuickBird imagery) can improve accuracy for specific project areas and management objectives, but currently may be cost-prohibitive at larger spatial extents.

wildlife (figs. 11 and 12). In figure 11, the primary components of road impacts—road presence and use—are identified. The road stressor submodel (fig. 12) specifically addresses the potential mechanisms by which roads can directly and indirectly affect wildlife and can be used to guide the selection of indicators. In the demonstration project, we focused on habitat loss and degradation, as well as landscape structure, but other indicators (spread of invasive exotic species, population change, and genetic diversity) also could be used.

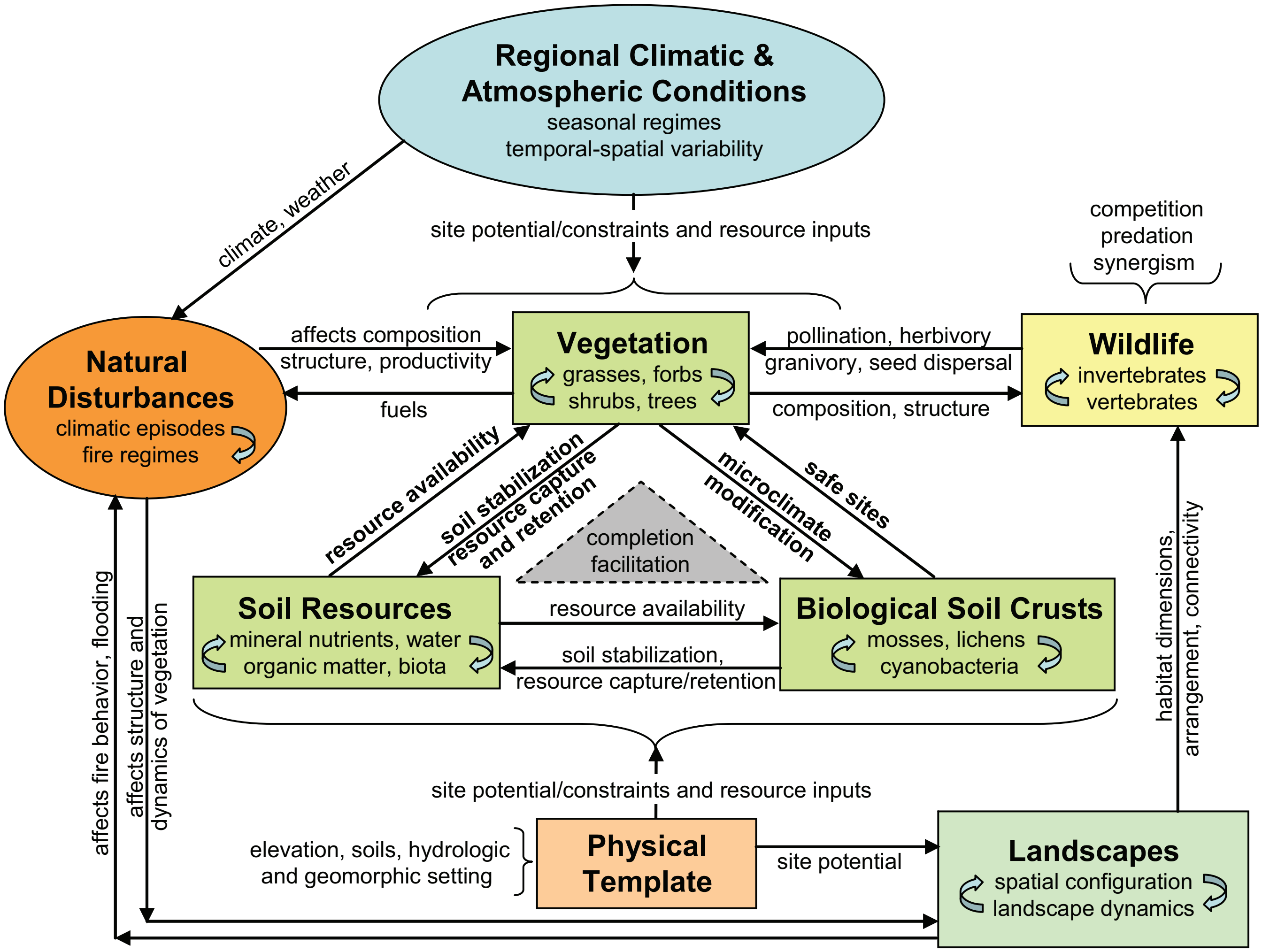

Figure 9. Conceptual model illustrating key structural components (rectangles) and functional relationships (arrows) of ecosystems for the Colorado focal area. Ovals represent natural drivers of temporal variability and change (adapted from Miller, 2005).

Step 4. Prioritize Indicators

The initial meetings with BLM and other stakeholders provided a list of priority species (see tables 2a and 2b for some examples). For the purposes of this exercise, we chose a high-priority species (greater sage-grouse) to illustrate an approach that can be used to model habitat and disturbance effects. The indicators we chose to evaluate were habitat availability and the effects of surface disturbance on the quality and spatial distribution of habitat. We also demonstrated the use of landscape indicators by conducting analyses of road densities and spatial distribution of roadless areas for all cover types in the study area.

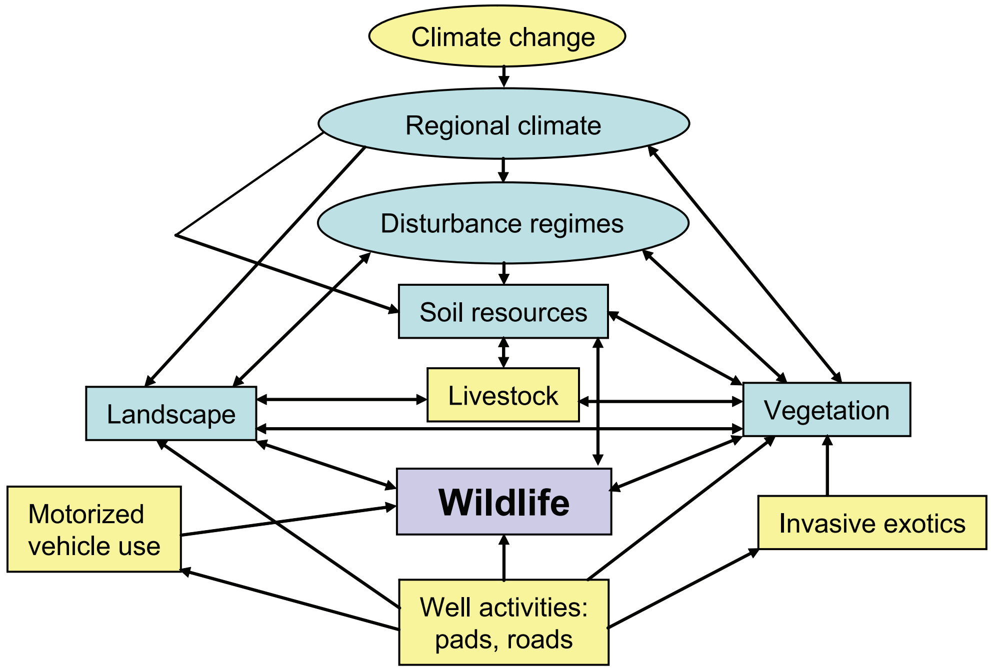

Figure 10. Conceptual model of major anthropogenic stressors affecting wildlife on U.S. Bureau of Land Management lands in the Colorado focal area. Potential anthropogenic stressors are indicated in yellow.

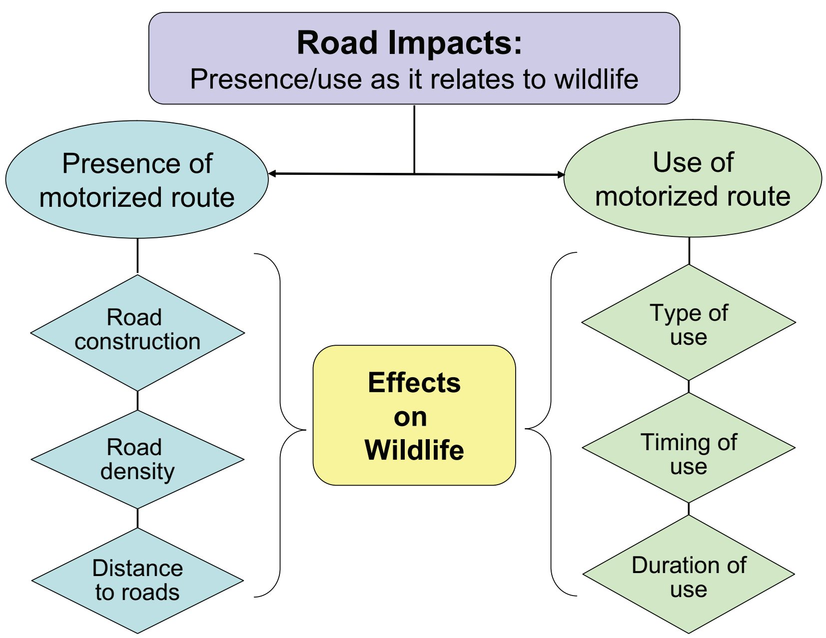

Figure 11. Conceptual submodel for the effects of road presence and use on wildlife. Two primary components of road impacts: presence (blue) and use (green) of roads are represented. Effects are considered both spatially and temporally.

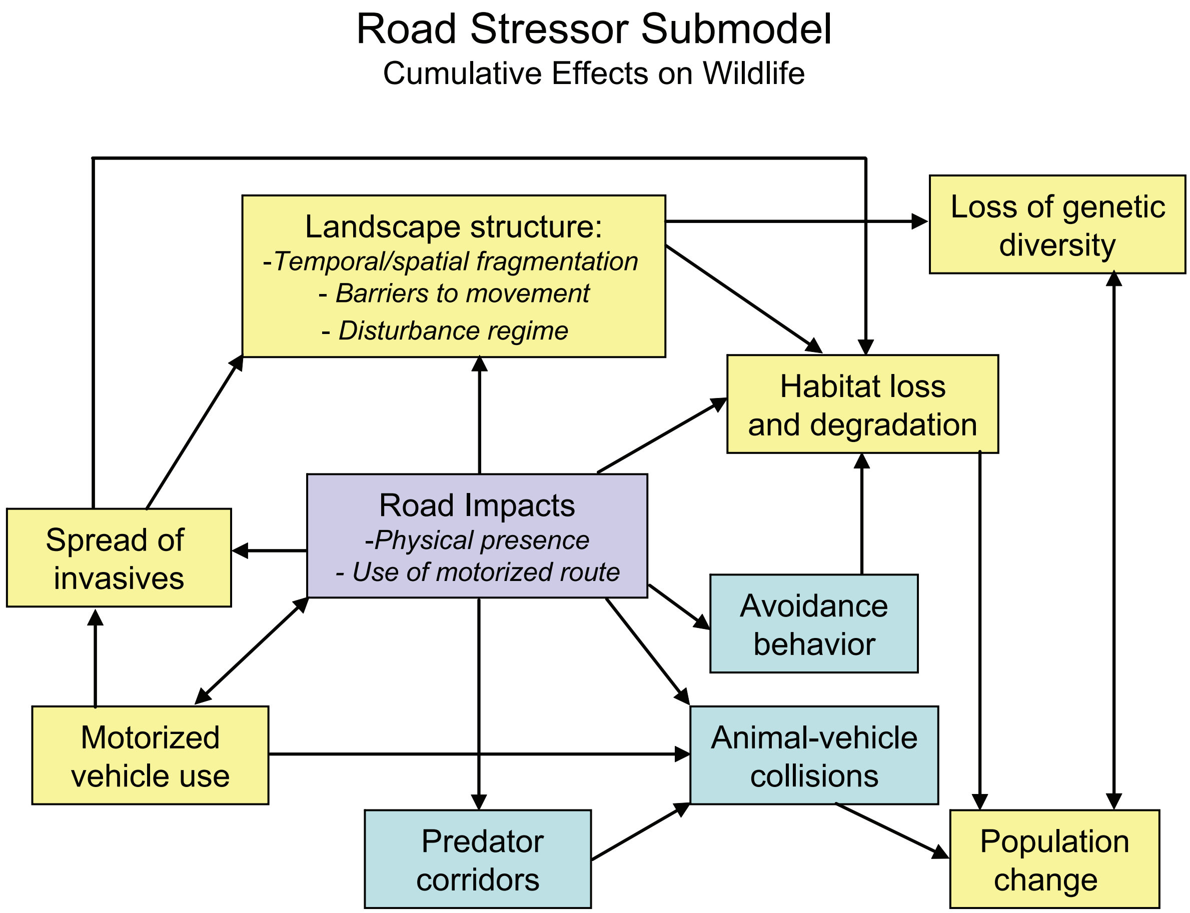

Figure 12. Conceptual submodel for the direct and indirect effects of roads on wildlife. Possible mechanisms are indicated in blue rectangles. Yellow rectangles represent additional mechanisms and potential indicators.

Step 5. Sampling Design and Analysis

Identify, Compile, and Evaluate Available Data

We compiled relevant data sets, including both survey data and GIS coverages, and created metadata. For the demonstration project, we used LANDFIRE vegetation maps (Rollins and Frame, 2006) to model habitat. Additional data sets used for the demonstration project are listed in the appendixes.

Characterize Habitats for Priority Species and Quantify Landscape Condition

To characterize habitat and landscape condition, we used the habitat modeling approach outlined in the Wyoming Basin Assessment (Rowland, Leu, and others, 2006), which includes two submodels: habitat and disturbance (fig. 13). We adapted this approach for the types of information available on greater sage-grouse. For the landscape analysis, we took a coarse-filter approach and addressed all cover types and evaluated the disturbance effects more generally on landscape characteristics. These approaches and results are discussed below. Additional details on the methods are provided in appendixes B and C.

Table 2a. Hierarchical monitoring priorities developed by the U.S. Bureau of Land Management White River Field Office to assess impacts of potential stressors on biological integrity.

Level 1 – Biological Integrity	Level 2 – Habitat type/attribute	Level 3 – Stressors	Level 4 – Indicators
Functional habitat	Mountain shrubland	Invasive plants Noise – vehicle use/drilling Habitat loss – roads/pads Livestock – grazing intensity	Invasive plants, Virginia's warbler
	Pinyon/juniper	Invasive plants Noise – vehicle use/drilling Habitat loss – roads/pads Livestock – grazing intensity	Invasive plants, pinyon jay, raptors, black-throated gray warbler
	Sagebrush	Invasive plants Noise – vehicle use/drilling Habitat loss – roads/pads Livestock – grazing intensity	Invasive plants, greater sage-grouse, Brewer's sparrow, sagebrush vole
	Thirteen Mile Tongue of Green River Formation	Invasive plants Habitat loss – roads/pads Livestock – grazing intensity	Invasive plants, T&E plants
Landscape-scale connectivity	Habitat fragmentation, corridors	Noise – vehicle use/drilling Habitat loss – roads/pads Livestock – grazing intensity	Elk, mule deer

Table 2b. Hierarchical monitoring priorities to quantify habitat loss and other impacts due to disturbance.

Level 1 – Disturbance	Level 2 – Activity	Level 3 – Potential impacts	Level 4 – Quantify impacts
Human disturbance	Energy development	Well pads	Acres surface disturbance
		Roads	Acres surface disturbance
		Motorized vehicle use	Intensity of road use
		Powerlines	Miles/density
	Livestock grazing	Alter vegetation composition and structure	Vegetation composition and structure
	Hunting	Motorized vehicle use	Intensity of road use
Natural disturbance	Wildfire	Alter vegetation composition and structure	Vegetation composition and structure

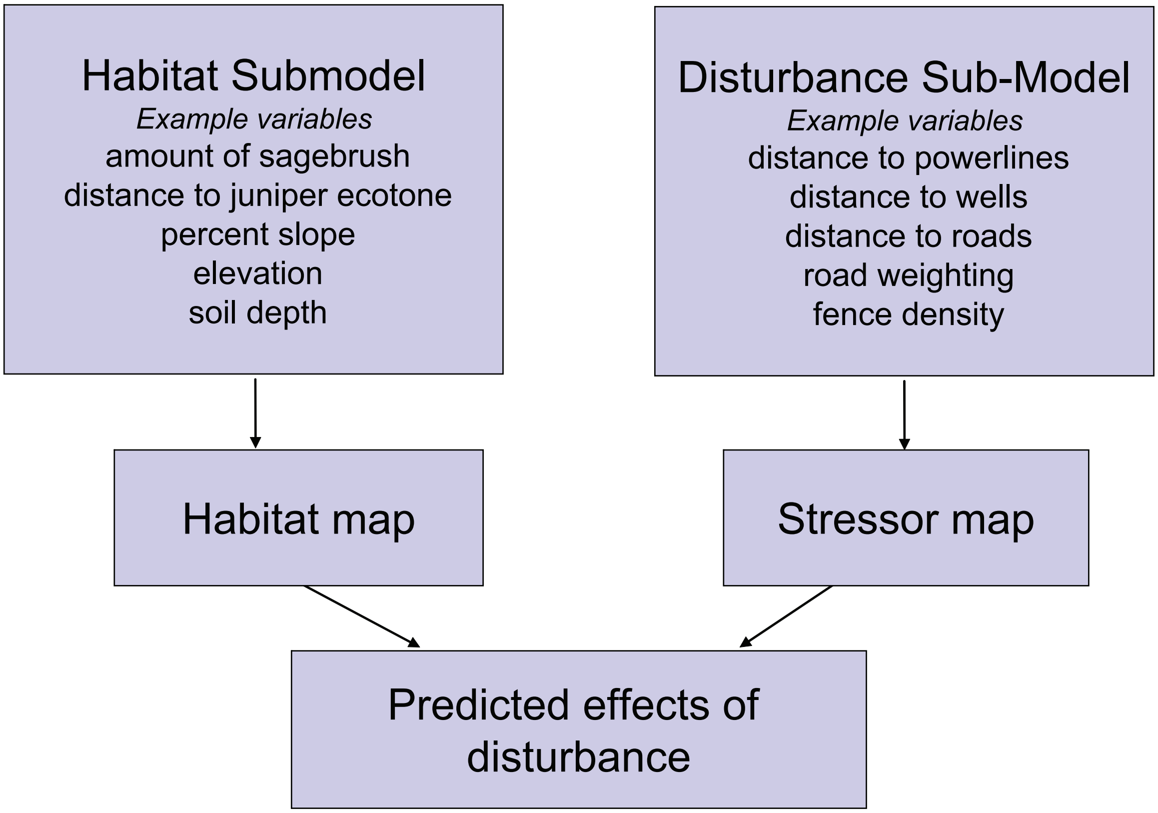

Figure 13. Overall approach to modeling effects of disturbance activities associated with energy development on habitat quality (adapted from Rowland, Leu, and others, 2006).

Example 1: Greater Sage-Grouse

To model habitat for greater sage-grouse, we adapted a habitat-disturbance model developed for a nearby area (Rowland, Leu, and others, 2006). We used the model to predict habitat quality at a regional level (the entire study area) based on general habitat affinities (sagebrush cover submodel) and disturbance effects (disturbance submodel; see appendix B for details on the model.) We compared differences in potential sage-grouse habitat with and without the disturbance submodel.

The distribution of the greater-sage grouse in the demonstration area was primarily limited to the White River, Little Snake, and Kremmling Field Offices, and few production areas occurred in Glenwood Springs or Grand Junction (appendix B, fig. B1). A small production area occurred on the Roan Plateau but was located on private lands. Because the Piceance Basin and Roan Plateau were not useful scales for this exercise, we focused our analysis of this species across the entire study area and compared the results among the five field offices.

The availability of sage-grouse habitat across the study area is predicted to greatly diminish when disturbance is included in the model (figs. 14 and 15). Both the quality and connectivity of greater sage-grouse habitat are substantially reduced by the direct and indirect effects of disturbance associated with roads and energy development (fig. 15b). For all field offices, the proportion of habitat in the lowest quality category increased with a concomitant decrease in the highest quality habitat (fig. 15). This was particularly pronounced in the Little Snake and Kremmling Field Offices where the greatest amount of high-quality greater sage-grouse habitat occurs (fig. 15). For example, disturbance reduced the amount of high-quality habitat (the highest three classes) from more than 35 percent to less than 15 percent of the sagebrush area in the Little Snake Field Office. Likewise, in the White River Field Office, the proportion of the lowest quality habitat class increased and all other potential habitat classes decreased (fig. 15). There is relatively little habitat available in the Glenwood Springs Field Office, and the model results indicate that disturbance affects most of this sage-grouse habitat (fig. 15).

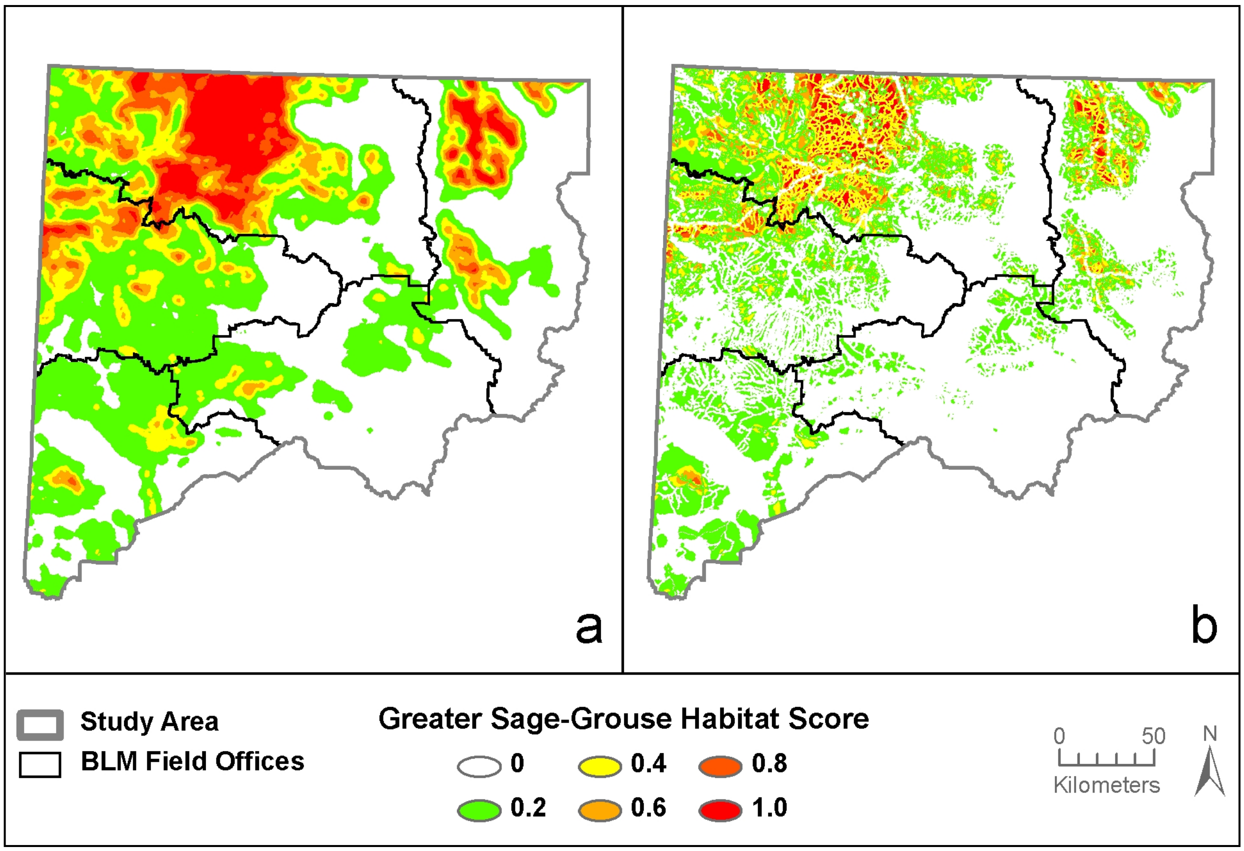

Figure 14. Greater sage-grouse habitat scores based on (a) sagebrush cover only and (b) combined sagebrush cover and disturbance submodels (habitat score midpoints are presented for combined model). The habitat score is assumed to reflect the probability of occurrence (Rowland, Leu, and others, 2006).

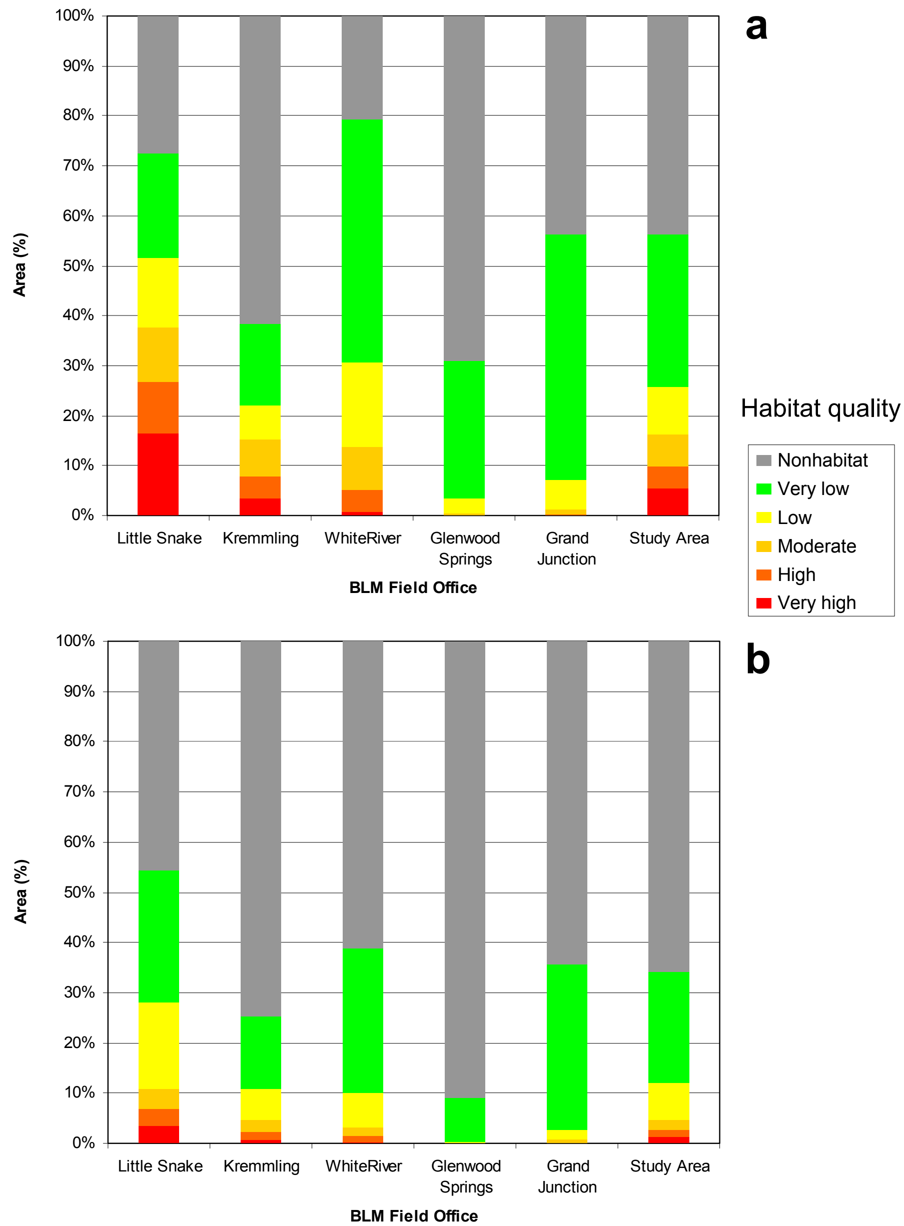

Figure 15. Distribution of greater sage-grouse habitat quality by U.S. Bureau of Land Management field office and for the entire study area based on (a) sagebrush cover submodel and (b) combined cover and disturbance submodels. Categories of habitat quality were derived from habitat scores (see appendix B; table B1).

We compared the direct loss of habitat resulting from surface disturbance (surface disturbance footprint) to the total disturbance submodel, which includes the direct and indirect effects of disturbance (appendix B, table B2). The importance of including the potential effects of disturbance beyond the footprint is illustrated in figure 16. The potential reduction in the amount of greater sage-grouse habitat due to the footprint is relatively minor and much less than the potential reduction in habitat quality due to the cumulative effects of disturbance (fig. 16). Typically, BLM assessments only quantify direct habitat losses due to energy development.

Example 2: Landscape Analysis

A goal of the BLM field offices is to develop tools to monitor fragmentation resulting from energy development. The fragmenting effects of energy development depend, in part, on the density and spatial distribution of wells and associated roads. (See appendix C for additional discussion of landscape effects.) In this sense, roadless areas can be considered the fragments. The size of fragments decreases with increasing road density. Small roadless areas can also become isolated from larger roadless areas as the number and size of roadless areas decreases across the landscape. By quantifying fragmentation, field office staff can evaluate the spatial effects of energy development, in addition to total acreage lost. Here we evaluate fragmentation by quantifying core areas. Core area is the portion of a roadless area in which the direct and indirect negative effects of roads are assumed to be minimal. What constitutes a core area will vary by species, as well as other factors, such as cover type and road use. Rather than establish core areas for a specific species, in this example we quantify core area for a range of distances to roads (appendix C).

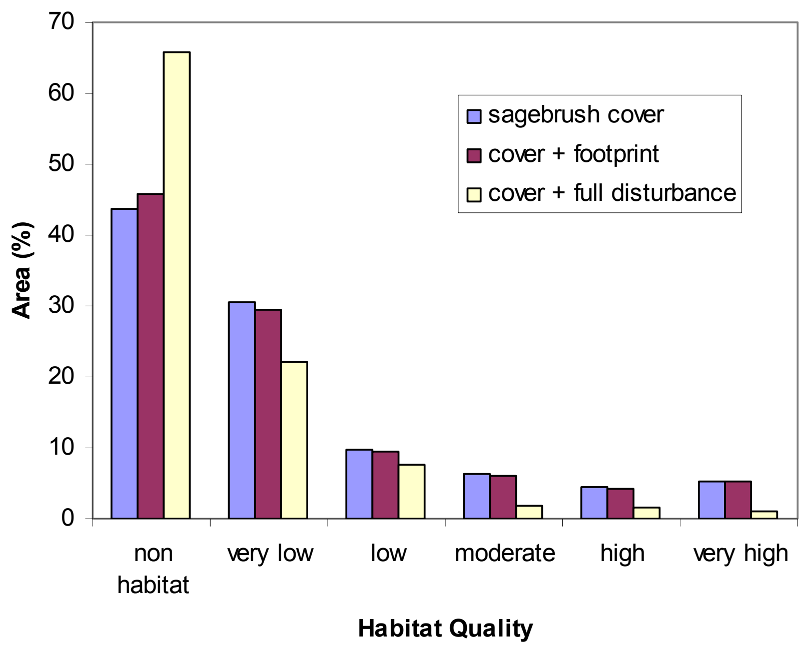

Figure 16. Differences in greater sage-grouse habitat availability for the study area based on three sub-models: (1) sagebrush cover only, (2) sagebrush cover and direct effects (footprint only) of disturbance, and (3) sagebrush cover and full disturbance (direct and indirect effects of disturbance; see appendix B; table B2).

The degree of fragmentation varied by field office, primarily for core areas at least 500 m from roads (fig. 17). In all field offices, more than 80 percent of the area was at least 100 m from a road. Within the Little Snake and White River Field Offices, approximately 20 percent of the area was greater than 1,000 m from roads, and nearly 50 percent of the Grand Junction Field Office was more than 1,000 m from roads (fig. 17). We examined this in more detail for two disturbance distances (250 m and 1,000 m) for the entire study area, by varying the minimum size of core areas (figs. 18 and 19). For both disturbance distances, the total core area was fairly constant up to a minimum size of 100 ha (250-m buffer, 70 percent; 1,000-m buffer, 30 percent; fig. 19a). Despite this constancy, the number of core areas dropped dramatically when fragments less than 10 ha were excluded (fig. 19b) indicating that these fragments contributed very little to the total area. Relatively undisturbed areas that were both large (>1,000 ha) and far from roads (>1,000 m) represented less than 20 percent of the entire study area (fig. 19a). This pattern is also illustrated by figure 18.

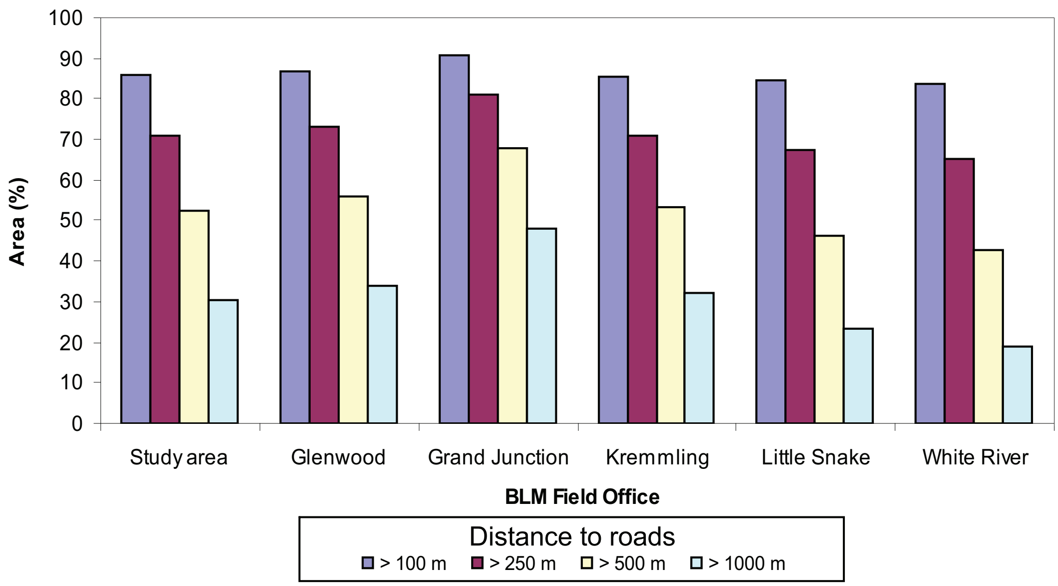

Figure 17. The percent of the entire study area and each U.S. Bureau of Land Management field office that is represented by core area for four different distances to roads.

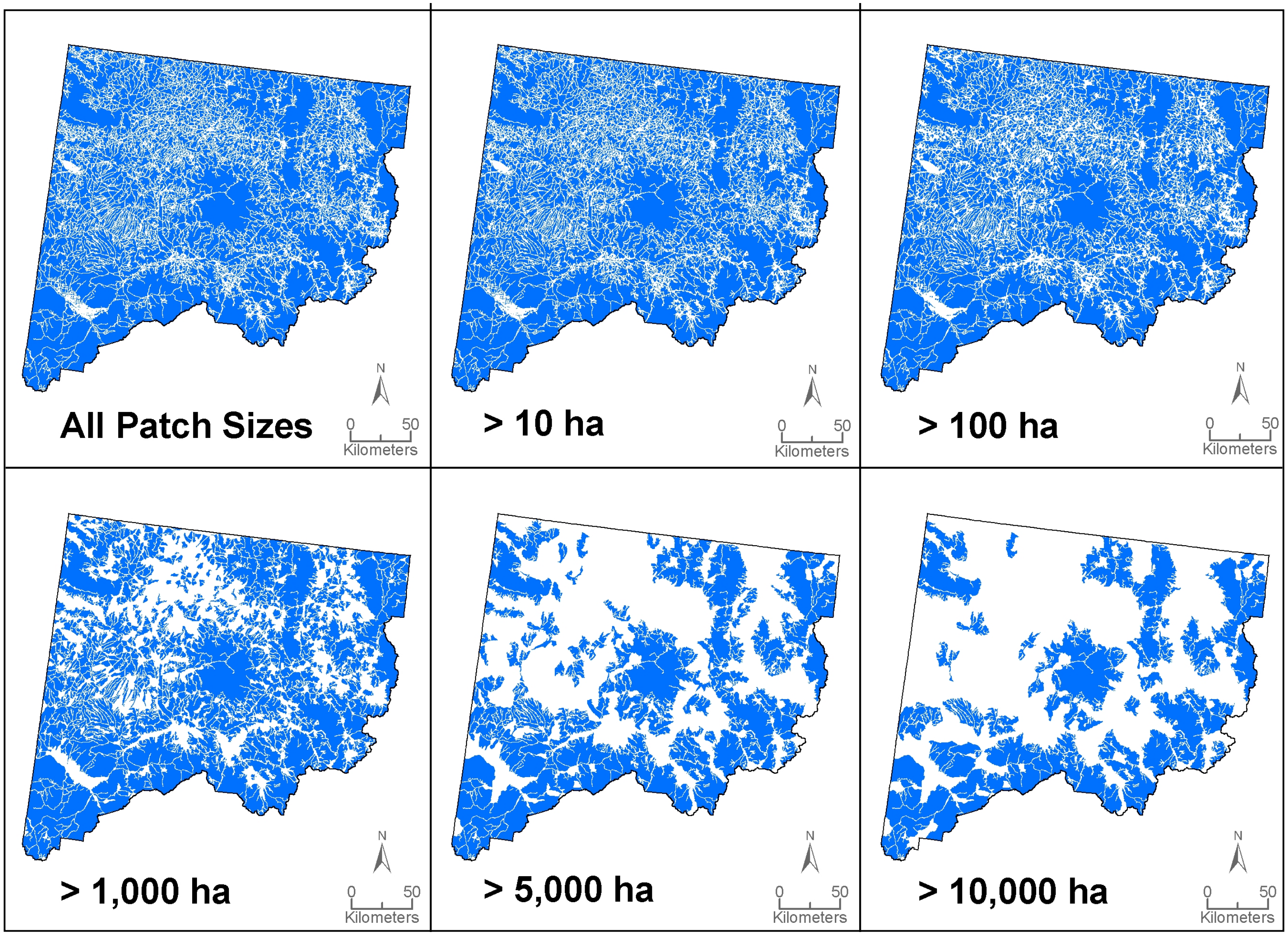

Figure 18. Core areas greater than 250 m from roads. Blue areas exceed the minimum size of core areas indicated at the bottom of each panel.

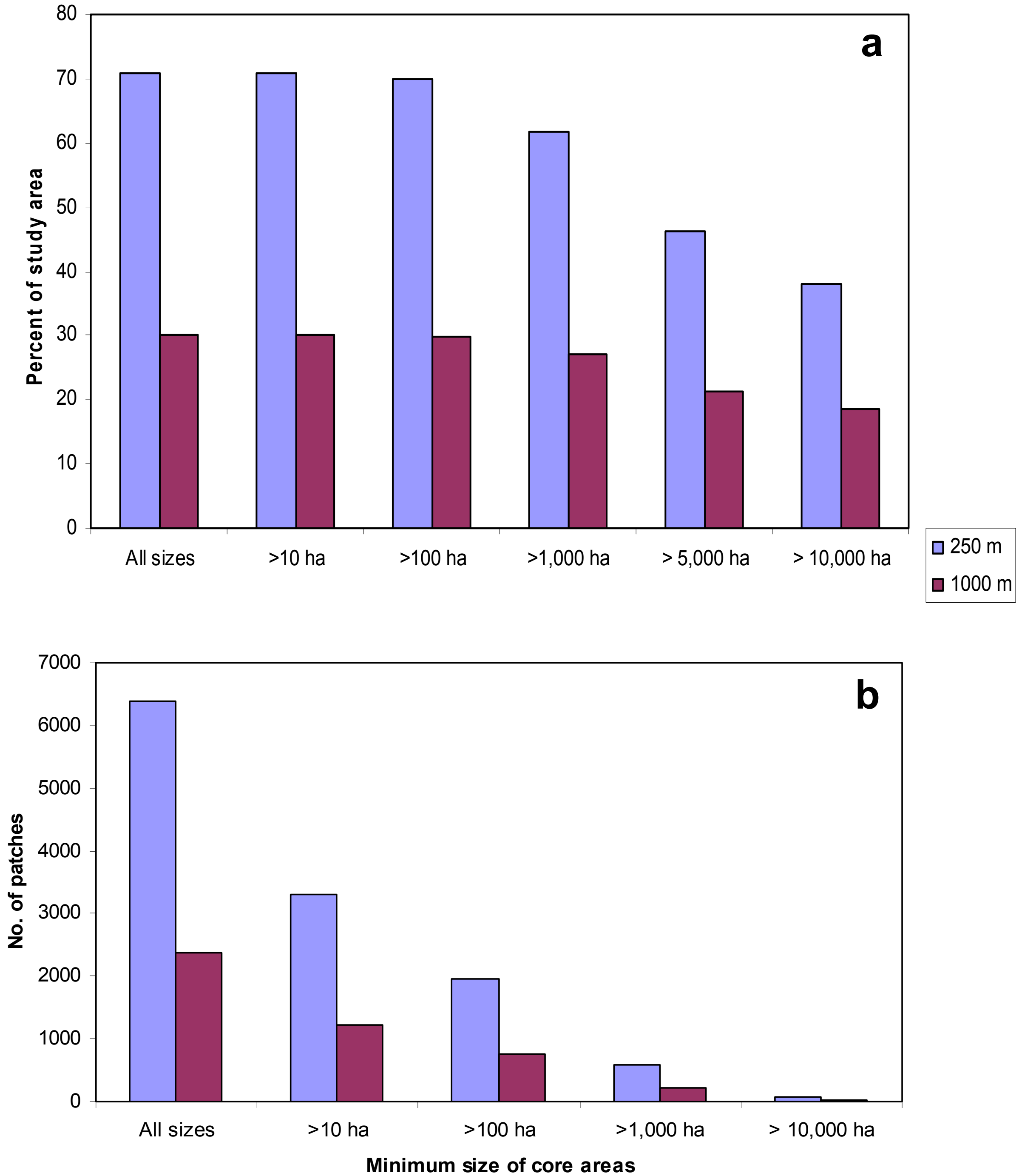

Figure 19. Core area based on two road-buffer sizes (250 m, 1000 m) for the overall study area: (a) percent of area and (b) number of patches.

Steps 6–7. Response Criteria and Links to Decision Making

Desired condition classes and targets can be based on the sage-grouse model results. For example, the six habitat-quality categories can be used as an index of habitat condition in each field office and for the study area as a whole. Habitat conditions without disturbance could be used as target conditions or baseline. The degree of departure from target condition due to disturbance could be used as a trigger for management actions (for example, road closures). Likewise, priorities for protection could be based on habitat quality and disturbance levels; for example, high-quality areas with relatively low-level disturbance might be targeted for more stringent guidelines for future energy development.

An existing program, the BLM Conservation Learning Network, is an example of steps 6 and 7. This cooperative effort between BLM and The Nature Conservancy has demonstrated success in creating a transparent process to develop response criteria for multiple priority species and habitats. This approach is useful for developing general conservation and management strategies and identifying restoration opportunities. The process is specifically designed to fit within established procedures used by BLM (for example, tied to resource management plans). The expected products from the learning network include indicators of condition, current condition ratings, desired condition ratings, impact analysis, management strategies, and a monitoring framework. These types of products were developed in a series of workshops between BLM and The Nature Conservancy.

Phase II: Collect Data to Address Priority Management Objectives Through Targeted Monitoring, Adaptive Management, and Research

Overview Phase II

A critical first step in Phase II is to refine management objectives based on information developed in Phase I. For each refined objective, management strategies and options will be created to establish a link between monitoring and management decisions. To guide the process of selecting appropriate management indicators, a set of hypotheses and predictions based on our current understanding of the system and its response to anthropogenic stressors will be developed. Existing monitoring programs that are a high priority and have met the design standards established in Phase I will be continued. Other monitoring programs may need to be updated to be consistent with standards established to achieve monitoring objectives. For management objectives with sufficient information to implement management actions (such as best management practices or lease stipulations), an adaptive management framework can often be an appropriate framework to link objectives to management decisions (figs. 20 and 21). In cases in which uncertainty is high and management options cannot be established, targeted research may be required to improve our understanding of the system. An essential component of adaptive management and research is to develop testable hypotheses and predictions based on the current understanding of the system, its anthropogenic stressors, and management options that are current or proposed.

Phase II will include traditional monitoring, adaptive management, and targeted research. The particular suite of activities will depend on the objectives, the types and quality of surveys, high priority information gaps, as well as funding constraints. Coordination among field offices and agencies in Phase III activities will be important to guide these activities, particularly in the initiation of new surveys and the standardization of existing surveys. This approach will increase the likelihood that monitoring data will provide useful information for management decisions.

The Role of Adaptive Management in Monitoring

Nichols and Williams (2006) highlight the key components of adaptive management and their relevance to monitoring, which are summarized below.

- Adaptive management is a sequential decision process that is especially useful when there is a high degree of uncertainty about the outcome of management actions.

- Management decisions are informed through a process that includes
  - developing management objectives;
  - identifying potential management actions;
  - developing or adapting models of system response to management actions;
  - measures of confidence in the models; and
  - monitoring data that provide estimates of system states.

- At each decision point, the appropriate management actions are evaluated for particular management objectives; the appropriate action is based on the estimated state of the system and the predicted responses of the system to management actions.

- Once the management action is implemented, monitoring is used to test the predictions of the model.

- This approach is iterative and implemented at each subsequent decision point, based on new estimates of system states and updated models.

Figure 20. Adaptive management overview.

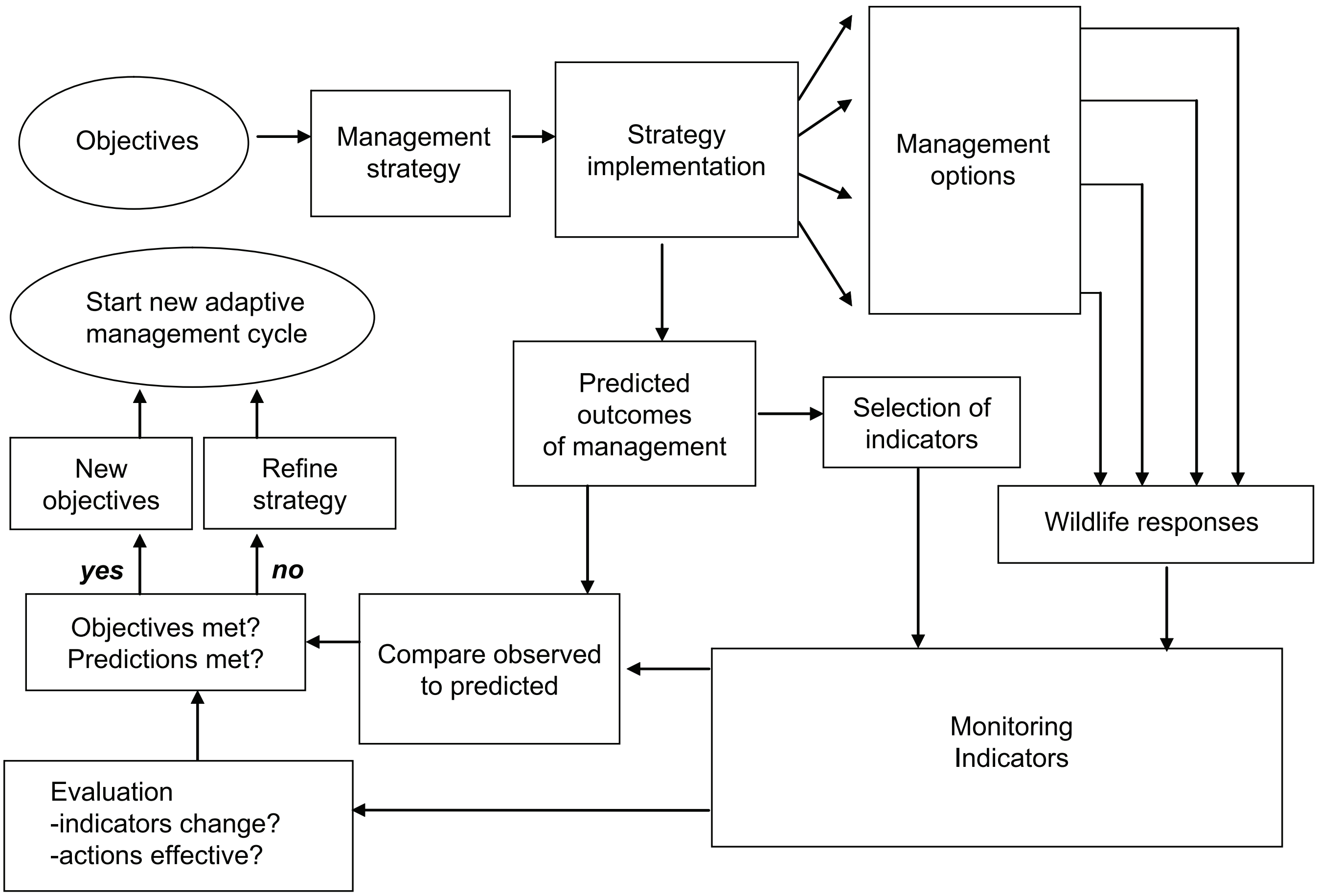

Figure 21. Adaptive management framework for monitoring outcome of management options and strategies (modified from Wilhere, 2002).

The refinement of objectives in Phase II is an iterative process and is based on the best available data and analyses, which are used to quantify the state of the system and the effects of management actions. Clearly defined objectives that are linked to management are critical to the design and implementation of an effective and successful monitoring program (Mulder and others, 1999). Indeed, the lack of well-defined objectives has been identified as a major cause of failure for past monitoring programs (Mulder and others, 1999). The refinement of management objectives and the *a priori* link to management options creates a structured process for informed decision making.

Phase II: Seven-Step Framework

Step 1. Refine Priorities and Management Objectives Developed in Phase I

Status assessments in Phase I will be used to refine priorities and objectives.

Step 2. Prioritize Stressors to Monitor and Identify Appropriate Scales of Assessment

Identification of stressors and appropriate assessment scales will be based on objectives and predictions to be tested.

Step 3. Validate and Refine Conceptual Models Developed in Phase I With New Data

Habitat models will be created or refined for priority species identified in Phase I that currently lack sufficiently accurate habitat models (see Zarnetske and others, 2007). New models may be added (for example, simulation models for vegetation change) to refine the evaluation of future energy development scenarios. Testable hypotheses and predictions linked to management actions will be developed.

Step 4. Select priority indicators

Indicators will be based on management objectives and expected outcomes of management actions, identified in steps 1 and 2. Performance measures for each management option can include biological goals, cost benefit analysis, and likelihood of successful outcome of management actions (Aldridge and others, 2004).

Step 5. Sampling Design and Analysis

This includes several components:

- Continue/expand focused monitoring. Existing monitoring programs that meet the criteria and objectives outlined in Phase I will be continued. Limited new monitoring may be initiated to meet Phase I criteria and address Phase III regional and national monitoring priorities. Careful evaluation of statistical power and other design issues relative to monitoring objectives is essential (see Thompson and others, 1998; Mulder and others, 1999; Balmford and others, 2003). To ensure that monitoring data can be used to meet objectives (such as sensitivity to detect trends), it is highly recommended that a statistician be consulted for this step.
- Forecast habitat and landscape effects. Future scenarios of energy development, based on short-term and long-term projections, will be used to forecast the cumulative effects of development on species and landscapes. Forecasting can be useful in refining management objectives and options and developing testable predictions.
- Implement an adaptive management framework for priority management objectives (fig. 21).
- Conduct targeted research on critical information priorities or to test key assumptions identified in Phase I.

Step 6. Establish and Integrate Management Targets, Thresholds, or Trigger Points

Refinement of condition classes relative to baseline or desired conditions of indicators is based on Phase I status and trends assessments. Modeling landscape conditions under proposed future development and for various management prescriptions can be used to develop landscape condition classes. These condition classes can then be used to develop management targets and triggers for management actions. This includes developing linkages between unacceptable condition classes and specific management goals or actions.

Step 7. Identify Opportunities to Integrate Assessments into Planning and Evaluation

Alternative management activities (including mitigation, setting restoration priorities, and proposed management actions) will be evaluated based on habitat and landscape models. These will be used for planning and evaluation activities, including Environmental Impact Statements, Resource Management Plans, and permitting activities.

Phase II Demonstration

For the Phase II demonstration, we continue with the sage-grouse example to illustrate how Phase I management objectives can be refined to develop an adaptive management framework corresponding to several Phase II activities. We also use landscape analysis of proposed travel management from the recent Resource Management Plan for the Roan Plateau to integrate several components of the adaptive management approach, which corresponds to step 7.

Step 1. Refine Priorities and Management Objectives Developed in Phase I

Although the BLM has identified broad goals in the Statement of Work for the focal monitoring plan and in initial meetings with BLM and other stakeholders, these goals need to be translated into more specific questions that can be evaluated using prospective monitoring data (Ringold and others, 2003). The refinement of specific management questions and policy goals can be achieved through structured and iterative interactions between scientists, BLM, and other participants (Ringold and others, 2003), and guided by conceptual models of ecosystem functions and stressors. For example, in Phase I it is appropriate to ask the broad question, "Are applied mitigation and best management practices (BMPs) for habitat and human disturbance related to energy development effective in the conservation of wildlife habitat…" (Falise and others, 2005), but in Phase II the question would need to be refined into a set of more specific questions in order to develop achievable monitoring objectives. Specifying BMPs (use native seed sources), wildlife habitat type (sage-grouse food and cover), and time scales (initial establishment of native plants versus trajectories of vegetation recovery following disturbance) exemplify the level of detail required to design effective monitoring programs (see table 3 for several examples of specific questions that have been identified in meetings and discussions with BLM staff; table 4 provides examples of BMPs related to energy development).

Table 3. Examples of hierarchical goals and monitoring questions identified by U.S. Bureau of Land Management (BLM) national, regional, and field offices staff. General statements can reflect goals and objectives across any BLM administrative level. Specific monitoring questions are necessary to develop effective monitoring programs. Levels 1–4 represent examples of general questions, whereas levels 5–6 are necessary for developing monitoring programs.

Level	Type of question	Statement
1	General	What are the stressors or agents of change that affect wildlife habitat?
2	General	How does energy development affect wildlife habitat?
3	General	What are the implications of landscape changes for migratory birds, BLM sensitive species, and species of management focus (for example, big game)?
4	General	How does fragmentation by roads affect movements of wildlife?
5	Specific monitoring	How does road presence and use inhibit dispersal of sage-grouse among seasonal habitats?
5	Specific monitoring	How does road presence and use inhibit mule deer movements between winter and severe winter habitats?
6	Specific monitoring	Are there critical corridors used during winter movements by mule deer that are at risk from roads planned for future energy development?

Table 4. Examples of monitoring needed for Best Management Practices related to energy development and wildlife management objectives.

Best Management Practice	Objective	Compliance indicators	Effectiveness indicators
Interim reclamation of well sites	Minimize habitat loss and fragmentation		Compare use of reclamation sites by priority species: (a) unreclaimed sites, (b) undisturbed (and/or pre-disturbed sites) (c) reclaimed sites meeting standards, (d) reclaimed sites not compliant with standards
	Re-establish native vegetation	Were native seed sources used? Were appropriate species planted? Were repeated disturbances reclaimed?	Monitor vegetation composition and cover through time: (a) in comparison to undisturbed (b) in comparison to natural disturbance (for example, post-fire)
Development planning	Minimize habitat loss and fragmentation, maximize the size of core areas, maximize the proportion of the planning area that is >500 m from roads	Have roads been established in correct positions (need spatial data from oil/gas companies)?	Are road closures effective? Is reclamation effective (see above)? Have core areas been increased or maintained (multi-scale analysis)?
Reduce vehicle traffic	Reduce vehicle traffic during critical wildlife use periods with seasonal road closures (public vehicles and operator vehicles)	Are seasonal road closures being observed by public and operators? Are speed limits being followed?	Are road closures effective? Is reclamation effective (see above)? How does wildlife use of areas differ before and after road closures (adaptive management?)

As an example of Phase II activities, we refined the following objectives identified by BLM field offices and outlined in Phase I:
(1) How do we evaluate the cumulative effects of energy development and mitigation activities on species of management interest or concern?
(2) How can cumulative effects be quantified relative to natural variation?
(3) How can we implement compliance and effectiveness monitoring to determine whether stipulations are met and restoration/mitigation goals are achieved?

The results of the modeling exercise in Phase I indicated that indirect habitat loss or degradation due to surface disturbance can greatly exceed direct losses of habitat. In addition, the patch size of high-quality habitat, as predicted by modeling exercises, decreased due to high densities of roads in the primary sage-grouse production areas. We use these results to refine our management objectives, develop testable hypotheses, and identify management options within an adaptive management framework.

Revised Management Objective

Maintain or increase existing populations of sage-grouse under the current and proposed rapid rates of energy development. Specifically, reduce the direct and indirect effects of road presence and use on greater sage-grouse.

Step 2. Prioritize Stressors to Monitor

The stressors to measure are road presence and use. Variables can include road type, timing of use, and vehicle type.

Step 3. Validate and Refine Conceptual Models

We provide two examples of activities that are included in step 3. The first is an adaptive management approach to evaluating the effects of roads on sage-grouse, and the second involves validation of sage-grouse disturbance models developed in Phase I.

Example 1: Adaptive Management Framework

We use the management objective (reducing effects of road presence and use) to develop testable hypotheses and predictions relating to surface disturbance in an adaptive management framework for the greater sage-grouse.

Hypothesis

Increased motor vehicle use leads to a decrease in habitat quality via direct mortality due to vehicle collisions, avoidance behavior (movement away from roads), increased predation, and habitat fragmentation.

Management Options

- Prioritize high-quality sage-grouse habitat based on habitat-disturbance models and Colorado Division of Wildlife production data (based on Phase I assessments).
- Define high-quality areas for protection and management.
- Reduce the indirect effects of surface disturbance on sage-grouse by closing and restoring roads in priority sage-grouse areas that have high densities of roads.
- Minimize creation of new roads in areas that currently have limited surface disturbance and are high-priority sage-grouse areas. Directional drilling (drilling multiple wells from a single well pad) and transportation planning can be used to minimize creation of roads.

Adaptive Management

To determine whether management options are effective in maintaining or increasing sage-grouse populations, indicators of sage-grouse populations (such as abundance, nestling survival, and recruitment) will be compared among the following treatments for areas identified as priority sage-grouse habitat (fig. 22):

- before and after road closures;
- before and after road closures and habitat restoration;
- before and after road restrictions (for example, seasonal closures and administrative use); and
- compare treatment areas to “control” areas wherein road densities are similar to pre-closure densities in the treatment areas and remain constant.

Research Topic

To better quantify the disturbance effects of roads on sage-grouse, indicators of sage-grouse population health (for example, survival and recruitment) will be compared across a gradient of road densities. A covariate might be vehicle use.

Example 2: Evaluate/Refine Models

The sage-grouse disturbance model used in Phase I was based on somewhat arbitrary distance categories and disturbance weightings. We evaluated the sensitivity of the model to the selection of disturbance weightings, particularly for the largest distance classes. In addition, we evaluated the two ways in which multiple disturbances were compounded (maximum versus additive). We conducted a sensitivity analysis by comparing the maps produced by several approaches (appendix B, figs. B2 and B3). Adaptive management and research could be used to test and refine the alternative disturbance models developed in Phase I (appendix B).

Step 4. Select Priority Indicators

Figure 22 shows possible monitoring indicators for the adaptive management example. In addition, covariates, such as vehicle use (to monitor road closure effectiveness) and vegetation composition and structure (to monitor restoration effectiveness), should also be measured to evaluate success of treatments. Additional models (such as state and transition model for vegetation dynamics; see appendix D for an example) may be helpful for selecting indicators to evaluate the success of restoration activities.

Step 5. Sampling Design and Analysis

There have been several recent papers on sampling design issues for monitoring sage-grouse (Connelly and others, 2003; Aldridge and others, 2004; Wambolt and others, 2006; Hagen and others, 2007). Developing standards can help to facilitate comparisons across studies and areas. Careful attention to sampling design and analysis (including the appropriate sampling scales, covariates, and power analysis) and the potential for replicating studies across field offices will be necessary to monitor greater sage-grouse adequately.

Step 6. Response Criteria

Models can be used to develop condition classes for greater sage-grouse habitat. For example, population and landscape models were used to develop condition classes for habitat quantity and quality for greater sage-grouse in the Interior Columbia Basin (Hemstrom and others, 2002; Wisdom, Rowland, and others, 2002; Wisdom, Wales, and others, 2002; fig. 23). Two submodels were used in this exercise. In the first submodel, habitat quantity and quality were used to predict habitat carrying capacity. The second submodel predicted habitat condition based on sagebrush area, habitat connectivity, and habitat carrying capacity. Model output was in the form of six condition classes relating to the distribution and

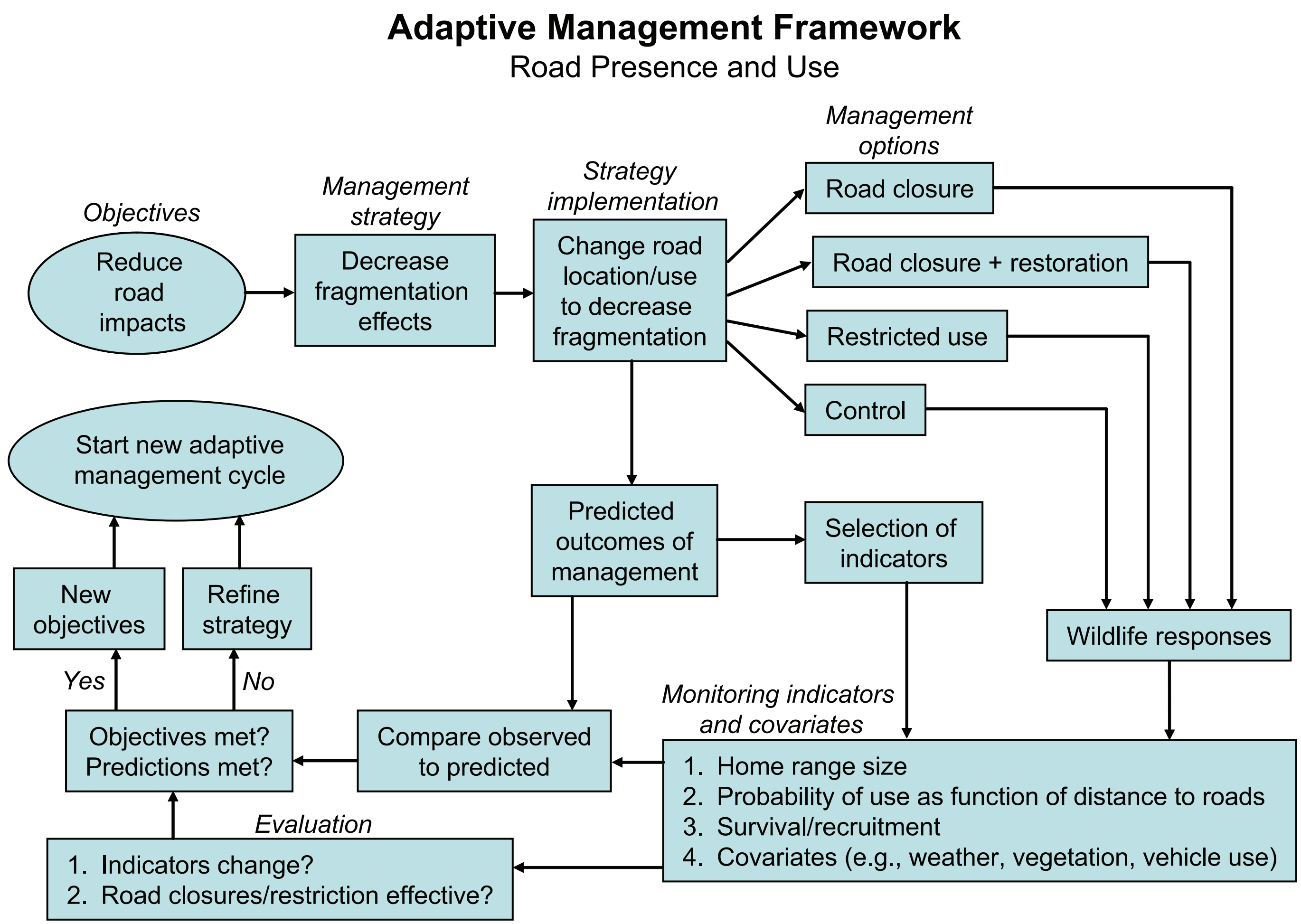

Figure 22. Adaptive management framework applied to wildlife management strategies to mitigate road presence and use.

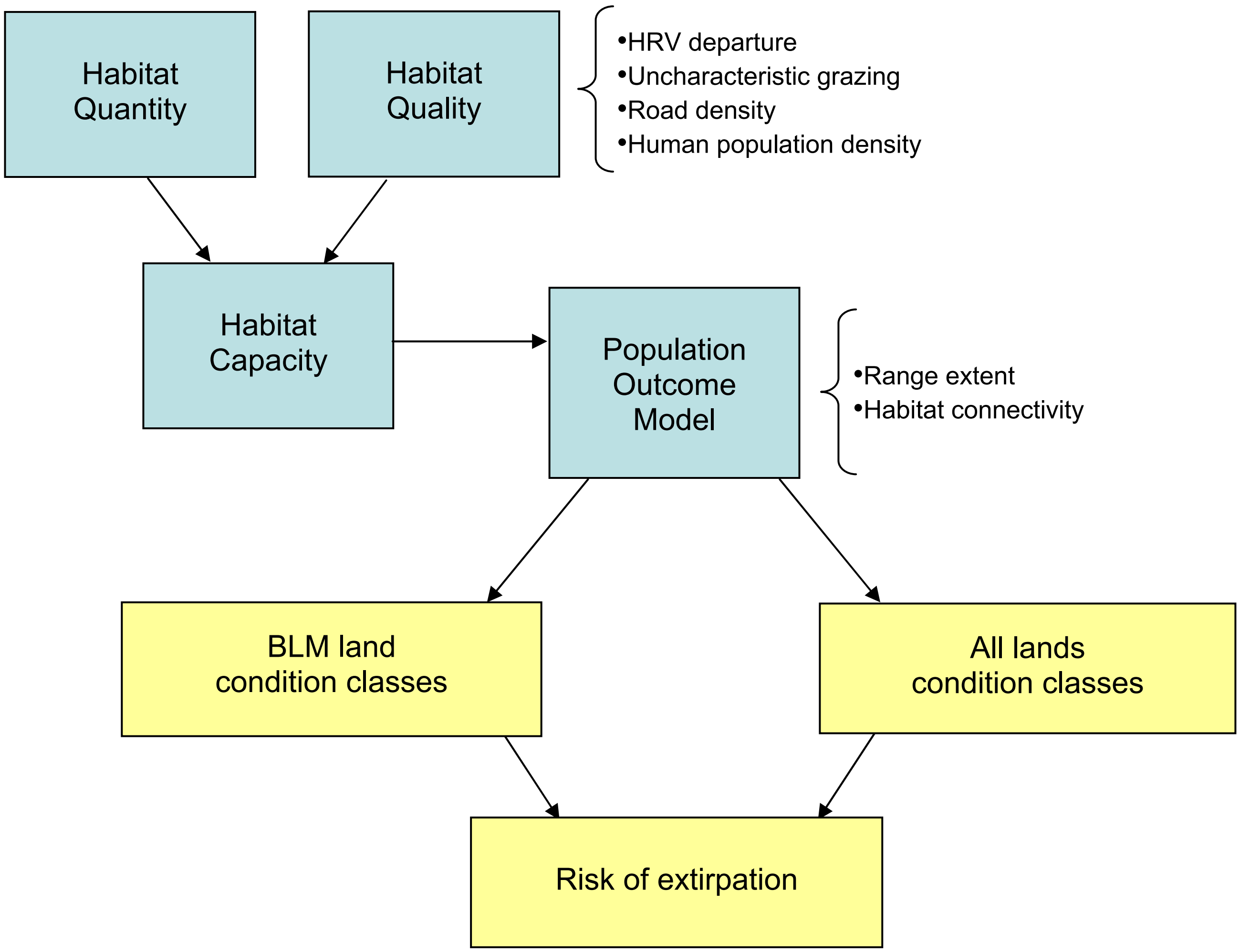

Figure 23. Overview of approach used to evaluate potential effects of restoration on greater sage-grouse in the Interior Columbia Basin (Wisdom, Rowland, and others, 2002). Blue boxes indicate the model components, which reflect habitat conditions (amount, quality, and spatial distribution). The model outcomes are condition classes for sage-grouse habitat on U.S. Bureau of Land Management lands compared to all lands, and overall risk of extirpation (yellow boxes). Condition classes for lands range from continuous, well-dispersed habitats to sparse, highly isolated habitats. Risk of extinction ranges from very low to very high. HRV refers to historic range of variation resulting from vegetation dynamics.

abundance of suitable habitats; conditions ranged from continuous and well distributed in the highest condition class to sparse and highly isolated in the lowest condition class. In addition, the model also predicted six classes relating to risk of regional extirpation. The model was used to evaluate current condition of BLM lands versus all lands for sage-grouse, and to project the effects of several management scenarios (for example, 50 percent reduction in grazing and post-fire restoration) 100 years into the future.

A different approach was developed by Aldridge and Boyce (2007), which identified critical nesting and brood-rearing habitat for greater sage-grouse. They predicted the relative probability of occurrence using spatial habitat models and the risk of nesting failure. The probabilities of occurrence and nest failure were used to identify habitats that are potential source (high probability of success) versus sink habitats (high probability of failure). The probabilities could be used for creating condition classes.

Once condition classes have been developed and projected effects have been evaluated, appropriate management actions (such as restoration and road closures) can be developed for each condition class. This approach can be implemented at multiple scales (including project, field office, and region).

Step 7. Identify Opportunities to Integrate Assessments into Planning and Evaluation

Example: Landscape Analysis

We also illustrate how modeling could be used to evaluate the fragmenting effects of roads for use in planning an adaptive management study. The adaptive management example provided above addressed both compliance and effectiveness monitoring related to mitigating the effects of roads. In this example, we illustrate how spatial analysis can be integrated into planning and evaluation for the Roan Plateau. Here, we use a coarse-filter approach by including all cover types, but this type of analysis is applicable to sage-grouse by focusing more specifically on sagebrush.

Management Objective

Reduce the fragmenting effects of roads on the Roan Plateau.

Hypothesis

Increased motor vehicle use leads to a decrease in habitat quality through habitat fragmentation and increased disturbance.

Management Options

Decrease fragmentation resulting from roads on the Roan Plateau by closing roads that contribute most to habitat fragmentation. Plan future roads associated with energy development so as to minimize fragmentation of large core areas.

Predicted Outcomes of Proposed Management Actions

To illustrate how spatial analysis may benefit in planning and management activities, we evaluated the consequences of the Proposed Management Plan developed for the upper plateau in the Roan Plateau Resource Management Plan and Environmental Impact Statement (EIS; U.S. Bureau of Land Managment, 2006). Because of the wildlife and wilderness values on the upper rim of the Roan Plateau, the recent management plan has been controversial, leading Senator Ken Salazar (D, Colo.) and Colorado Governor Bill Ritter to seek a 120-day delay for additional review (Hartman, 2007). One criticism of the plan is that it does not take into account the fragmenting effects of creating additional roads on the upper rim.

The proposed plan calls for phased energy development such that the maximum surface disturbance will not exceed 350 acres at any one time (appendix E, table E1). Because only 75 acres will be impacted by well pads on the upper rim, the predominant ecological effects are expected to result from road creation and disturbance; in other words, the 75-acre disturbance footprint is proportionally small (<1 percent of the total area of the upper rim). Currently, 157 miles of roads exist on the upper plateau. The plan also proposes to close and reclaim 19 miles of existing roads and to restrict use (such as, administrative use only) on an additional 68 miles (appendix E, table E1; fig. 24). We conducted an analysis of roadless areas under current and proposed conditions to evaluate the effects of existing roads and proposed road closures on habitat fragmentation. At current road densities, disturbance within 500 m of roads potentially affects most areas of the upper plateau (fig. 25a).

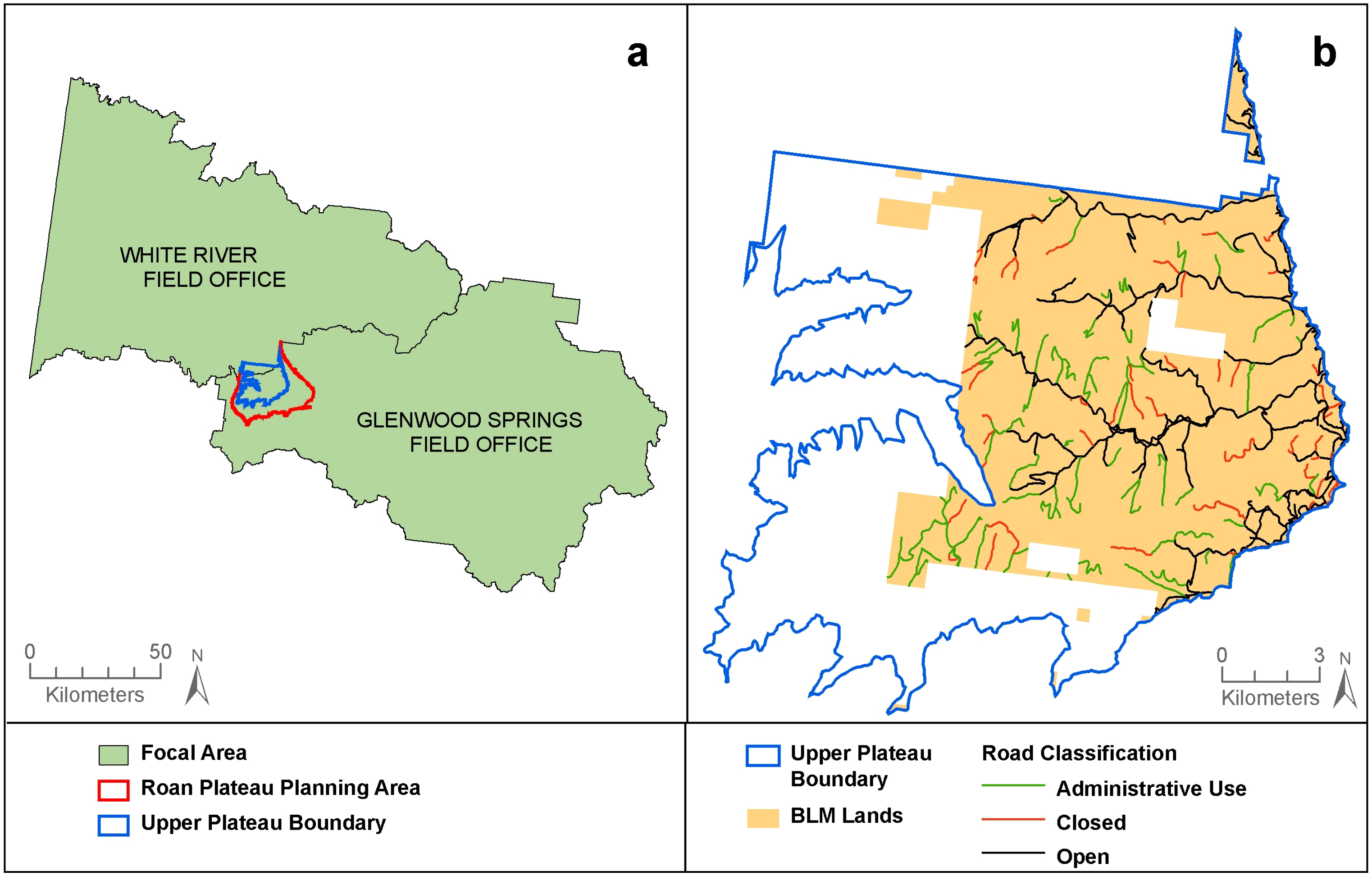

Figure 24. Maps of the Roan Plateau Planning Area showing (a) boundaries of the upper plateau in relation to the focal area and (b) proposed road closures/restrictions on U.S. Bureau of Land Management lands under the Roan Plateau Resource Management Plan.

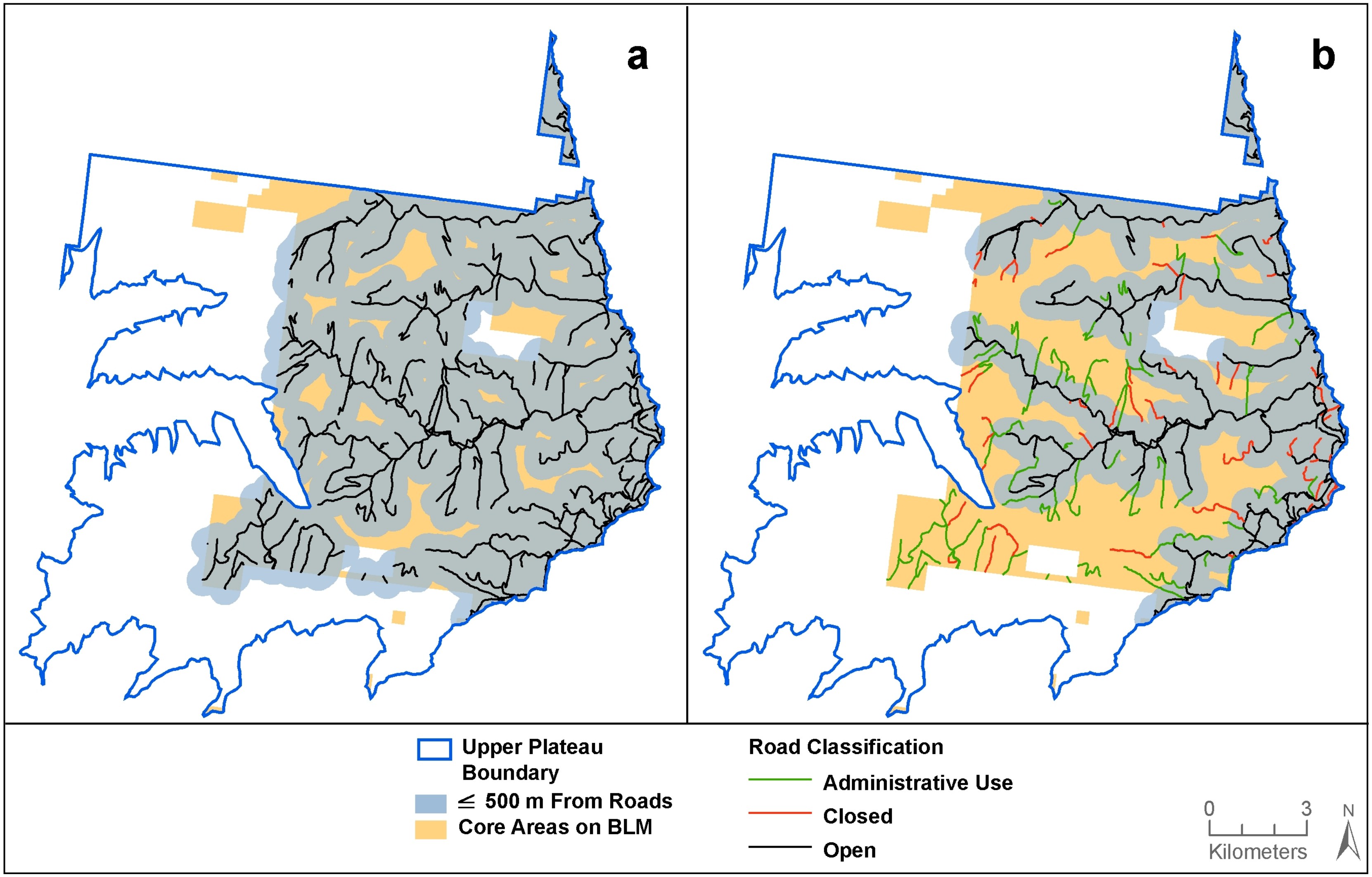

Figure 25. Core area analysis for the upper Roan Plateau based on (a) existing roads and (b) proposed road closures/restrictions under the Resource Management Plan.

The comparison of current and proposed road densities indicates that strategic road closures can minimize the effects of road disturbance in currently fragmented patches, and thereby offset the disturbance effects of new roads. Both restricted access (such as, administrative use only) and full closure increased the size and total acreage of core areas; collectively the restrictions and closures will increase total core area on the upper plateau by 31 percent (figs. 25 and 26). The spatial analysis on the upper Roan Plateau demonstrates how spatial analysis could be used to evaluate the benefits of road closures in the EIS. Spatial analysis also can be used to prioritize areas for new road development that minimize reductions in the size of core areas.

This analysis was based on the assumption that restoration activities will remove or greatly reduce the fragmenting effects of roads related to disturbance. Although complete road closure will reduce or remove human disturbance, restoration of vegetation communities needs to be monitored over time to ensure that vegetation succession continues over time frames longer than 1–5 years (for example, compliance and effectiveness monitoring). The predicted effects of the road closures could be used to guide an adaptive management study to evaluate the effects of this management plan (fig. 22).

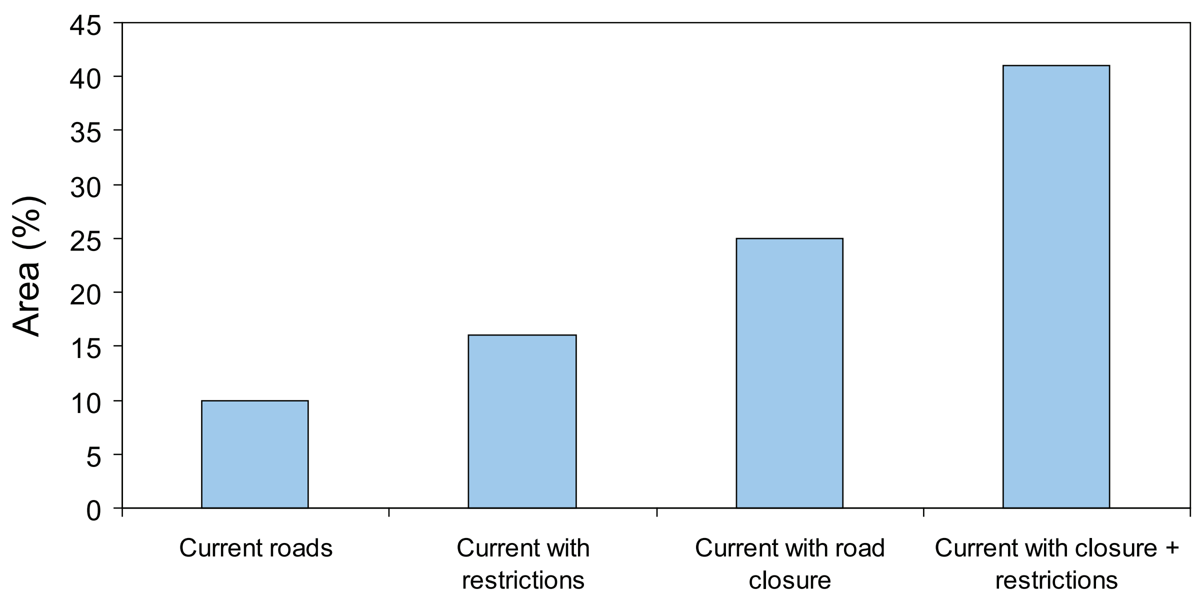

Figure 26. Core area analysis for current roads and proposed restrictions or road closures on the upper Roan Plateau. Area represents percent of the upper Roan Plateau that is greater than 500 m from roads. Road restrictions allow administrative use only.

Phase III: Coordination and Integration of Regional, National, and Interagency Monitoring Strategies

Overview Phase III

Effective monitoring requires information across a range of spatial and temporal scales. Broad-scale monitoring provides a context to (1) identify monitoring priorities that can address local needs, (2) prioritize species for management actions, and (3) identify management issues that may be less evident at local scales (U.S. North American Bird Conservation Initiative Monitoring Subcommittee, 2007). Establishment of standards and protocols for monitoring and coordination of monitoring among agencies, organizations, and initiatives can improve the effectiveness and efficiency of monitoring (U.S. North American Bird Conservation Initiative Monitoring Subcommittee, 2007).

By identifying common monitoring objectives and identifying opportunities to standardize and collaborate on data collection, Phase III will contribute to regional, national, and continental conservation of critical natural resources. This collaboration and coordination will help to ensure that data can be exchanged readily and will facilitate analysis across scales. Analysis at multiple scales will guide regional planning and provide a context for management decisions at smaller scales. Although most monitoring will be conducted at the local scale for the purpose of directing field office decisions and evaluations, it is also important to evaluate how efforts at a field office contribute toward conservation of species and systems at larger spatial scales. A national monitoring team—comprising statisticians and scientists, national, State, and field office representatives, and liaisons with other agencies—is necessary to guide this phase.

Phase III: Seven-Step Framework

Step 1. Specify Priority Regional, National, and Interagency Goals

As a part of this activity, identifying field offices with similar ecological and resource management issues will improve the efficiency and effectiveness of the national monitoring programs. The NPS Vital Signs Monitoring Program can provide considerable guidance in this endeavor because it entails a well-documented process (available online) based on considerable input from broad scientific and management communities with diverse backgrounds. In addition, use of the NPS template provides cross-referenced goals and indicators that will facilitate integration among Department of Interior bureaus. Because the NPS approach also follows the seven-step framework of Mulder and others (1999), it meets the objectives of BLM (appendix A, fig. A1).

Steps 2–3. Use Conceptual Models and Stressors Identified in Phases I and II

Priority stressors will be identified at regional and national levels.

Step 4. Select Indicators

A core set of priority indicators will be established based on regional and national information needs. This will help to ensure that information can be scaled-up from the local level to higher administrative levels. Priority indicators or information needs shared with other agencies will be identified. Other interagency monitoring coordination and strategies have been developed (see U.S. North American Bird Conservation Initiative Monitoring Subcommittee, 2007), which can be used to guide the development of national and regional standards for wildlife monitoring. Indeed, many monitoring frameworks were intended to be used as a template by other federal agencies (Manley and others, 2004; O'Dell and others, 2005).

Step 5. Establish a Sampling Design

The development of standards and protocols for a core set of regional and national priority indicators will be developed. In addition, standards for designing and managing databases will be developed to facilitate assessments and evaluations across field offices and regions as well as nationally.

Step 6. Define Response Criteria Relative to Regional and National Objectives

Models used in Phase II for developing condition classes also can be applied at larger scales.

Step 7. Link to Decision Making

Opportunities to better integrate monitoring information into regional and national planning and management decisions will be defined and guidelines developed (fig. 27).

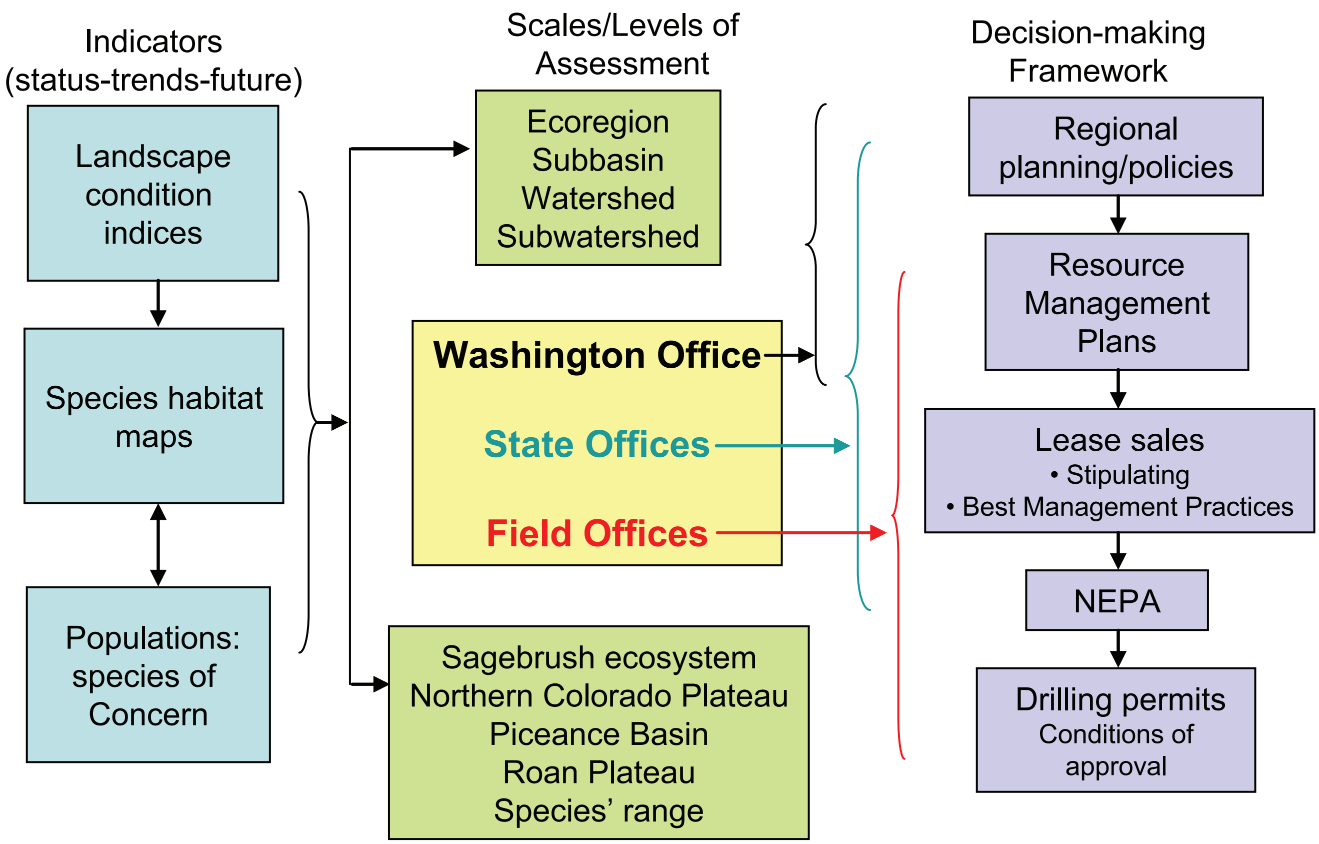

Figure 27. Overview of monitoring plan relationship to decision-making framework related to energy development. Indicators (blue boxes) are evaluated at several temporal scales (current status, trends, and future) and spatial scales (green boxes) for reporting/analysis at various administrative levels (yellow box) and the relationship to decision-making framework related to energy development (purple boxes). Nested spatial scales of analysis (upper green box) or focal scales of analysis (lower green box) illustrate alternative scales of evaluation that can be addressed by this framework. National Environmental Policy Act (NEPA) activities include preparation of Environmental Impact Statements.

Phase III will be informed by Phase I status assessments. Phase II activities also will provide information to Phase III. However, standards, protocols, and priorities developed in Phase III are necessary for expanding monitoring in Phase II. Our purpose in initiating Phase II prior to Phase III is to allow for continuation and initiation of high-priority and focused monitoring and research. This allows information to be collected while Phase III is underway so that monitoring/research will not be delayed by the longer process involved with implementing Phase III. However, we caution against greatly expanding Phase II for a set of high priority objectives until Phase III activities for those objectives have been completed.

Phase III Demonstration

Here we report on BLM's national sage-grouse habitat conservation strategy (U.S. Bureau of Land Management, 2004) as an example of Phase III activities.

Example: Sage-Grouse

BLM's national sage-grouse habitat conservation strategy (U.S. Bureau of Land Management, 2004) provides an example of Phase III coordination of management and monitoring. The purpose of the strategy is to provide comprehensive guidance on managing, restoring, and enhancing sagebrush habitat on public lands administered by the BLM. It was designed to support and promote the range-wide conservation of sagebrush habitats for sage-grouse and other sagebrush-obligate species. The national strategy complements conservation planning for sage-grouse at the State level, and is designed to help integrate local, State, and national efforts into BLM programs. The overall guidance can be modified as needed to achieve local or regional objectives or ongoing collaborative efforts. The major goals of the conservation strategy are to

- improve the effectiveness of the management framework for addressing conservation needs of sage-grouse on lands administered by the BLM;
- increase understanding of resource conditions to prioritize habitat maintenance and restoration;
- expand partnerships, available research, and information that support effective management of sage-grouse habitat; and
- ensure leadership and resources are adequate to continue ongoing conservation efforts and implement national- and State-level sage-grouse habitat-conservation strategies and plans.

For each goal, several strategies were developed. Each strategy outlined actions, responsibilities, and deadlines. To provide specific examples of Phase III activities, we organized some of the strategies into the seven-step framework.

Step 1. Specify Priority Regional, National, and Interagency Goals

The four overall goals listed above form the umbrella for other specific goals or strategies. Some examples include those listed below.

- Develop the management framework for addressing conservation of sage-grouse on lands administered by the BLM.
- Policies and program direction will be coordinated at the national and BLM State and field office levels.
- Research needs will be identified, prioritized, and facilitated to develop relevant information for sage-grouse and sagebrush habitat conservation in coordination with the Western Association of Fish and Wildlife Agencies.

Steps 2–3. Use Conceptual Models and Stressors Identified in Phases I and II

Knowledge of resource conditions and priorities will be improved to support efforts aimed at maintaining or restoring habitats. This includes completing and maintaining region- and range-wide assessments, and State-level mapping of sage-grouse habitats and disturbance regimes, which corresponds to coordination and support of Phase I activities.

Step 4. Select Indicators

The strategy emphasis is on mapping sagebrush ecosystems and sage-grouse habitat as indicators of sage-grouse populations.

Step 5. Establish a Sampling Design

A database that describes and tracks conservation efforts in sagebrush habitats will be developed and maintained. Standardized and scientifically based methods for data collection and use relevant to sagebrush systems will be developed. Collection, transfer, and information sharing among all BLM partners and cooperators will be facilitated.

Step 6. Define Response Criteria Relative to Regional and National Objectives

Although response criteria were not explicitly stated as a goal, strategies to address this issue include

- providing guidance to ensure that sage-grouse habitat conservation measures are integrated with the management and land use planning process; and
- establishing mandatory guidelines for managing sagebrush habitat for sage-grouse conservation.

Step 7. Link to Decision Making

Strategies that address this step include

- ensuring that leadership and resources are adequate for implementing national- and State-level sage-grouse and sagebrush habitat-conservation strategies and plans; and
- revising or developing fire management plans for each State to include sage-grouse habitat-management guidance.

Summary

The demonstration project focused on one species, but included landscape-level analyses that also could benefit multiple species. It is important to keep in mind, however, that the greater sage-grouse cannot represent all species or habitat conditions necessary for a functioning ecosystem (Rowland, Wisdom, and others, 2006). Ideally, a monitoring program would include a suite of species and cover types to monitor, as well as other natural resources. Because there can be conflicting needs among species and multiple uses, inevitably there will be trade-offs to evaluate. Models can help evaluate the consequences of management decisions among the conflicting needs of species, resources, and multiple users of BLM lands.

The three-phase monitoring plan is designed to be a flexible framework for developing monitoring programs by BLM. To establish a clear link between monitoring and management decisions, we emphasize setting clear objectives that are tied to management strategies and predicted outcomes. It is intended to be an iterative process, beginning with a core set of monitoring priorities and expanding incrementally with experience and funding opportunities. This approach will help to avoid timely delays and costly mistakes that could result from creating monitoring programs that are initially too complex or comprehensive.

To facilitate the adoption of the monitoring plan into existing BLM operating procedures, the plan incorporates many aspects of successful BLM programs. This includes the Wyoming and Great Basin assessments, the sage-grouse habitat-conservation strategy, and the BLM Learning Network. For each phase, the set of activities can be implemented independently to create tools and products that can improve BLM evaluation and planning. The phases are intended to be complementary, and information developed in each phase is essential to guide the priorities and activities of other phases.

The first step is to summarize the available information to immediately improve ecological evaluations of energy development. In addition, information from Phase I is necessary for Phases II and III. In some cases, Phase III may be underway and may occur concurrently with Phases I and II. However, monitoring or research that addresses an urgent information need may be refined or initiated prior to the full development of regional or national priorities and standards.

To provide a comparison of the phases, we summarize the monitoring issues addressed, the expected products, and the staffing levels needed for each phase.

Phase I

Monitoring Issues Addressed

A major difference between the emphasis of other national monitoring programs and Phase I activities is our initial focus on spatially explicit habitat modeling using GIS. This approach will allow evaluation of cumulative and indirect effects beyond individual project areas that may result from surface disturbances. Phase I is modeled after the process developed for the Wyoming Basin assessment (Rowland, Leu, and others, 2006). Additionally, the use and creation of metadata for existing surveys (including some legacy data) will allow better documentation and transparency of the information used for management decisions. Using habitat models will allow better assessment of status and trends for species that are currently monitored and to add assessments of high-priority focal species that lack adequate survey data. For low-priority species and species for which suitable habitat models are lacking, coarse-level assessments (based on cover types or landscapes) may be used for status assessments. The GIS capabilities and linkage of indicators to Land Health Standards will allow assessment at multiple spatial scales and across administrative levels to provide improved opportunities for integration of information among field offices.

Expected Products

In addition to status assessments for priority species and systems, Phase I will provide metadata for priority data sets, conceptual models, habitat and surface disturbance maps, summaries of the direct and indirect effects of land use change (for example, energy development), indicators of landscape-level effects, identification of key information gaps and assumptions, priority survey and research needs, and initial management objectives and targets.

Staffing/Funding Needs

Because this phase relies primarily on existing data and models, funding will be used primarily for short-term modeling/assessment projects. Contracting with other government and nongovernmental organizations that have relevant expertise in such analyses (including USGS, academic institutions, The Nature Conservancy/Natural Heritage Programs, and Rocky Mountain Bird Observatory) may be a cost-effective way to achieve many Phase I activities. Ongoing staffing and funding will be necessary for maintaining and updating databases, analysis and dissemination of data, and conducting periodic updates of status and trends. Training on the use of assessment tools will be necessary at all administrative levels of BLM. Previous ecological assessments by BLM and USFS, and extensive literature reviews and conceptual model development by the NPS monitoring program, are available.

Consequently, there is a large body of information that can be used in Phase I of this project, thereby increasing program efficiency by capitalizing on the groundwork established by NPS and USGS scientists involved in the NPS monitoring program.

Phase II

Monitoring Issues Addressed

A key focus of Phase II is refining management and monitoring questions, objectives, and predictions based on the results of Phase I assessments; this step is critical in linking monitoring to the decision-making framework. Standards and protocols for data collection, management, and analysis developed in Phase I will be implemented for all data collection performed in Phase II. Identifying priority monitoring needs and improving statistical design of monitoring data can help to identify poorly designed or low-priority monitoring that can be eliminated, thereby increasing the efficiency of monitoring efforts.

Expected Products

Data and data summary capabilities will be maintained in an accessible database format for new and existing surveys. Analysis of monitoring and research tied to management objectives, strategies, and options will provide results in a format that can inform decision-making and planning activities. At identified time intervals, assessment of status and trends will be completed for priority species, habitats, and stressors.

Staffing/Funding Needs

Funding for additional short-term projects and assessments and longer-term funding for new surveys will be needed. Funds required for new monitoring can be redirected from low-priority or poorly designed monitoring. Staffing levels are similar to those for Phase I if contracts are employed to fund cooperators with the expertise necessary for developing and implementing adaptive monitoring and research, thereby minimizing the need for additional staff.

Phase III

Monitoring Issues Addressed

Regional, national, and interagency coordination will be emphasized in this phase. In some cases, existing national frameworks that support Phase III activities may be in place prior to the initiation of Phase I and Phase II activities; thus, Phase III activities can occur prior to Phase I, but ideally coordination will be ongoing based on new information acquired and lessons learned in Phase I and Phase II.

Phase III will provide linkages to regional and national monitoring programs by incorporating priorities outside of the focal field offices. Collaboration between BLM, FWS, and NPS in developing monitoring protocols will facilitate Department of Interior assessments and management across bureau jurisdictions and increase data quality by increasing sample sizes, expanding the level of inference, and facilitating cross-jurisdictional assessments and management strategies. Although it is expected that BLM will focus primarily on prospective monitoring, there may be opportunities to cooperate with ongoing national retrospective monitoring that addresses BLM information needs. Additional opportunities for coordinated adaptive monitoring and adaptive management (providing feedback into monitoring and management activities) will be identified, particularly at the regional level.

Expected Products

Phase III will produce an integrated monitoring program that addresses priority objectives shared by BLM, Department of Interior, and other agencies and organizations. It will be focused, coordinated, and scientifically valid to facilitate analysis at regional and higher levels. For example, compliance and effectiveness monitoring protocols and standards (a high priority in the focal area) can be implemented across BLM administrative levels, thereby facilitating evaluation beyond a particular field office. The GIS models and analytic capabilities, particularly when applied to regional (for example, Southwest Regional GAP; http://ftp.nr.usu.edu/swgap/swregap_landcover_report.pdf) or national (for example, LANDFIRE and NLCD) vegetation maps, also will allow assessments across administrative (field offices, state offices, and nationally) or ecological (such as, watersheds and ecoregions) levels (fig. 27).

Staffing/Funding Needs

Coordinators for program development and integration within regional and national BLM programs, status assessments, and evaluations will be necessary, especially beyond the field office level. National and regional monitoring teams will be required. The NPS program can provide guidance on the types of expertise and the administrative levels needed on the team (see O'Dell and others, 2005).

BLM Objectives for the Development of the Monitoring Plan

Below we summarize how the Colorado monitoring plan addresses the five objectives of the BLM steering committee.

Develop a generally applicable methodology for BLM regional monitoring programs using the seven-step process outlined above.

Although the three-phase monitoring plan was developed relative to specific local field office objectives, it was designed to be flexible and more generally compatible with the mandates and protocols that guide BLM activities. The three-phase approach draws from successful BLM programs (Wyoming Basin Assessment and National Sage-Grouse Habitat Conservation Strategy) and existing or developing monitoring programs (FWS, NPS, and USFS) to create an iterative framework that guides the process of program development. The monitoring plan is intended to be implemented incrementally, beginning with the highest priority species and management issues and building on the lessons learned, coordination among administrative levels, and available funding. It can be applied at the field office or regional level, but regardless of which level it is applied to, it has ties to larger scales including the national level in Phase III. Although developed for monitoring wildlife in relation to energy development, it can be applied to other wildlife management issues and across disciplines.

Implement methodology to produce a report that prototypes a specific BLM regional monitoring program for the White River and Glenwood Springs Field Offices.

The demonstration project illustrates the types of activities involved with each phase for priority species and management issues related to energy development. We chose greater sage-grouse and analysis of landscape pattern to highlight the types of activities that could be used to improve the current assessment process using the three-phase approach. We also demonstrated how it could be useful in planning documents such as the Roan Plateau Resource Management Plan. The examples are explicitly tied to specific management objectives and options due to the importance of this linkage in the successful implementation of a monitoring program. We also highlight modeling activities and the spatial analysis of available data, which are currently under used in planning and assessments, to improve evaluations of the direct and indirect effects of energy development. By applying the monitoring plan to the focal BLM field offices, we provide concrete examples of how the proposed plan can be implemented.

Provide BLM with feedback and recommendations based on the experience of developing the methodology and applying it to a specific region.

One of the most challenging issues is to clearly articulate the ways in which the monitoring program will be used by BLM. Clear guidance, however, is critical to the design and success of a monitoring program. In addition, communication and input from all levels of the BLM is necessary so that the process has input from both BLM administration and field offices. This will help ensure that the plan meets local, regional, and national information needs and will be accepted and used at all administrative levels. To this end, a development team ideally will include representation from all levels of BLM. The process of developing a sound monitoring program is not trivial, and its successful development will require the input and expertise of BLM and other partners.

The use of legacy data presents significant challenges because in many cases there is a lack of standardization, established protocols, valid statistical design, and data management procedures. A data management system that provides standards and guidelines for quality control, metadata, data accessibility, and facilitates analysis across administrative levels is necessary for both legacy and new monitoring data.

Existing staff and training may not be adequate to rapidly implement this program due to the current high work loads of field office staff. Cooperative partnerships with agencies that have developed considerable expertise in planning and implementing monitoring programs (including the USGS and The Nature Conservancy) will allow BLM to capitalize on the experience of other agencies in developing such programs, without the need for a significant increase in staff, extensive training, or redirection of responsibilities.

Develop recommendations that will aid BLM in selecting indicators and adopting appropriate thresholds for management response.

The existence of nonlinear thresholds at which systems rapidly change from one state to another has been discussed frequently but is poorly documented. In many cases, we lack the information to detect thresholds, or a given system may simply change in a gradual fashion. Without a better understanding of ecological thresholds, it may be better to evaluate condition classes for the systems and species of concern. The condition classes can be developed from the best available information, which in many cases may be based on expert opinion or derived from models. Management targets can be created from the combined input of scientific expertise and stakeholder objectives. The condition classes should be updated regularly based on monitoring information, adaptive management, and research. In particular, improved understanding of the effects of landscape condition on species of concern is an important monitoring objective.

Recommend how the product can be integrated within the land use planning process.

We have illustrated several examples of how the activities of each phase can be used in the land planning process. For example, in Phase I, comparisons among field offices within a larger region can be used to evaluate and prioritize management activities within field offices. In Phase II, spatial modeling of surface disturbance for proposed energy development activities on the Roan Plateau can help to determine guidelines for prioritizing road closures and road creation to minimize fragmentation. In Phase III, national strategies for managing greater sage-grouse can provide proactive guidelines to field offices for monitoring standards and BMPs for energy development that minimize or reverse habitat loss.

To ensure that monitoring information is linked to the land use planning process, integration is best established during the development of monitoring objectives. The importance of this linkage led us to focus on refining monitoring objectives and *a priori* connections to management options in Phase II. The first step in each phase involves developing clear monitoring objectives and identifying how the information will be used. Phase I objectives will be primarily local but informed by regional or national objectives, whereas Phase III objectives will be primarily regional or national, but informed by local priorities. Planning activities at local, regional, and national levels will benefit from regional and national assessments.

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References Cited

Aldridge, C.L., and Boyce, M.S., 2007, Linking occurrence and fitness to persistence—A habitat-based approach for greater sage-grouse: Ecological Applications, v. 117, p. 508–526.

Aldridge, C.L., Boyce, M.S., and Baydack, R.K., 2004, Adaptive management of prairie grouse—How do we get there?: Wildlife Society Bulletin, v. 32, p. 92–103.

Baker, W.L., 2006, Fire and the restoration of sagebrush ecosystems: Wildlife Society Bulletin, v. 34, p. 177–185.

Balmford A., Green, R.E., and Jenkins, M., 2003, Measuring the changing state of nature: Trends in Ecology and Evolution, v. 18, p. 326–330.

Busch, D.E., and Trexler, J.C., 2003, Monitoring ecosystems—Interdisciplinary approaches for evaluating ecoregional initiatives: Washington, D.C., Island Press, 447 p.

Connelly, J.W., Reese, K.P., Schroeder, M.A., 2003, Monitoring of greater sage-grouse habitats and populations: Moscow, Idaho, University of Idaho College of Natural Resources Experiment Station Bulletin 80.

Connelly, J.W., Knick, S.T., Schroeder, M.A., and Stiver, S.J., 2004, Conservation assessment of greater sage-grouse and sagebrush: Cheyenne, Wyo., Western Association of Fish and Wildlife Agencies, unpublished report, 13 chapters plus 6 appendices.

Falise, R., Durtshe, B., Spencer, D., Rinkes, T., Payne, J., Belinda, S., and Claerbout, A., 2005, Progress report for the regional energy monitoring strategy for wildlife: Lakewood, Colorado, U.S. Bureau of Land Management, unpublished report, 12 p.

Hagen, C.A., Connelly, J.W., and Schroeder, M.A., 2007, A meta-analysis of greater sage-grouse *Centrocercus urophasianus* nesting and brood-rearing habitats: Wildlife Biology, v. 13, Suppl. 1, p. 42–50.

Hartman, T., 2007, Salazar wins delay in Roan Plateau plan: Denver, Colo., Rocky Mountain News, August 4, 2007, http://www.rockymountainnews.com/drmn/local/article/0,1299,DRMN_15_5658962,00.html.

Hemstrom, M.A., Wisdom, M.J., Hann, W.J., Rowland, M.M., Wales, B.C., and Gravenmier, R.A., 2002, Sagebrush-steppe vegetation dynamics and restoration potential in the Interior Columbia Basin, U.S.A.: Conservation Biology, v. 16, p. 1,243–1,255.

Knutson, M., Laskowski, H., Lor, S., and Sutherland, T., 2005, Strategic plan for the National Wildlife Refuge System Biological Monitoring Team Pilot Project, fiscal years 2006-2010: La Crosse, Wisc., U.S. Fish and Wildlife Service, Biological Monitoring Team, 16 p. plus 2 appendices.

Manley, P.N., Zielinksi, W.J., Schlesinger, M.D., and Mori, S.R., 2004, Evaluation of a multiple-species approach to monitoring species at the ecoregional scale: Ecological Applications, v. 14, p. 296–310.

Miller, M.E., 2005, The structure and functioning of dryland ecosystems—Conceptual models to inform long-term ecological monitoring: U.S. Geological Survey Scientific Investigations Report 2005–5197, 64 p. plus 3 appendices, http://pubs.usgs.gov/sir/2005/5197.

Mulder, B.S., Noon, B.R., Spies, T.A., Raphael, M.G., Palmer, C.J., Olsen, A.R., Reeves, G.H., and Welsh, H.H., 1999, The strategy and design of the effectiveness monitoring for the Northwest Forest Plan: Portland, Oreg., U.S. Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-437, 114 p. plus 5 appendices.

Nichols, J.D., and Williams, B.K., 2006, Monitoring for conservation: Trends in Ecology and Evolution, v. 21, p. 668–673.

Noon, B.R., 2003, Conceptual issues in monitoring ecological resources, *in* Busch, D.E., and Trexler, J.C., eds., Monitoring ecosystems—Interdisciplinary approaches for evaluating ecoregional initiatives: Washington, D.C., Island Press, p. 27–71.

O'Dell, T., Garman, S., Evenden, A., Beer, M., Nance, E., Perry, D., DenBleyker, R., and others, 2005, Northern Colorado plateau inventory and monitoring network, vital signs monitoring plan: Moab, Utah, National Park Service, Inventory and Monitoring Network, http://science.nature.nps.gov/im/monitor/plans/NCPN_MonitoringPlan.pdf.

Ringold, P.L., Mulder, B.S., Alegria, J., Czaplewski, R.L., Tolle, T., and Burnett, K., 2003, Design of an ecological monitoring strategy for the forest plan in the Pacific Northwest, *in* Busch, D.E., and Trexler, J.C., eds., Monitoring ecosystems—Interdisciplinary approaches for evaluating ecoregional initiatives: Washington, D.C., Island Press, p 73–99.

Rollins, M.G., and Frame, C.K., 2006, The LANDFIRE prototype project—Nationally consistent and locally relevant geospatial data for wildland fire management: Fort Collins, Colo., U.S. Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-175.

Rowland, M.M., Leu, M., Hanser, S., Finn, S.P., Aldridge, C.L., Knick, S.T., Suring, L.H., Boyd, J.M., Wisdom, M.J., and Meinke, C.W., 2006, Assessment of threats to sagebrush in the Wyoming Basin, Version 2, March 2006: Boise, Idaho, USGS, Snake River Field Station, unpublished report.

Rowland, M.M., Wisdom, M.J., Suring, L.H., and Meinke, C.W., 2006, Greater sage-grouse as an umbrella species for sagebrush-associated vertebrates: Biological Conservation, v. 129, p. 323–325.

Thompson, W.L., White, G.C., and Gowan, C., 1998, Monitoring vertebrate populations: San Diego, Calif., Academic Press.

U.S. Bureau of Land Management, 2004, National sage-grouse habitat conservation strategy, http://www.blm.gov/nhp/spotlight/sage_grouse/docs/Sage-Grouse_Strategy.pdf.

U.S. Bureau of Land Management Glenwood Springs Field Office, 2006, Roan Plateau Planning Area—Resource management plan amendment and environmental impact statement, August 2006: Glenwood Springs, Colo., U.S. Bureau of Land Management, 440 p.

U.S. North American Bird Conservation Initiative Monitoring Subcommittee, 2007, Opportunities for improving avian monitoring: U.S. North American Bird Conservation Initiative Report, http://www.nabci-us.org/.

Wambolt, C.L., Frisina, M.R., Knapp, S.J., and Frisina, R.M., 2006, Effect of method, site, and taxon on line-intercept estimates of sagebrush cover: Wildlife Society Bulletin, v. 34, p. 440–445.

Wilhere, G.F., 2002, Adaptive management in habitat conservation plans: Conservation Biology, v. 16, p. 20–29.

Wisdom, M.J., Rowland, M.M., and Suring, L.H., 2005, Habitat threats in the sagebrush ecosystem—Methods of regional assessment and application in the Great Basin: Lawrence, Kans., Alliance Communication Group, 272 p. pus 7 appendices.

Wisdom, M.J., Rowland, M.M., Wales, B.C., Hemstrom, M.A., Hann, W.J., Raphael, M.G., Hothausen, R.S., Gravenmier, R.A., and Rich, T.D., 2002, Modeled effects of sagebrush-steppe restoration on greater sage-grouse in the Interior Columba Basin, USA: Conservation Biology, v. 16, p. 1,223–1,231.

Wisdom, M.J., Wales, B.C., Rowland, M.M., Raphael, M.G., Holthausen, R.S., Rich, T.D., Saab, V.A., 2002, Performance of greater sage-grouse models for conservation assessment in the Interior Columbia Basin, USA: Conservation Biology, v. 16: 1,232-1,242.

Zarnetske, P.L., Edwards, T.C., Jr., and Moisen, G.G., 2007, Habitat classification modeling with incomplete data—Pushing the habitat envelope: Ecological Applications, v. 17, p. 1,714–1,726.

Glossary

best management practices (BMP) Practices designed to ensure that energy development is conducted in an environmentally responsible manner to minimize potential impacts to wildlife and other natural resources (see table 4 for examples of BMPs).

compliance monitoring Monitoring used to evaluate whether an action (for example, restoration) has been implemented as stipulated in a lease or other provision (see table 4 for examples of compliance monitoring indicators).

core area The portion of a roadless area that is free from the disturbance effects of roads. Because species vary in their sensitivity to disturbance, minimum core area required can vary among species. The type of road, vehicle type, timing of use, and cover type are some of the factors that could influence the disturbance effects of roads and, in turn, core area size.

effectiveness monitoring Monitoring used to evaluate whether an action achieved its objectives (see table 4 for examples of effectiveness monitoring indicators).

lease stipulations Provisions that modify standard lease rights and are attached to, or made part of, the oil and gas leases. For example, a timing lease stipulation (such as, seasonal restrictions) prohibits mineral development activities for time periods less than a year (such as, drilling operations or excavation is prohibited during the nesting period for sensitive species known or suspected to breed in the area).

legacy data Existing data collected by the U.S. Bureau of Land Management. Often, data standards (protocols, data entry, metadata, and data management) are lacking; thus, legacy data vary in quality and accessibility.

validation monitoring Monitoring used to validate the assumptions linking cause-effect relationships.

Appendixes

Appendix A. Existing Monitoring Frameworks and Assessments

A number of regional or national monitoring programs are currently being developed and initiated by several other Federal agencies. To identify opportunities for improved cross-agency coordination, to avoid duplication of efforts, and to learn from the experience of cooperating agencies, we first reviewed the ongoing efforts at a national level by the U.S. Fish and Wildlife Service (FWS), National Park Service (NPS), U.S. Forest Service (USFS), and U.S. Geological Survey (USGS). In particular, we reviewed the development of NPS's monitoring program for the Northern Colorado Plateau Network (O'Dell and others, 2005) because this area overlaps geographically with the BLM focal area. We also reviewed two ecoregional assessments for sagebrush ecosystems—the Great Basin (Wisdom and others, 2005) and Wyoming Basin (Rowland, Leu, and others, 2006) sponsored by BLM— and status assessments for species of concern and terrestrial ecosystems prepared by Region 2 of the USFS. Both the Wyoming Basin and USFS Region 2 overlap the Colorado focal area. Two recent syntheses of conceptual and operational aspects of developing ecosystem monitoring programs and examples from case studies (Mulder and others, 1999; Busch and Trexler, 2003) also contributed to the development of our monitoring plan.

In 2006, the FWS initiated a pilot project for biological monitoring and adaptive management for the refuge system (Knutson and others, 2005). The focus is on high priority monitoring needs for multiple refuges in Regions 3 and 5. The three major goals of the program are to (1) evaluate the success of wildlife and habitat objectives and track management and conservation of natural resources, (2) initiate adaptive management and develop new tools and techniques to fill information gaps, and (3) contribute to regional, national, and continental conservation of trust resources by partnering with other programs and agencies to facilitate exchange of information (Knutson and others, 2005). The first goal primarily addresses management objectives that have a relatively high degree of confidence regarding the outcome of management actions, whereas the focus of the second goal is on management actions that have a high degree of uncertainty about the expected outcomes.

An important aspect of the FWS approach is its emphasis on adaptive management (goal 2). An overriding goal of the FWS pilot project is to coordinate adaptive management projects and develop monitoring programs and databases among multiple refuges. Coordinated monitoring that addresses information needs common to numerous refuges will help to support habitat management across broad landscapes. Standardized monitoring protocols for common objectives will improve the quality of refuge data and improve its information value (Knutson and others, 2005). Each refuge and region will contribute tools and products to ensure that the program develops in a decentralized (bottom-up), but coordinated (top-down) manner.

There are many similarities between legacy data collected by BLM field offices and issues identified for FWS refuges regarding the efficiencies of existing surveys and monitoring activities. There are few resources for monitoring efforts or to evaluate existing efforts, and standardized protocols, databases, and analyses are often lacking. Consequently, there are often delays or inadequacies in dissemination of information, application of monitoring to management actions or planning, and storage of data (Knutson and others, 2005). In addition, it is difficult or impossible to assemble or evaluate multi-refuge data (Knutson and others, 2005).

The NPS and USFS have been developing and expanding their national monitoring programs. The networks developed by the NPS may be a useful approach for BLM, which lacks a regional framework for coordinating monitoring activities. Using the networks to coordinate the development of monitoring plans for parks with similar ecological conditions and management issues, the NPS has built a comprehensive and scientifically sound program for monitoring vital signs. The development process, however, is substantial and precludes rapid implementation. Likewise, the USFS approach is comprehensive in the number of wildlife species and scales surveyed (Manley and others, 2004), and is linked to an existing broad-scale monitoring framework (such as, Forest Inventory Analysis, or FIA). If used as models for BLM, the scope of both the NPS and USFS monitoring programs could delay implementation of a BLM monitoring strategy. For example, the program developed by the NPS is not fully implemented, and the development process by NPS monitoring networks takes many years to complete (http://science.nature.nps.gov/im/monitor/schedule.htm). Indeed, many NPS networks have not yet completed the final phase (fig. A1). Because BLM lacks an existing sampling framework like FIA, the costs to implement this type of wildlife monitoring program *de novo* will be sizeable. Developing a monitoring program based on the NPS and USFS models will require considerable time, expertise, and funding for full implementation. Yet, monitoring information is urgently needed by BLM to evaluate rapidly expanding energy development.

Although there are similarities among other Federal monitoring programs, including common objectives and problems with current monitoring, there is an important distinction in emphasis among programs. Both the NPS Vital Signs Monitoring and the USFS national wildlife monitoring frameworks are largely **retrospective** (also referred to as surveillance monitoring) in that they are designed as a mechanism to detect changes over time and may not target specific stressors (Noon, 2003). The FWS pilot project is primarily **prospective** because it evaluates questions or hypotheses related to the effects of management activities (Noon, 2003). Likewise, the monitoring objectives for the Colorado focal area are generally prospective because they address known or hypothesized effects of energy development activities. Prospective monitoring is in essence hypothesis testing, whereas retrospective monitoring is designed to be an early warning of population changes.

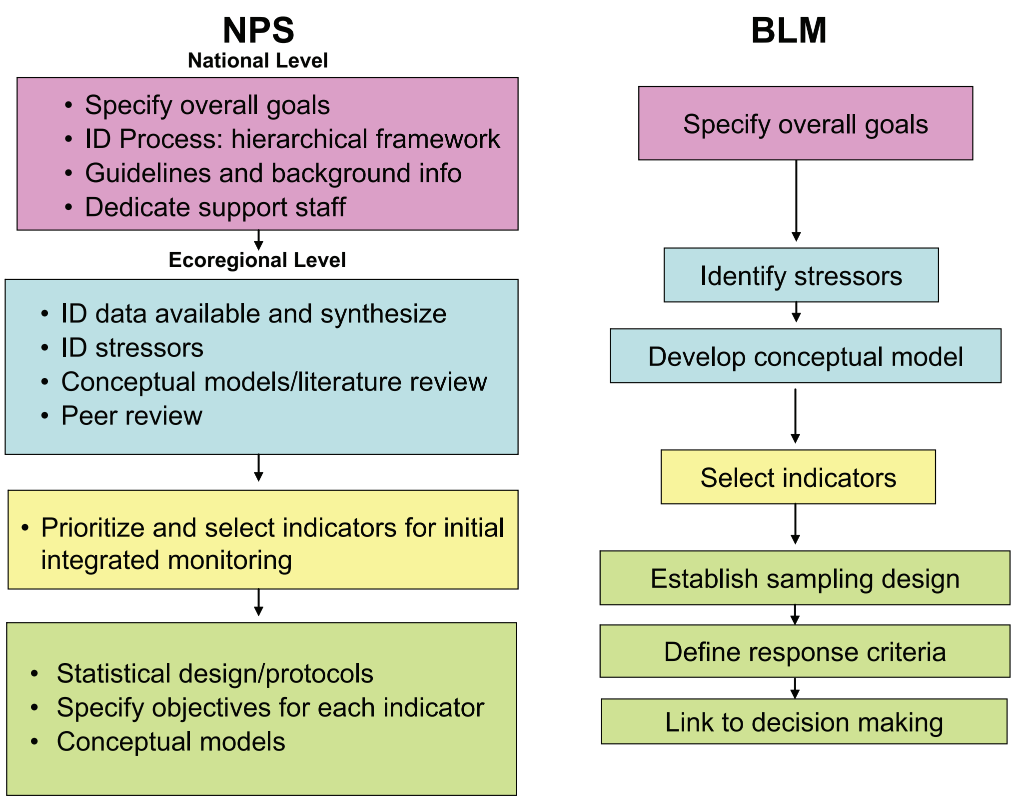

Figure A1. Comparison of National Park Service (NPS) monitoring phases to Mulder and others (1999) used by Bureau of Land Management (BLM). Phase I (blue), Phase II (yellow), and Phase III (green) generally take 4–5 years for completion by each NPS network.

In developing the BLM monitoring plan, we relied primarily on the Wyoming Basin assessment and the FWS pilot monitoring project. Although the final products of the NPS and USFS monitoring programs will be scientifically valid and have a high probability of obtaining useful monitoring data, the comprehensive, top-down approach slows implementation. In contrast, the sagebrush regional assessments (Wisdom and others, 2005; Rowland, Leu, and others, 2006) were completed more rapidly (C. Aldridge, oral commun., 2007). Further, the focus of NPS and USFS programs on retrospective monitoring does not address many of the goals for the focal area. The focus of the FWS on adaptive management provided valuable guidance in the development of a prospective monitoring framework. Because of the rapid pace of energy development in the focal area, the timely development of a monitoring program that has strong links between management objectives, actions, (for example, mitigation or stipulations relating to energy development), and outcomes (such as, effectiveness of management actions) is paramount.

Appendix B. Habitat and Disturbance Modeling for Greater Sage-Grouse

Phase I. Habitat-disturbance Model

To predict habitat quality for the entire study area we used two submodels: (1) a sagebrush cover submodel was used to predict potential habitat based on general habitat affinities and (2) a disturbance submodel was used to incorporate the loss of habitat quality resulting from the direct and indirect effects of surface disturbance. The submodels were combined to provide an index of habitat quality.

For this analysis, we selected LANDFIRE data as opposed to other vegetation maps (Colorado Vegetation Classification Project, National Land Cover Data, and Southwest Regap) for several reasons. First, BLM will be using LANDFIRE data products to support BLM land monitoring at a national level. Second, a regular and possibly automatic updating process of data layers in LANDFIRE is planned, thereby providing an established process for updating BLM analysis and assessment products for use in monitoring and planning. In addition, LANDFIRE vegetation succession and disturbance histories are being modeled for each of the ecological system classes, which will be useful for assessments and planning. Finally, LANDFIRE provides a consistent mapping protocol across broad scales (for example, at greater extents than Colorado) so it provides opportunities for consistency of analyses across ecological and jurisdictional boundaries. This will facilitate analyses at multiple scales.

The sagebrush cover submodel was used to rank potential habitat based on the proportion of sagebrush cover (Rowland, Leu, and others, 2006). We used a moving window analysis in which the proportion of sagebrush was quantified (based on LANDFIRE Existing Vegetation Type) in a 3-km (1.9-mi) radius buffer surrounding each pixel, which corresponds to the home range size of greater sage-grouse (Rowland, Leu, and others, 2006). Each pixel was assigned a score ranging from 0 to 1.0 depending on the proportion of the surrounding pixels in the 3-km window that were classified as sagebrush. In this model, 0 represents no habitat (<0.05 percent sagebrush cover) and 1.0 represents a high probability of occurrence (>70 percent sagebrush; table B1). All sagebrush cover types were included. The highest habitat quality score from the resulting habitat map corresponded closely with greater sage-grouse production areas as documented by the Colorado Division of Wildlife (figs. B1 and B2).

Table B1. Greater sage-grouse habitat submodel.

Proportion sagebrush	Probability of occurrence	Habitat quality[1]
<0.05	0	Nonhabitat
0.05–0.25	0.2	Very low
0.25–0.40	0.4	Low
0.40–0.55	0.6	Moderate
0.55–0.70	0.8	High
>0.70	1.0	Very high

[1]Habitat-quality classes are provided as an aid to interpretation of habitat scores and are based on the assumption that probability of occurrence increases with increasing sagebrush cover at the coarse scale of the maps (Rowland, Leu, and others, 2006).

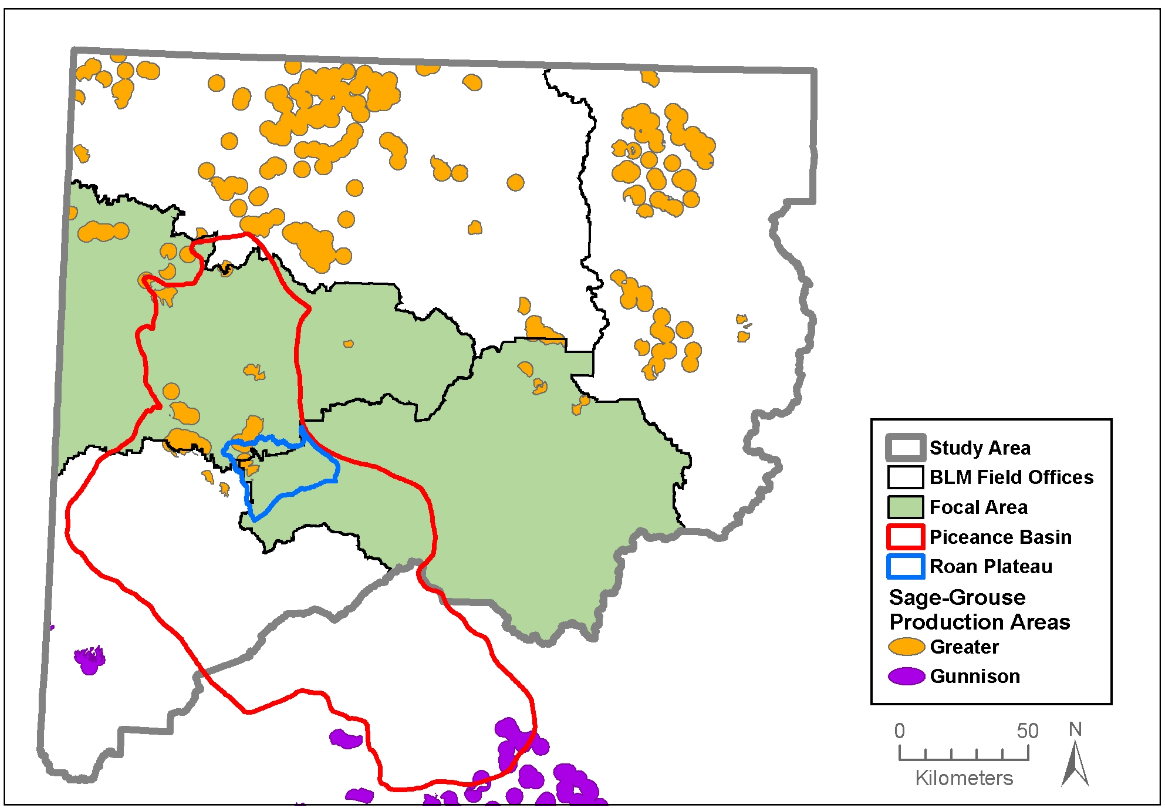

Figure B1. Greater and Gunnison sage-grouse production areas in the Colorado study area and Piceance Basin based on Colorado Division of Wildlife data.

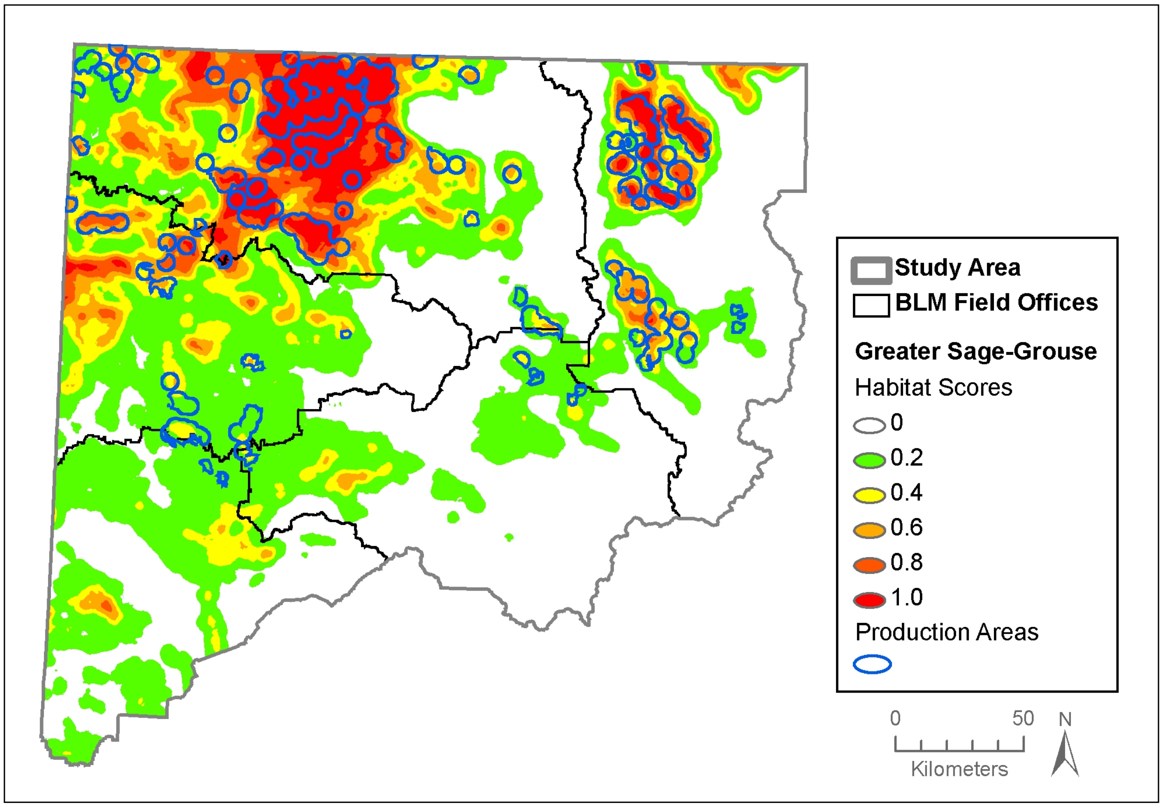

Figure B2. Map of greater sage-grouse habitat score from the habitat submodel in comparison to known production areas (Colorado Division of Wildlife data).

The disturbance submodel we used was a modification of the Wyoming Basin model (Rowland, Leu, and others, 2006). Surface disturbance can reduce habitat quality both directly as habitat loss and indirectly (for example, vehicle disturbance). The degree of indirect impacts from surface disturbance was assumed to decrease as a function of distance from the surface disturbance, and as such was evaluated within several distance categories. We included the disturbance resulting from three levels of road use as specified in the original submodel (interstate, State highway, and secondary roads obtained from U.S. census TIGER line files). Because quantitative information on road-use frequency is generally lacking, it is often assumed that intensity of disturbance is greatest for interstates and least for secondary roads. Other disturbance variables we included were well-pad locations, both active and inactive (obtained from the Colorado Oil and Gas Conservation Commission; COGCC), and areas of human development (cities obtained from Colorado Department of Transportation; oil and gas facilities obtained from COGCC). The original submodel included several additional disturbance factors (burn areas, campgrounds, communication towers, irrigation channels, landfills, and power lines) that we did not include in our disturbance submodel because suitable GIS data were not readily available.

For each of the variables included in the disturbance submodel, we used the original distance classes without modification (table B2). The breakpoints were loosely based on empirical evidence of disturbance effects and appeared reasonable based on published data (table B2; Rowland, Leu, and others, 2006). In contrast, the disturbance weighting assigned to each distance class (buffer size) was

Table B2. Greater sage-grouse disturbance submodel. The original weights were from the model developed for the Wyoming Basin (Rowland, Leu, and others, 2006); the revised weights (in bold text) were used for the final analysis.

Variable	Distance classes	Disturbance weight	
		Original	Revised
Interstate highway	0–45 m[1]	1.0	**1.0**
	45–500 m	0.95	**0.95**
	500–2000 m	0.8	**0.7**
	2000–4000 m	0.7	**0.25**
	4000–7500 m	0.2	**0.05**
State/Federal highway	0–45[1]	1.0	**1.0**
	45–135	0.9	**0.8**
	135–1,000	0.7	**0.4**
	1,000–2,000	0.5	**0.05**
	2,000–3,000	0.2	**0.01**
Secondary road	0–45[1]	1.0	**1.0**
	45–495	0.7	**0.5**
	495–1,000	0.2	**0.05**
Active well	0–45[1]	1.0	**1.0**
	45–1,000	0.8	**0.6**
	1,000–3,000	0.5	**0.2**
	3,000–5,000	0.2	**0.01**
Inactive well	pixel with location[1]	1.0	**1.0**
Human impact zone	pixel with urban or energy facilities[1]	1.0	**1.0**
	45–500 m	0.9	**0.9**
	500–1,000m	0.8	**0.6**
	1,000–7,000 m	0.3	**0.15**

[1]Used for quantifying direct effects of surface disturbance.

apparently based on expert opinion rather than empirically derived equations. As a result, the weightings for disturbance effects at very large distances from roads (for example, >2 km from interstate highways) seemed unrealistically high and based on limited or questionable evidence (see Connelly and others, 2004, p. 13.13–13.14). Furthermore, to combine disturbances from multiple sources or distance classes, Rowland, Leu, and others (2006) used a maximum disturbance weighting assigned to each pixel. Consequently, in areas of overlapping disturbances, the lower disturbance weightings were not included in the overall disturbance scores. To address these issues for this exercise, we revised the submodel by reducing the disturbance weights assigned to the larger distance categories (table B1) and used an additive disturbance score for each pixel (summed weights for all disturbances affecting a pixel; maximum additive disturbance score = 1).

To evaluate the total (direct and indirect) effects of disturbance on habitat quality, the habitat score was multiplied by 1 - the disturbance score. To evaluate the direct loss of habitat resulting from surface disturbance (surface disturbance footprint), we modeled the disturbance footprint as a buffer 0–45 m from the road or well pad (disturbance weight = 1; table B2) and set the disturbance weight to 0 for all other buffer distances. In summary, we compared the results of three models on sage-grouse habitat: (1) sagebrush cover submodel only, (2) sagebrush cover and disturbance footprint submodels, and (3) sagebrush cover and full disturbance submodels (fig. 16). For the sagebrush cover submodel, the map represents the actual scores for each pixel (fig 14a). For the full habitat model, the following categories were used: 0 = 0–0.10; 0.2 = 0.10000001–0.30; 0.4 = 0.30000001–0.50; 0.6 = 0.50000001–0.70; 0/8 = 0.70000001–0.90; and 1.0 = 0.90000001–1.00 (fig. 14b). To aid interpretation, we used habitat quality (table B1) for figures 15 and 16.

Phase II. Sage-Grouse Habitat-Disturbance Model Sensitivity Analysis

To evaluate the consequences of potentially inflated weightings for the farthest distance classes and the use of maximum disturbance scores, we conducted a sensitivity analysis by comparing the maps produced by several approaches (fig. B3). First, we created a disturbance map for the study area based on the original Wyoming Basin submodel (the original disturbance weights and the maximum disturbance score; fig. B3a). Second, we used the maximum disturbance score but used the revised disturbance weights (table B1; fig. B3b). Finally, we used an additive disturbance score based on both the original disturbance weights (fig. B3c) and revised disturbance weightings (fig. B3d). It is important to note that both additive and maximum disturbance scores are the same regardless of whether there is one or more than one disturbance of a particular type present within a distance class. For the coarse-level analysis we present here, we assumed that this simplification would not have significant effects. This problem could be addressed by incorporating an index of road density (Aldridge and Boyce, 2007).

We present all four disturbance maps to illustrate some of the potential issues involved in modeling. Because the original disturbance submodel was based on maximum disturbance scores, it is difficult to evaluate additional impacts resulting from new energy development in areas where disturbances previously existed (fig. B3a). Likewise, the additive scores with the original disturbance weightings resulted in extremely high disturbance scores over much of the demonstration area, making it difficult to evaluate the effects of new development (fig. B3c). The map derived from maximum values of the revised weights showed very little variation across much of the known greater sage-grouse production areas and had relatively low disturbance scores (fig. B3b). The sensitivity analysis illustrates how model selection and underlying assumptions may result in dramatically different maps that can greatly affect subsequent analyses and conclusions. The particular model that is chosen will depend, in part, on the objectives and the scale of resolution that is required.

We elected to use the additive disturbance submodel based on revised weights (fig. B3d) because it allowed us to (1) avoid swamping out more significant disturbances at close distances by reducing the impacts predicted at distances greater than 1 km from roads and (2) address cumulative impacts from multiple disturbances. This submodel reflected the greatest amount of variation in disturbance among greater sage-grouse production areas and thus, was more useful for the demonstration project. Each of these approaches has inherent benefits and drawbacks, but we used the map that best illustrates how the modeling approach could be used in assessments and planning activities. Ideally, in a comprehensive assessment (such as, Phases I and II), expert review and the use of empirical data to evaluate the validity of each approach would be performed prior to using models for assessment and planning activities.

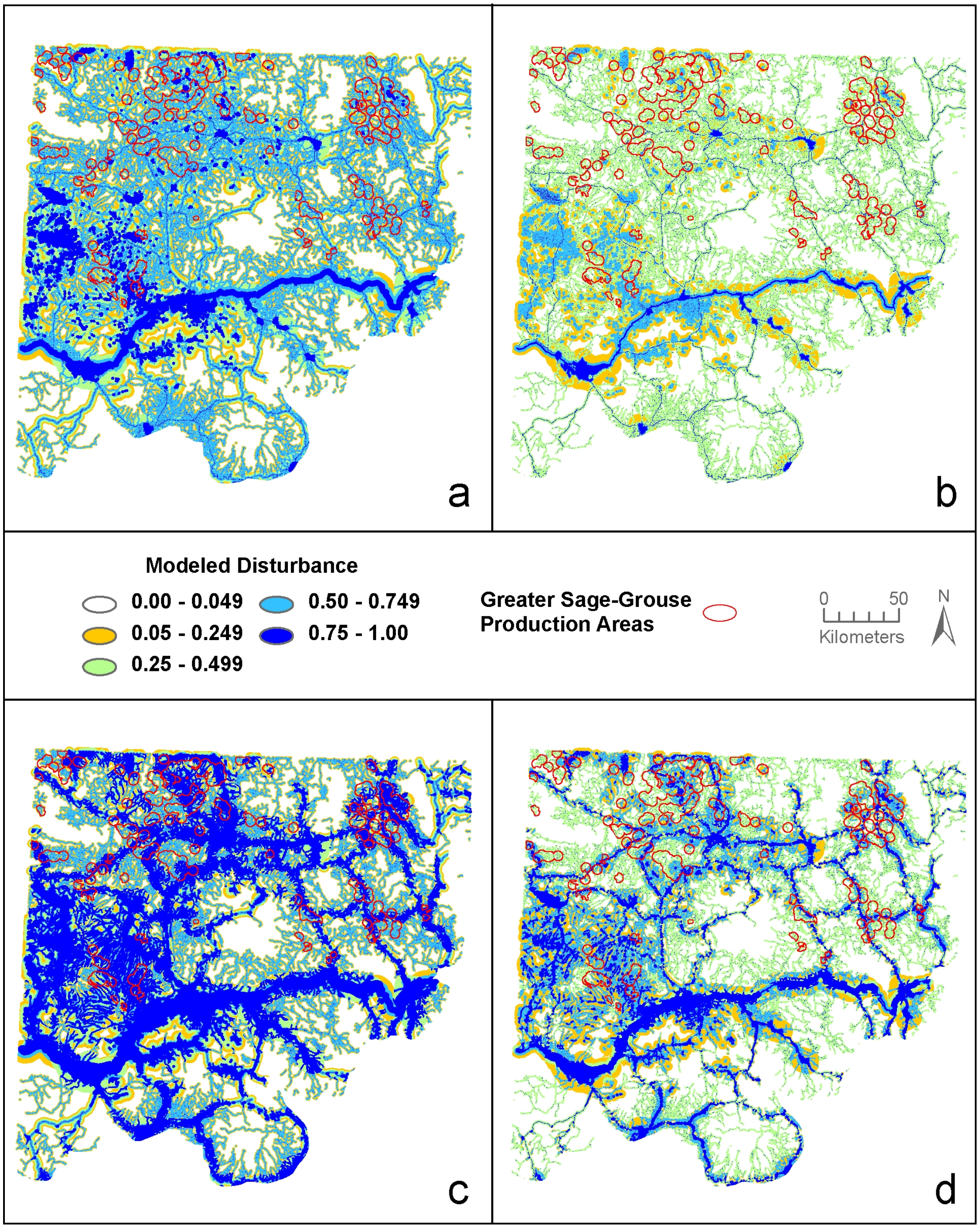

Figure B3. Results of greater sage-grouse disturbance submodel: (a) original model with maximum overall score, (b) revised disturbance values and maximum overall score, (c) original disturbance values and additive overall score, and (d) revised disturbance values and additive overall score (panel d was used for further analyses).

Appendix C. Landscape Analysis

Quantifying the effects of fragmentation is difficult for many reasons. Some habitats are naturally patchy and such underlying heterogeneity confounds our ability to quantify fragmentation. Landscapes are also variable in time, and the dynamics resulting from natural processes (including succession, fire, and drought) may affect spatial patterns (fig. 9). In addition to scale-dependency issues, fragmentation cannot be quantified by a single index. Furthermore, species vary in their sensitivity to road characteristics, such as frequency of use, density, and size (fig. 11), and some species may actually benefit from roads. Finally, the consequences of fragmentation are poorly understood, which makes it difficult to relate indices of fragmentation to specific effects on ecosystem functions or species responses. The negative effects of fragmentation not only depend on the size and spatial distribution of remnant fragments, but also depend on species sensitivity to roads.

Nevertheless, it is worthwhile to characterize the landscape with and without anthropogenic disturbance at a variety of scales to evaluate the spatial consequences of energy development activities. In addition, many species are not priorities for conservation or management, or there is not sufficient information for conducting the type of modeling activities we conducted for sage-grouse. Yet, under NEPA requirements, BLM is mandated to assess potential effects including direct, indirect, or cumulative ecological effects. Thus, characterizing landscape condition will address NEPA requirements using a coarse-filter approach to assessments and may provide a safety net for species that are not specifically targeted for modeling or other monitoring activities. The successful application of this approach relies on the assumption that large, roadless areas are more likely to maintain the full range of ecosystem functions (fig. 9) than small, isolated patches, and consequently will better provide for a diverse array of species.

To evaluate fragmentation, we conducted our analyses at three nested scales (study area, field office, and upper Roan Plateau) using several landscape indices. To avoid issues with the underlying spatial heterogeneity, we did not partition the analysis by cover type. We varied buffer sizes (distance from roads) and core area sizes (minimum area without road effects). The buffer sizes (100 m, 250 m, 500 m, 1000 m) and core areas (10 ha, 100 ha, 1,000 ha, 10,000 ha) were selected to represent a range of sensitivities to the disturbance and fragmenting effects of roads.

Appendix D. State and Transition Model for Greater Sage-Grouse

An example of a state and transition model for Wyoming big sagebrush in the Interior Columbia Basin is provided in figure D1. Although this model does not apply to the focal area due to differences in vegetation states, it provides an example of the type of state and transition models that could be used in Phase II activities.

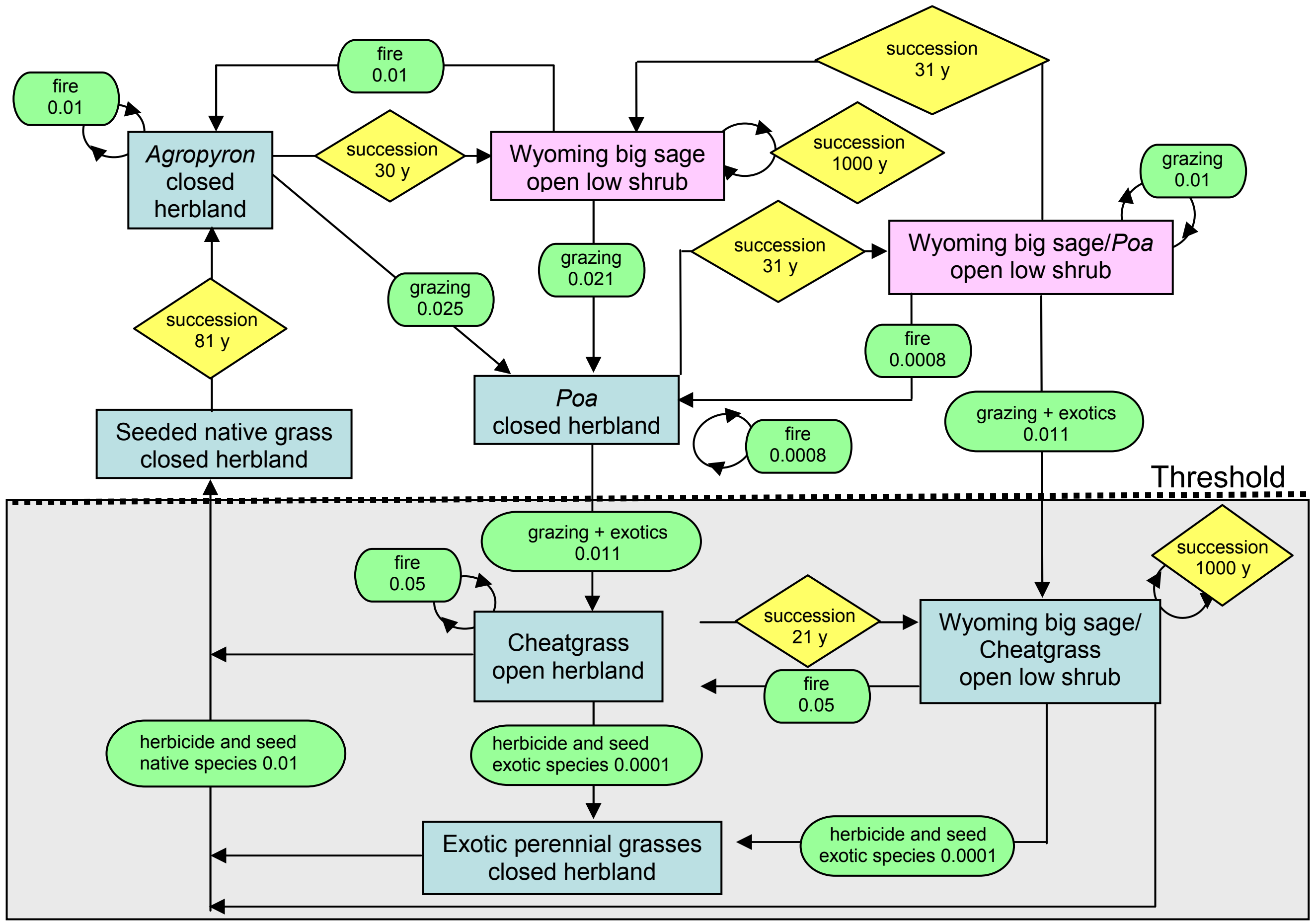

Figure D1. Example of a state and transition model for Wyoming big sagebrush potential vegetation types in the Interior Columbia Basin (adapted from Hemstrom and others, 2002). Boxes represent vegetation states (cover types and structural stages) that could result from a combination of potential vegetation and management prescriptions. Pink boxes represent high-quality habitat conditions for greater sage-grouse. Arrows represent transitions between vegetation states. Yellow diamonds show successional transitions and the number of years needed to reach potential vegetation types. Succession transitions of 1,000 years (y) indicate stable states. Green ovals show transitions resulting from disturbance (grazing, fire, chemical treatments, and seeding) and the annual probability of moving from one state to another. The dotted line represents a transition threshold. The vegetation states in the gray-shaded area below the threshold represent altered conditions resulting from grazing, exotics, and fire; restoration of altered vegetation states to potential vegetation types is difficult and requires active intervention (for example, herbicide and native seeding).

Appendix E. Road Analysis for the Roan Plateau

We evaluated the effects of existing roads and proposed road closures on habitat fragmentation by comparing roadless areas under current and proposed conditions (Table E1). We assumed that road closures and restrictions will decrease the disturbance resulting from activities along roads. Although the proposed plan does not allow for additional roads to be built without reclaiming existing roads, the time frame for reclamation (demonstration of 1–5 years duration) is assumed to be insufficient for full restoration to pre-disturbance vegetation structure for most of the cover types present on the upper plateau (including sagebrush, pinyon-juniper, and mixed conifer forest). The plan restricts creation of new roads to specific areas, primarily ridge tops. We assumed that areas greater than 500 m from roads would have minimal disturbance. To evaluate road fragmentation, we restricted disturbance effects of roads to 500 m. Currently, roads on the upper plateau exist at fairly high densities (fig. 25b), such that only 10 percent of the area is greater than 500 m from roads (fig. 25).

Table E1. Resource Management Plan and Environmental Impact Statement (U.S. Bureau of Land Management Glenwood Springs Field Office, 2006) recommendations for Roan Plateau (upper rim/plateau only; total upper plateau = 34,758 acres).

EIS recommendation	Limits
Motorized routes on Federal land (currently 157 miles)	138 mi (no net increase; new roads must be preceded by road reclamation to maintain this cap)
Existing road closures	19 mi
Administrative use roads (restricted use)	68 mi
New wells	210
New well pads	13
Total area new well pads	75 ac
Maximum surface disturbance (roads, wells, and pipelines)	350 ac at any given time; excess must demonstrate reclamation and indication of recovery
Maximum well-pad density	1/640 ac
No surface occupancy[1]	21,000 ac
Areas of Critical Environmental Concern	23,000 ac (some overlap with areas of no surface occupancy)
Estimated rate of drilling	2 wells/year
Other constraints on drilling	<20 % slope

[1]No surface occupancy means no permanent oil or gas facilities allowed.