Managing and Monitoring Wyoming's Wildlife:
Strategies and Tools for Success



THE HEINZ CENTER

Wildlife Conservation Program

MANAGING AND MONITORING WYOMING'S WILDLIFE: STRATEGIES AND TOOLS FOR SUCCESS

REPORT AND WORKSHOP SUMMARY

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Appendices:

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1.0 Report Overview

This report is intended to serve as a tool and reference for Wyoming wildlife and resource managers who navigate significant challenges and a rapidly changing landscape in their conservation work.

The report provides a synthesis of the programs that monitor the status and condition of wildlife and ecosystems in Wyoming, and suggests ways in which the monitoring data from these programs could be used to improve the practice of wildlife management in the state.

The findings contained in this report are from a May 2011 participant-driven workshop that was co-hosted by the Wyoming Bureau of Land Management (BLM) and the Wyoming Game and Fish Department (WGFD). "Pioneering Performance Measures for Wyoming Wildlife" was an interactive, multi-stakeholder workshop focused on the use of monitoring data in conservation planning by the U. S. Bureau of Land Management and the importance of monitoring and evaluation in implementing the revised Wyoming State Wildlife Action Plan (SWAP).

The workshop was one of a series of similar meetings being held across the western United States that are engaging natural resource agency leaders, and wildlife and ecosystem experts. A neutral convener, the Washington, D.C.-based nonprofit the Heinz Center, facilitates the workshops. The process is designed to build consensus on wildlife conservation priorities, to increase collaboration on monitoring priority conservation targets, and to help leverage resources across existing monitoring programs.

At the Wyoming meeting, conservation partners from across the state gathered for three days in Cheyenne to focus on three priority ecosystems: sagebrush, riparian areas, and prairie grasslands. These priority ecosystems were selected in advance through a cooperative effort to align the highest priority ecosystems of Wyoming Bureau of Land Management and the Wyoming Game and Fish Department.

1.1 Organization of the Document

This workshop report highlights the existing wildlife monitoring programs in Wyoming, introduces the concept of an integrated wildlife monitoring program, and discusses next steps towards developing an integrated monitoring approach. It also includes conceptual models, lists of stressors and management actions, and lists of candidate indicators for each high priority target that were developed during the workshop. Throughout the report, the concepts presented are supported by

examples drawn from the workshop.

The report begins with introductory material on monitoring programs, including a discussion of the terminology around monitoring, performance measurement, and evaluation.

Chapter 3 describes the stressor-based approach to wildlife management, while Chapter 4 takes an in-depth look at the three target ecosystems of the workshop and describes the collaborative process used to select these shared conservation targets.

Subsequent chapters include an overview of indicators and how they can be derived, and a review of existing monitoring programs in Wyoming - with a particular focus on programs that could help inform the indicators selected by workshop participants.

The report concludes with ideas for concrete actions to continue moving forward beyond the workshop, emphasizing activities that would be manageable, low-cost, and utilize available data and existing protocols.

Information and ideas shared by the workshop participants - and summarized in this report - provide an important foundation for the development of integrated monitoring approaches for wildlife and ecosystems in the state, and for a future of successful, collaborative wildlife management in Wyoming.

2.0 Introduction to Monitoring and Assessment

The state of Wyoming and its federal partners have a long history of monitoring wildlife populations and ecosystem conditions, ranging from Wyoming Game and Fish Department (WGFD) efforts to track big game populations, to Bureau of Land Management efforts to monitor rangeland health, and USDA Forest Service inventories of forest condition and forest stands.

In recent years, monitoring activities have also focused on determining the status and trends of at-risk or imperiled wildlife species. Wildlife assessment activities, including surveys and monitoring, have been essential in guiding management activities for wildlife resources in Wyoming. The assessments vary in focus from harvestable deer and elk populations to imperiled fishes, rare butterflies, and migratory waterfowl.

Wildlife monitoring in Wyoming was once a matter of conducting an annual census of Wyoming's rich game species diversity. Today, wildlife monitoring programs are increasingly sophisticated, with new tools for data collection, mapping, and analysis. At the same time, the state and its partners receive more mandates to survey for and assess the status and trends of an ever-growing list of rare, imperiled, or protected wildlife species. The growth in the number of potential monitoring targets, especially among protected wildlife species, is placing significant demands on the resources of the department and its partners. Emerging concerns about the responses of Wyoming's wildlife to environmental change and new energy developments pose further challenges for the state's wildlife monitoring programs. Historically in Wyoming, as in its neighboring states, wildlife management and conservation planning has focused on sustaining wildlife species in their current habitats. However, a diverse landscape that is increasingly experiencing (and will continue to experience) rapidly changing environmental conditions requires that planning, management, and monitoring under the State Wildlife Action Plan (SWAP) must take new dynamic and anticipatory approaches. Managers will need to be creative when addressing future challenges, using existing conservation tools in new and innovative ways. This is especially true for monitoring and evaluation programs, where there are exciting new opportunities for scientists and program managers to coordinate and collaborate across agency and jurisdictional boundaries in order to provide society with the information needed to manage our rapidly changing environment.

2.1 Setting Performance Measures

The process of setting performance measures for the Wyoming SWAP must take into account a range of information from diverse sources: data about key threats and stressors to wildlife and ecosystems

in the state; information about the existing management activities of the WGFD and its partners; and in-depth information about the underlying monitoring designs and data collection activities for the programs that currently track wildlife and ecosystems in Wyoming.

Identifying key threats and stressors helps frame management questions and clarify how monitoring programs could collect data about the effects of threats and stressors. Identifying the full suite of current management activities helps focus monitoring attention on the short- and long-term outcomes of conservation actions. And reviewing the set of existing monitoring programs is the first step towards better collaboration and integration across programs and among partners. Such integration has clear practical benefits, including efficiencies in data collection as well as the ability to make comparisons across complementary data sets (e.g., comparisons between wildlife population trends and vegetation condition at the same sites or areas).

2.1.1 Monitoring Design

For wildlife management planning to be effectively informed, the monitoring schemes and performance measures that service wildlife management activities in the state need to consider the full breadth of environmental changes that will directly and indirectly affect desired species over both shorter and longer terms. Recognizing the diverse types of potential environmental changes and anticipating wildlife responses, this includes the need to:

- **Integrate ongoing monitoring efforts** that have historically provided essential population status and trend data to wildlife managers;
- Place ongoing monitoring efforts into an **adaptive management framework**; and
- **Enhance sampling and survey designs** to increase the possibility of picking up signals from local ecosystem responses to environmental disturbances that put Wyoming's desired wildlife at risk for extirpation, extinction, or population decline.

Adaptive management - also known as "learning by doing" - will not only require well-designed monitoring schemes, it will also require integration of those assessment activities with information gathered from directed research and from species and ecosystem models. Integrated monitoring will in many circumstances need to be initiated as pilot studies, with initial sampling programs amended sequentially as accruing data are used to resolve uncertainties in the monitoring design.

2.1.2 Types of Monitoring

Wildlife and natural resource monitoring activities in the state may continue to proceed in the following three categories:

1. ***Implementation monitoring***, which is the monitoring of management actions in relation to planned activities; cataloguing the completion of wildlife management

projects or habitat restoration activities as they were designed; and documenting compliance with environmental regulations and mitigation obligations in project implementation.

2. ***Effectiveness monitoring***, which assesses the effectiveness of management actions in achieving desired wildlife responses and improved habitat conditions.
3. ***Status and trend monitoring***, which documents the status and trends of targeted wildlife, their essential habitats and resources, and environmental agents that cause change in both. Status and trend monitoring is the principal data gathering effort that informs management planning about overall environmental and resource conditions relative to established environmental objectives and thresholds. Typically, this type of monitoring serves to track the condition of indicators selected to represent a set of conditions pertinent to environmental objectives in the SWAP.

2.1.2.1 Monitoring for Environmental and Climate Change

In order for monitoring to capture environmental and climate change, a new approach is needed that will require adjustments to monitoring programs, including:

- Sustaining ongoing data collection efforts that target desired game and fish species, species listed as threatened or endangered, and other valued species, including species that might be useful as early-warning indicators of environmental change.
- Incorporating concurrent data collection of appropriate environmental variables known or expected to contribute to landscape occupancy and habitat use by desired wildlife species.
- Sampling widely for wildlife and environmental variables across those geographic and vegetation gradients that provide the template upon which wildlife species distributions and abundances will adjust in response to shifting physical and biological conditions.

2.1.3 Choosing Indicators

The Wyoming Game and Fish Department currently fields a diverse group of survey, monitoring, and assessment programs. In combination with other data sets on land cover, soils, climate, and hydrology, data from these programs are being used to help inform ongoing and future management activities of wildlife and other key natural resources within the state.

In particular, analyses of time-series data for species and environmental variables can link changes in population trends to changes in candidate environmental variables. By linking changes in population trends to broader environmental variables, wildlife species have the potential to serve as "indicators" of habitat quality and ecosystem integrity. Wildlife species of particular interest for such analyses include: taxa which are associated with vegetation communities and land-cover types that are limited in geographic extent, taxa associated with highly fragmented ecological communities, and taxa found along the upper limits of elevational gradients. Monitoring of these species will focus attention on ecological indicators that clearly allow cause-effect interpretations of signal changes in the indicator status or trend.

Ultimately, integrated and systematic monitoring schemes can be implemented in the most extensive vegetation communities and land-cover types, and in highly restricted and at-risk communities and associations. In these locations, prospective sampling will use designs that maximize the likelihood that deterministic changes in wildlife status and trends will be observed and identified, and the environmental determinants of those changes can be assigned.

2.1.4 Indicators and Adaptive Management

To be successful, monitoring throughout the state under the Wyoming SWAP needs to be highly structured and form part of an integrated adaptive management program for wildlife species and habitat features. Such programs can be informed by and designed around a series of requisite elements, including:

- Articulation of **explicitly defined management options** for targeted wildlife species and their habitats;
- Use of **ecological models** that characterize the relationships between desired wildlife or habitat conditions, environmental indicators, and environmental threats and stressors;
- **Data collection in monitoring schemes** that anticipate the application of the information gathered in identifying and directing candidate management actions and prioritizing those actions; and
- Rigorous **evaluation of assessment outcomes**.

A stressor-based approach is one way to meet monitoring program requirements and to identify performance measures.

3.0 A Stressor-Based Approach to Wildlife Conservation and Wildlife Monitoring

One of the essential elements in the Wyoming SWAP is a discussion of the threats and stressors that affect wildlife and ecological communities in the state. Threats and stressors obviously have considerable importance for wildlife managers; in fact, Aldo Leopold (1933) traced the development of modern wildlife management back to very early concerns about poaching and the illegal harvesting of game and fish species. Since Leopold's time, advances in ecological science have provided managers with important new understandings of threats and stressors such as invasive species, habitat fragmentation, and climatic variability.

In this report, we follow a stressor-based approach in order to develop a framework for monitoring the condition of wildlife resources and the effectiveness of wildlife conservation activities in the state of Wyoming. The conceptual models in the appendices focus on the interactions between individual threats and stressors and a particular conservation target. The models show causal pathways by which individual threats and stressors affect the target, and show how particular conservation activities are intended to reduce, eliminate, or ameliorate particular threats or stressors. The models thus differ from other ecosystem models that show interactions among individual components (as in food web diagrams) or flows of energy or nutrients through a system.

3.1 The Value of a Stressor-based Approach

For wildlife managers, there are several practical justifications for adopting a stressor-based approach to management and monitoring.

- Much of traditional wildlife management has focused on reducing or ameliorating threats and stressors to individual species or vegetation communities. Methods have been developed for controlling many of the most pervasive threats and stressors (e.g., fire management, invasive species control, erosion control, mine reclamation).
- Threats and stressors are often anthropogenic in nature. It stands to reason that if human activities are responsible for creating the threat or stressor in the first place, then humans may be able to reduce or even undo the adverse effects of the threat or stressor.
- Funding from state and federal government agencies is often focused on specific threats or stressors, such as invasive species, new energy development, or climate change.

3.2 Stressors and Threats in Wyoming

The general list of threats and stressors for Wyoming – as with every state – is necessarily broad and comprehensive. Beyond a general discussion of these threats, it is also important to understand how specific threats and stressors are affecting the individual Species of Greatest Conservation Need (SGCN) and the specific ecosystems of conservation interest within the state.

In each state's Wildlife Action Plan, detailed information about known or potential threats and stressors for each species and community of conservation interest are listed. Such details are critically important for wildlife managers who must then develop customized management prescriptions and monitoring frameworks for individual species and ecological communities.

During the workshop, Glenn Pauley, SWAP Coordinator for WGFD, presented on the recent revisions to the Wyoming SWAP. The revised plan was approved by WGFD in January 2010 and subsequently by the U.S. Fish and Wildlife Service in early 2011. The SWAP identifies five leading conservation challenges, which arose in part from the detailed information collected during the process described above. These five threats and stressors were also repeatedly identified as common to many of the target habitat systems that were the focus of this workshop (i.e., sagebrush, riparian areas, and prairie grasslands). Below are descriptions of these five main threats and stressors. A full list of threats and stressors identified by workshop participants can be found in Appendix 1.

3.2.1 Rural Subdivision and Development

Wyoming has seen an increase in exurban and rural development at a rate of roughly 15 percent per year. This growth reflects trends in housing development brought on by more telecommuting, a growing retiree population, individuals' desire for larger homes and larger home sites, and a general movement by Wyoming residents and non-residents towards more rural lifestyles. In addition, Wyoming's population has grown steadily over the past few decades. From 2008-2009 Wyoming had the nation's fastest population growth rate (WGFD 2010).

The majority of rural subdivision and development is occurring on privately owned agricultural and ranchlands, which in Wyoming contain high amounts of vital wildlife habitat. For example, 50 percent of winter habitat for some of the state's key big game species is located on private land, and crucial biodiverse habitats such as riparian areas are often located on private agricultural lands (WGFD 2010). A 2010 WGFD study anticipated that up to 2.6 million acres of the state's most productive ranchlands could be converted to residential development by 2020.

Impacts on wildlife from these developments include decreased habitat quantity and quality, increased human-wildlife conflict, over-utilization of remaining habitat by wild animal populations due to decreased space, and adverse impacts on aquatic vegetation and species

communities from the development of new water storage and diversion structures. Because of increases in man-made structures and human population, wildlife and habitat managers are also having increased difficulty in implementing management techniques, such as hunter harvest to control wildlife numbers or periodic fire for vegetation management.

3.2.2 Energy Development

Over the past decade, Wyoming was the number one domestic exporter of energy, and the state's future in energy development is growing. In the U.S., Wyoming is the number one producer of coal, the number two producer of natural gas, and ranks eighth in crude oil production. The mining industry extracts high levels of resources and contributes billions of dollars to the state's economy. Bentonite, trona, uranium, and coal bed methane are all mined in Wyoming (WGFD 2010)

In addition to current production capacity, Wyoming is also estimated to have one of the largest untapped energy reserves in the country. This includes having roughly half of the highest potential on-shore wind energy sites, and the largest uranium reserves for nuclear energy. The estimate also considers factors such as potential solar and geothermal energy sites, as well as large resources of more unconventional energy sources such as oil shale (WGFD 2010).

With rising energy demands, it is anticipated that development of infrastructure to access these resources (e.g., roads, pipelines, transmission lines) will grow. Wildlife managers are concerned about the (potentially irreversible) impacts this development will have on terrestrial and aquatic wildlife and plant communities, and the ecosystems they rely upon. Impacts may include: habitat loss, physiological stress to wildlife, species disturbance and displacement, habitat fragmentation and isolation, alteration of ecosystem functions and processes (e.g., water quantity and quality), introduction of competitive and predatory species, as well as potential air quality issues with certain types of development. As has been seen in the past, it is also probable that growth in energy related development will bring a rise in human population to nearby cities and towns, which can add more layers of wildlife conservation challenges. Therefore it is critical that future energy development in the state is well-planned in order to minimize or prevent impacts to wildlife and ecosystems.

3.2.3 Invasive Plant Species

In Wyoming, invasive terrestrial plants cover approximately 1.3 million acres (or two percent) of the land, and WGFD anticipates that the spread of these species will likely increase in the

future. This will present new challenges to natural resource and wildlife managers in the state.

Although the significance of a particular species can vary by watershed or conservation issue/priority, the most well known species in the state include tamarisk (i.e., salt cedar), Russian olive, and cheatgrass. Invasive plants such as these can: reduce forage for wildlife and livestock; alter hydrologic cycles; diminish important breeding and protective habitat for wildlife; change fire regimes; increase erosion and sedimentation rates; and impact nutrient cycles and soil properties. For example, tamarisk covers 650,000 hectares in the western part of the state, and estimates predict tamarisk will cause $7 to $16 billion in lost ecosystem services (e.g., flood control, water supply, and wildlife benefits) over a 55-year period (WGFD 2010).

Aquatic invasive species can also significantly impact systems in the state, affecting: drainage for agriculture and forestry; water quality, quantity and flow; flood control; animal and human health; irrigation; hydropower generation; recreational and commercial activities; and land values. The most notable aquatic invasive species in Wyoming are the New Zealand mud snail and Myxobolus cerebralis (a parasite that causes whirling disease). However zebra and quagga mussels, which are more damaging species present in neighboring states, are a greater threat. Wyoming is home to four river basins: the Missouri-Mississippi, Green-Colorado, Snake-Columbia, and the Great Salt Lake. As a headwater state, Wyoming is working to halt the spread of these aquatic species and others downstream (WGFD 2010).

The spread of invasive plant species can be brought on by a number of factors. For example, invasive species may benefit from variations brought on by climate change, such as major fluctuations in temperature and precipitation, or in the frequency and intensity of natural disturbances (e.g., fire, drought). Land disturbance from human and other natural causes (which are all on the rise) also contribute to the spread of invasives. Examples include: development, disruption of natural disturbance regimes, overgrazing, and off-road vehicle use.

3.2.4 Climate Change

According to WGFD, the biggest impact on the quality and quantity of wildlife habitat in Wyoming will result from the exacerbation of non-climate stressors and ecosystem change agents due to climate change (2010). In many cases, the warmer, drier climate predicted for the region may significantly affect native fish and wildlife populations, particularly in the face of other stressors such as increased habitat loss and disturbance, land and resource development, and the expanding presence of non-native invasive species.

As changes to habitats occur, species will be forced to try and adapt or seek better conditions. However, increasingly fragmented habitats combined with limited conservation areas and

increased human development will create a situation where the ecological boundaries may be impassable to wildlife. This and other related factors may contribute to the extirpation of populations or even species (Heinz Center 2011).

3.2.5 Disruption of Historic Disturbance Regimes

Natural disturbances affect most ecosystems and the wildlife they support. Examples of natural disturbance include: floods, wildfires, droughts, storms, and disease outbreaks.

Periodic disturbances are normal and necessary for an ecosystem to maintain its productivity and functionality. Although disturbance regimes can naturally change over time, emerging factors have the potential to dramatically alter, suppress, or accelerate these regimes. These factors include fragmentation and modification of environments due to human activities, as well as variations caused by impacts such as climate change. Rapid changes in disturbance regimes may have dire and detrimental consequences on the systems they influence. A notable example in the western U.S. are pine bark beetle outbreaks, which have destroyed forest areas and in doing so are also affecting air quality. In Wyoming, the disturbance regimes of greatest concern to wildlife and natural resource managers are disruptions in historic water flow (i.e., stream flow), and alterations in fire and grazing regimes (WGFD 2010).

Although these five conservation challenges are some of the leading threats to ecosystems in Wyoming, there are many other challenges facing aquatic and terrestrial systems in the state. Additional threats and stressors were discussed throughout the Wyoming workshop. Chapter 5 of this report provides a description of the exercise used to identify and discuss the key threats and stressors to the workshops target ecosystems. A full list of these threats and stressors can be found in Appendix 1.

3.3 Challenges and Opportunities in Wyoming

Throughout the workshop, participants shared their broader insights about the challenges and conditions in Wyoming.

Many felt that one of the key problems contributing to decline in the sagebrush system, for example, is a lack of education and awareness. While a person driving along the highway might look at the sagebrush and think it is intact, someone with a trained eye would note signs of deterioration such as lack of younger plants in the sagebrush stand. One participant described the situation as a slow but steady consistent and continual alteration – with the landscape slowly altering to a more xeric state.

This conversion is the result of many factors, including gradual erosion, lowering of the water table, and development activities.

As mentioned, although participants cited a combination of factors which they felt were responsible for the root of the problem, primarily a lack of public understanding and awareness is their primary concern. Contributing factors to this lack of understanding include neglect, lack of knowledge, and underestimation of the threat's magnitude. The current situation was described as one in which there is a high level of threat and a low level of concern. Participants unanimously agreed that to change the rate of habitat loss in the state, one needs the support of the general public.

To address the awareness challenge, participants noted the need to translate information into language and materials easily understood and in forms easily accessed by the public. The public must understand the consequences, the social value of natural resources, and the ultimate trade-offs associated with various courses of action. With this information, they can make informed decisions about wildlife and habitat conservation that will affect all citizens in Wyoming for generations.

On multiple occasions throughout the workshop, participants noted that there is an abundance of project- specific monitoring that takes place in Wyoming, particularly in conjunction with new energy development. This monitoring could be used to develop baseline indicators such as noise threshold and structural diversity. However, because these monitoring activities are site specific, there are concerns over the applicability of the data that are collected at broader spatial and temporal scales. One idea for future collaboration and research is to evaluate how all of the site- and project-specific monitoring might feed into a system that can create a better overall picture of wildlife and habitats.

Because of the abundance of site-specific monitoring information, a question was posed to the group: What data from these short-term monitoring efforts could be useful for establishing important relationships of cause-and-effect between conservation actions, threats and stressors, and the conservation targets? The group noted that even short-term data offers valuable insights into these causal relationships. However they also highlighted several problems with these data sets, including reliability, replicability, and long-term maintenance of the data.

Because sage grouse has been proposed for listing under the federal Endangered Species Act, much energy and resources are being devoted to tracking the status of this species. The state of Wyoming has identified core sage grouse areas based on current data rather than historical data. The database for sage grouse data is structured as a statewide framework, with areas of greater intensity of data collection and sage grouse utilization. In the future, participants suggested comparing results from the core area studies with more localized studies in areas that have been less thoroughly sampled.

Participants felt that there is a lot of money being spent on monitoring in Wyoming, and a lot of monitoring being done, with often only minimal links between the two. Like their colleagues in other states, Wyoming’s wildlife managers hope to someday have a system that will enable them to share

data across monitoring programs to help them improve their efficiency, use resources more effectively, and improve the results of their conservation work.

At the conclusion of the workshop, the group identified the top three short-term opportunities for collaboration and next steps (see Section 9.3).

4.0 Shared Priorities for Conservation and Monitoring

4.1 The Challenge of Multiple Conservation Targets

The word "target" is used in many different ways by wildlife and natural resource managers. A "target" can be a desired population size, a land protection goal, a financial or budgetary objective, or the species or area that is itself the focus of management.

Following the lead of groups like The Nature Conservancy and World Wildlife Fund, many conservation organizations are adopting a more restrictive definition for the word "target" (Heinz Center 2008). By this definition, a "target" is a particular species, vegetation community, landscape, or defined geographic area which is the subject of conservation management. In this chapter the word "target" is used in this more restrictive sense to develop a preliminary set of performance indicators for state wildlife managers and their partners.

Even using the more restrictive definition of the word, the Wyoming SWAP lists a significant number of potential conservation "targets." These conservation "targets" include all of the SGCN (see Appendix 2) and all of the ecosystems or vegetation communities of conservation interest within the state. Each species, ecosystem, and vegetation community listed is a worthy conservation target, deserving careful attention from wildlife and natural resource managers, scientists, and field biologists. At the same time, the state and its partners have limited resources available for conservation activities, making it unrealistic to focus on all the possible targets, and therefore some taxa will necessarily receive attention before others. This is especially true in the case of monitoring activities, where there are extremely limited resources available for monitoring individual species or ecosystem attributes.

Considerable resources are already dedicated to monitoring populations of species that are known to be of conservation interest, such as species listed under the U.S. Endangered Species Act. The monitoring of individual species is a complicated endeavor that requires considerable knowledge of a species' biology, development and testing of sampling protocols, and a firm understanding of the statistical basis for translating monitoring data into estimates of population trends and other information needed by wildlife and natural resource managers. Monitoring of individual species is both time- and labor-intensive, with significant commitments of staff and financial resources. In the current funding environment, support for new monitoring programs or projects focused on individual species is likely to be extremely limited for the foreseeable future.

In many cases, **monitoring of ecosystems or vegetation communities** may be more tractable than individual species monitoring. For many communities, such as grasslands, shrublands, and forests,

there are readily available metrics of composition and structure that can be applied at the stand or plot level. Many of these same metrics can also be assessed using remote sensing imagery from satellites or aerial photographs. Focusing on ecosystems or vegetation communities as monitoring targets has the added benefit that the monitoring programs for individual species often fit geographically within particular large-scale ecosystem or vegetation types (for example, sage grouse monitoring efforts occur within sagebrush communities).

Furthermore, the presence or abundance of individual animal species can provide indirect measures of ecosystem function or vegetation condition (as in the case of species that are sensitive to fire or to the presence of certain invasive species).

Given the limited resources for monitoring species and ecosystems, it is often desirable to select a set of highest-priority species, ecosystems, or vegetation communities that can serve as foci for monitoring. In this initial approach for Wyoming, the focus is on large-scale vegetation communities or ecosystems as the primary set of conservation targets for collaborative, multi-agency, multi-jurisdictional monitoring. Each of these broad targets contains within it many individual species and sub-communities which are themselves potential targets of management and monitoring.

Monitoring activities for individual species can help inform efforts to understand the status and trends of the larger system within which these species are embedded. Within a given ecosystem, individual species are often associated with particular habitat variables such as stand density or canopy cover. Such species could potentially serve as "indicators" of their associated aspects of habitat condition. Taken together, trends in the suite of species associated with a particular ecosystem or community can also help measure the overall ecosystem response to environmental stressors.

4.2 Identifying Shared Priorities and Targets in Wyoming

Working together, Dennis Saville (WY BLM) and Glenn Pauley (WGFD) developed a collaborative list of priority ecosystem-level management and monitoring targets for their two agencies in advance of the May 2011 workshop. They independently surveyed colleagues and key decision-makers within each of their agencies to identify the top five conservation targets (sensitive species or important habitat areas) that will require the most time and resources over the next 18 to 24 months. For both agencies, sagebrush ecosystems emerged as a top priority, followed closely by riparian ecosystems. Prairie grasslands were identified as a third ecosystem of priority, with particular interest to the BLM.

4.3 Results: Overview of Workshop's Target Ecosystems

Below are descriptions of the three systems selected for analysis at the workshop: sagebrush, riparian areas, and prairie grasslands.

4.3.1 Sagebrush

The 2010 Wyoming SWAP notes that Wyoming contains more sagebrush-dominated landscapes than any other state, estimated between 23.5 and 37 million acres. Sagebrush may be found at elevations from 4,000 to 9,500+ feet, with varying topography, soil types, and precipitation gradients. Sagebrush communities can contain large patches of single species, or an assortment of sagebrush species and subspecies. Other plant species associated with sagebrush include: rabbitbrush, aspen, mountain shrubs, salt desert shrubs, and conifers. Wildlife supported by the sagebrush habitat include: elk, mule deer, pronghorn, sage grouse, sage sparrow, Brewer's sparrow, pygmy rabbit, sagebrush vole, and the sagebrush lizard (WGFD 2010).

While many states have sagebrush habitats, Wyoming is notable because it supports approximately 54 percent of the greater sage grouse in the United States, and the largest populations of migratory ungulates in North America. Other Species of Greatest Conservation Need associated with sagebrush habitats include the swift fox, white-tailed prairie dog, Swainson's hawk, Great Basin skink, Great Basin spadefoot, and various species of bats.

Invertebrate communities, while not well understood, may be critical to the effectiveness of sagebrush as wildlife habitat. Human uses of the system include: agriculture, mining, energy development (e.g., oil, gas, coal-bed methane, wind), outdoor recreation, and urban/suburban development (WGFD 2010).

Natural disturbances are a key component to the structure and composition of sagebrush systems. They include fire, herbivory, precipitation, plant disease, and burrowing animals. Threats and stressors to the system as outlined in the SWAP include: invasive plants, incompatible energy development and mining practices, rural subdivision, off-road vehicle use, varying management goals, conflicting views about sagebrush ecosystem ecology and wildlife management, incompatible grazing management practices, conifer encroachment, drought, and climate change.

A large amount of sagebrush habitat in Wyoming occurs on public lands, thus providing management opportunities in light of ongoing natural resource conflict and habitat conversion issues. A number of existing initiatives are addressing sagebrush conservation issues, including:

- the Sage grouse Core Area Strategy;
- local sage grouse working groups;
- WGFD's Strategic Habitat Plan and Mule Deer Working Group;

- Wyoming Landscape Conservation Initiative;
- Jonah Interagency Office;
- coordinated resource management;
- Natural Resource Conservation Service; and
- various groups conducting site-specific habitat treatments.

4.3.2 Riparian systems

Riparian systems represent about 1.2 percent of the state of Wyoming. They are a sub-component of the more broadly defined wetland habitat type described in the Wyoming SWAP. Riparian systems can be found in both mountain and lowland areas, which differ in stream gradient, temperature, and vegetation. Sedges and short willow shrublands are often found in mountain riparian systems, with alder and tall willows increasing in lower elevations, along with Engelmann spruce, narrowleaf cottonwood, lodgepole pine, and aspen. Lowland riparian areas contain trees such as boxelder, cottonwood, willow, and elm. The understory shrubs in lowland areas include chokecherry, hawthorn, rabbitbrush, and silver sagebrush (WGFD 2010).

Over 60 percent of terrestrial vertebrate species in Wyoming are believed to show preference for riparian habitats, particularly birds. This includes the yellow-billed cuckoo and willow flycatcher, two of the most imperiled migratory species in Wyoming (WGFD 2010).

Riparian areas are important wildlife movement corridors and migration habitats. Elk, moose, mule deer, and pronghorn, as well as shrews, jumping mice, and bats, are all dependent on riparian habitats for at least part of the year. Beaver ponds provide habitat for several species of native fish, including the Colorado River cutthroat trout and the Yellowstone cutthroat trout. Ponds also provide habitat for river otter, mink, and muskrat. Frogs, toads, salamanders, snakes and turtles also inhabit riparian areas. Additional species with a preference for riparian habitats are SGCN outlined in the SWAP, including: the bald eagle, myotis bat species, gartersnakes, and the Columbia Spotted and Northern Leopard frogs (WGFD 2010).

The SWAP notes that riparian areas are among the habitat types most used and altered by human activity and development. Most urban development occurs near riparian

zones, and a high percentage of riparian areas are privately owned today. Agriculture, recreation, travel, water development, and housing all compete for riparian resources. Threats and stressors to riparian habitats as outlined in the SWAP include: water development/altered flow regimes, drought, climate change, invasive species, ungulate grazing and browsing, rural subdivision and development, and incompatible energy development practices (WGFD 2010).

Because of the considerable diversity of wildlife in riparian areas, these threats and stressors have the potential to impact an important segment of the state's overall wildlife diversity.

Current initiatives to protect and restore riparian areas include:

- WGFD's Strategic Habitat Plan;
- land programs such as the Wyoming Wildlife and Natural Resource Trust, WGFD Trust Fund, and USDA Farm Bill programs;
- coordinated resource management teams;
- basin and statewide water plans;
- programs to implement water management strategies and in-stream flow plans; and
- individual projects to conduct beaver transplants and invasive species mapping and removal (WGFD 2010).

4.3.3 Prairie Grasslands

According to the SWAP, Wyoming has among the highest proportion of intact grasslands in the United States. Prairie grasslands occur below 7,000 feet in elevation and can be found primarily in eastern Wyoming.

During the workshop, Glenn Pauley (WGFD) noted that about ten percent of the state (or a little over six million acres) is considered grassland. Many of Wyoming's prairie grassland areas are privately owned (i.e., ranches). Shortgrass prairie occurs in the southeast corner of the state and consists of species such as buffalo grass and blue grama. Mixed-grass prairie can be found throughout the eastern portion of the state, where the varieties include: needle-and-thread, western wheatgrass, blue grama, Sandberg's bluegrass, prairie Junegrass, upland sedges, and Indian ricegrass (WGFD 2010).

Some of Wyoming's best-known wildlife species, including pronghorn and the western meadowlark, are found in prairie grassland systems. Other wildlife found there include: prairie dogs, black-footed ferret, burrowing owls, mountain plover, swift fox, ferruginous hawks, and golden eagles. Due to habitat conversion in the Great Plains,

the core distribution of many wildlife species is now found in Wyoming (particularly for mountain plover, swift fox, ferruginous hawk, and pronghorn) (WGFD 2010).

Historically, regular disturbances such as drought, fire, and grazing created a mosaic of vegetation of different growth stages and composition. Currently, livestock grazing (which somewhat mimics historical bison grazing) coupled with Wyoming's low population density has allowed grasslands to remain relatively intact. Increased pressures from ranching will affect the integrity of the system, as will oil and gas extraction, wind power, recreation, and housing development. Threats and stressors identified in the SWAP include: energy development, invasive plant species, off-road vehicle use, reduced vegetation structure and species diversity due to altered disturbance regimes, drought, climate change, rural subdivision and development, conversion to agriculture, and improper use of pesticides and herbicides.

The Wyoming SWAP notes that Great Plains grasslands are among the most imperiled ecosystems in North America. Initiatives to protect this important system include:

- a plan published in 2006 for Bird and Mammal SGCN in Eastern Wyoming;
- Farm Bill programs;
- WGFD's Strategic Habitat Plan, as well as their Public Lands/Private Wildlife Program, Landowner Incentive Program, and Habitat Extension Services;
- U.S. Fish and Wildlife Service Partners for Fish and Wildlife Program;
- the Prairie Plains and Pothole and Great Plains Landscape Conservation Cooperatives;
- Thunder Basin Grasslands Prairie Ecosystem Association;
- the Shirley Basin-Laramie Rivers Conservation Action Plan; and
- the Southeast Wyoming Cheatgrass Partnership.

5.0 Conceptual Modeling

5.1 Introduction

Previous sections of this report have discussed how stakeholders can work together to identify priority conservation targets, and why adaptive management is essential to managing wildlife in an uncertain future.

Once shared priority conservation targets have been identified, conceptual models can be used to show linkages between the targets, threats and stressors, and conservation actions. Such conceptual models can be important tools in conservation planning, in the development of assessment and monitoring programs, and in the identification of opportunities for future management and research activities.

Conceptual models describe in graphical or narrative form the ecological system subject to management, allowing inference about how that system works. A model of riparian vegetation function on the Colorado River, for example, describes the relationships between vegetation and the wildlife that depend on it, the hydrological and other physical processes that affect those relationships, and the role of human activities in disturbing and sustaining the system.

Conceptual models also document a specific version of the hypotheses about how wildlife survive and persist, and how the ecological systems that they depend on function. They illustrate the relationships between ecosystems, threats, and management actions that have been observed by state wildlife biologists and their conservation partners. The models thus represent the current status of knowledge among state wildlife managers regarding these conservation targets - not only of how they function, but also of their ability to impact targets through management actions.

Conceptual models that explicitly link targeted wildlife species to essential resources and environmental stressors naturally lead to the identification of ecological factors that need to be targeted by management actions, and to candidate environmental parameters that should be measured by monitoring efforts.

In the formulation of a conceptual model, the combination of environmental influences that drives an ecological system often becomes apparent. This in turn allows planners to rank the importance of different attributes in determining system function, affecting the status and trends of wildlife populations. Using conceptual models helps us to assure that our current and future management

actions target the correct ecosystem features and attributes, and to maximize the likelihood that management activities in the state will produce desired outcomes.

By utilizing conceptual models, managers seek a clear articulation of what is known about wildlife and the ecological systems that support them - systems which are subject to management, assessment, and monitoring. These activities produce explicit descriptions of how the state's land and wildlife managers believe their targeted ecosystems and wildlife operate. The process of developing species- and ecosystem-specific conceptual models has proven to be an effective way of exposing differences of opinion regarding the essential relationships between desired wildlife species and the diverse environmental drivers that influence them, as well as the management actions that are intended to benefit them.

Conceptual models serve to identify key system elements, including targeted species, the structure and composition of the ecosystem in which they exist, and the processes that link those species with other biotic elements and physical attributes of the system. The models describe how the system may be impacted by environmental stressors (e.g., disturbances, perturbations) generated by both natural and anthropogenic sources, and how management can intervene to reverse undesirable ecological conditions or wildlife population trends. These descriptions variously take one or more forms, which include box and arrow diagrams, drawings or cartoons accompanied by narrative descriptions, simple linear pathway illustrations, or straightforward text descriptions.

5.2 Core Principles

Several important principles were considered in the formulation of the conceptual models contained in this report.

First, because it is not fully understood how the ecosystems that support our wildlife operate, models are nearly always incorrect in one or even a number of ways. Repeated refinement of these models is necessary as new information or new understandings of ecological interactions become available. Nonetheless, each iterative model tends to reduce uncertainties that confound our management efforts.

Second, as adaptive management efforts become increasingly effective, the conceptual models can improve. As more is learned about how systems function, management can become more effective and efficient.

Finally, the conceptual models generated are essential tools to facilitate learning. They represent a common understanding of how these systems in Wyoming work, providing opportunities for collaboration and coordination across existing conservation efforts. The models also help us to identify key areas of uncertainty, highlighting areas where more information is necessary to make better management decisions.

5.3 Exercise: Conceptual Modeling of Wyoming Priority Habitats

During the May 2011 workshop, participating conservation partners used a simple exercise to develop a series of conceptual models for the set of high-priority targets that were previously identified through a collaborative process.

These conceptual models articulate the relationship between threats, stressors, and conservation actions, which are described in further detail below.

5.3.1 Setting the Stage: Developing Statements of Desired Condition

A prerequisite to the conceptual model is a statement of desired condition. Desired condition statements articulate the requirements for a functioning ecosystem by incorporating key ecosystem attributes. Collaboratively defining what a system should look like, in cooperation with conservation partners, helps to articulate shared future management goals. Strategies for achieving stated goals are implicit in the conversation about conservation actions and monitoring, and are an important part of the discussion.

For each target, the group developed a list of desired conditions through a brainstorming exercise. This exercise is designed to identify the ideal attributes for a functioning system, which have the potential to be assessed through visits to a particular site or area of conservation/management interest. Attributes that were commonly listed for ecosystem-scale targets include:

- Characteristic vegetation (e.g., composition, age structure, patchiness)
- Intact watershed (e.g., adequate buffer zone to upland disturbances)
- Full suite of associated and/or obligate vertebrate species
- Absence of key stressors (e.g., invasive species, roads, vehicle traffic)
- Disturbance regimes within expected parameters (e.g., fire, flooding, insect)
- Resilience and recovery from natural events
- Absence of structures that impact wildlife (e.g., roads, wells, wind turbines, transmission lines)

Later in the workshop process, desired condition statements together with the conceptual models begin to identify potential indicators of ecosystem condition or management effectiveness. These potential indicators are further narrowed down to a manageable set of critical measures. Indicators are developed for each level in the model – desired condition, threats and stressors, and conservation actions.

5.3.2 Model Components: Defining Threats, Stressors and Conservation Actions

As noted in the introduction to this Section (5.1), a conceptual model demonstrates linkages between three core elements: a conservation target, threats and stressors to the target, and management actions that may benefit the target through their ability to reduce threats and stressors.

During the workshop, participants brainstormed lists of potential threats and stressors for each target. ***Threats*** are actions or processes that have the potential to cause direct harm to a particular target, while ***stressors*** are actions or processes that cause stress to the target.

Once identified, threats and stressors were sorted into two groups: ***direct threats and stressors***, which operate directly on the target; and ***indirect threats and stressors***, which operate on the target through an intermediary. For example, off-highway vehicle use impacts the prairie grassland landscape directly, and would therefore be considered a direct threat to the ecosystem. By comparison, land user attitudes towards the ecosystem would operate indirectly through their influence on OHV users, and thus would be seen as indirect. The stakeholder working groups agreed by consensus on the classification of individual threats and stressors into the direct or indirect categories.

Next, lists of potential ***conservation actions*** were brainstormed that either directly benefit the target or counter one or more of the threats and stressors. It is important to note that some conservation actions, such as habitat treatments, can and do have unintended impacts on non-target species.

The complete lists of threats, stressors, and conservation actions resulting from this exercise are found in Appendix 1.

5.3.3 Model Construction

For purposes of constructing the conceptual model, the threats and stressors were written on small “Post-It” notes and arranged around a central “Post-it” note listing the conservation target that was placed at the center of a large sheet of poster paper.

The next step was to draw arrows between threats/stressors and the conservation target, and between the various threats and stressors to show patterns of interactions between the threats/stressors and the target. The arrows indicate causal pathways, with the item on the blunt end of the arrow causing some form of change in the item

on the pointed end of the arrow. Reciprocal relationships are possible (arrows pointing in both directions between two stressors, for example), as are loops. Arrows were drawn by the workshop facilitators once the project stakeholders achieved consensus regarding the direction and placement of each arrow.

The group identified the most significant threats/stressors for each target, recognizing that different threats and stressors operate at different temporal and spatial scales and that certain threats are likely to be more significant for particular conservation targets than others.

In the last step of model construction, the individual conservation activities were written on "Post-It" notes and these notes were added to the model, with arrows showing how those conservation activities would affect particular threats/stressors or the target itself. Most conservation activities map to one or more of the threats/stressors. An example of a conservation activity that addresses a threat or stressor would be the removal of invasive vegetation. An example of a conservation activity that addresses the target directly would be the augmentation of a population of a particular fish species through translocation, when the fish species itself is the target. Again, the arrows were drawn between conservation activities, threats/stressors, and the conservation target once the project stakeholders had achieved consensus on the direction and placement of each arrow.

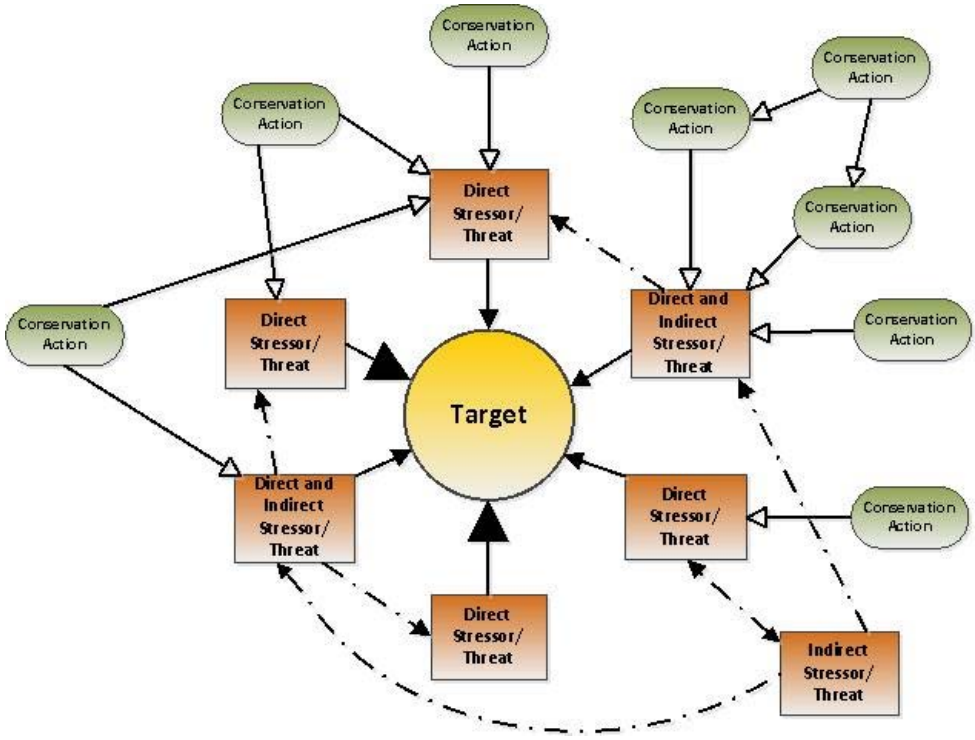
5.3.4 Model Refinement

Following the workshop, facilitators from the Heinz Center refined and reconstructed the models using Microsoft Visio software. The resulting models are found in Appendix 3. As noted earlier in the chapter, these models will continue to evolve with increased knowledge of the complex systems and interactions they depict.

5.4 Conceptual Models for Priority Ecosystems in Wyoming

Through the exercise described in Section 5.3, three conceptual models were developed (see Appendix 3), one for each target ecosystem identified by the group. A sample conceptual model is shown in the figure below.

Each model includes a target system (yellow circle), a suite of threats or stressors (direct and/or indirect – represented by orange boxes), and possible conservation actions to alleviate the threats or stressors (green boxes). The arrows indicate cause-and-effect relationships, and can either be uni-directional or multi-directional.



A key to understanding components of the conceptual models:

- ***Direct stressors*** (orange squares typically placed closest to the target) have a solid line with a solid arrowhead leading from them. Thicker arrowheads indicate the most significant stressors/threats to the target, as determined by the stakeholder group.
- ***Indirect stressors*** (orange squares typically placed farther from the target) have a dashed line with a solid arrowhead leading from them.
- ***Conservation actions*** (green ovals typically placed on the outer ring of the circle) have a solid line with an open arrowhead leading from them.

Note that some stressors can have both *indirect* and *direct* effects. For example, in the sagebrush conceptual model (Appendix 3), rural subdivision has a *direct* effect on sagebrush systems as well as *indirect* effects through other stressors such as roads, power lines, and ORV use.

5.4.1 Sagebrush

The first model in Appendix 3 depicts the direct and indirect threats, as well as conservation actions, for the sagebrush system. Workshop participants brainstormed a list of 15 threats and stressors, of which 11 had direct impacts to the system. Of those 11 direct threats and stressors, five were seen as particularly challenging: incompatible energy development/mining, incompatible grazing management practices, invasive species, roads (both main roads and two-track roads), and ORV use. Other important threats and stressors included categories such as rural subdivision (both a direct and indirect stressor, including

broader development such as new industrial facilities), chemical and mechanical treatments, fences, disruption of natural disturbance regimes, and climate change. Nearly all of the 12 conservation actions discussed impact the top five threats and stressors, including: reclamation, grazing management, big game management, education (particularly impacting ORV use), habitat treatments (including prescribed fire), suppression-response to fire, ORV management and regulation, and development approval processes (related to energy development).

While creating the model, the sagebrush breakout group noted the interrelatedness of many of the threats and stressors. For instance, fences and roads are interconnected, as are other activities that lead to fragmentation. In turn, corridor preservation is a management action that applies to all fragmenting activities, including rural subdivision and energy development. Other examples include climate change and its influence on many stressors (particularly insect outbreaks), and the link between incompatible grazing and drought.

Participants perceived invasives control as an overarching way to treat many of the major concerns. Proper permitting was applied to ORV use, pipelines, powerlines, energy development, grazing, and invasives. Fire management was split into two distinct categories: prescribed fire (a long-term habitat treatment) and fire suppression/response (a short-term action to minimize fire and invasives).

5.4.2 Riparian Areas

The second conceptual model in Appendix 3 shows threats/stressors and conservation actions affecting riparian areas in Wyoming. Break-out group members brainstormed a list of 21 threats/stressors to the system, including bank stabilization, channelization, illegal dumping, levees, rural subdivision and development in the floodplain and watershed, floodplain development (other infrastructure and commercial), ungulate grazing and browsing, low water quality and water pollution, recreation (e.g., camping, rafting, trees for firewood)and ORV use, invasive species (e.g., Russian olive, tamarisk), and water development/altered flow regime (including irrigation). Of these 21 threats and stressors, three were identified as a priority or most impactful to the system: water development/altered flow regime, invasive species, and ungulate grazing browsing. Five were shown to impact the system only in an indirect way: climate change, drought, changed snow patterns, wildfire, and pests (e.g., bark beetle). The remaining 16 threats/stressors impact the system directly, and often indirectly as well.

Participants also brainstormed 13 conservation actions that can be used to address certain threats/stressors, including: in-stream flow conservation efforts, fencing/managed grazing, invasive plant control, 404 permitting activities under the Clean Water Act, watershed and agricultural best management practices (BMPs) and buffers, wetland and oxbow restoration, and bank stabilization to improve fish habitat and protect portions of the stream. Group members consider riparian habitat restoration and treatments an activity that can positively influence all the threats/stressors. Bank stabilization is considered both a threat to riparian areas as well as a conservation action depending on how it is used.

Because of the large number of threats and stressors identified by the group, and the recognition by members that most were interrelated, this conceptual model differs from the other in this report. The *indirect* interactions between the threats/stressors that *directly* affect riparian areas are not shown for readability. The focus instead is on the conservation actions, those management activities that WGFD and other agencies may make to improve or maintain the health of the system.

5.4.3 Prairie Grasslands

Before breaking into two sub-groups to develop the sagebrush and riparian models (5.4.1 and 5.4.2; Appendix 3), the full group worked together to create a conceptual model for prairie grasslands (Appendix 3).

Of the 13 threats identified, 12 were designated as direct stressors. These included fire, grazing, OHV use, energy development, and fragmentation (especially as the result of fencing).

The group decided that OHV use, rural subdivision and development, energy development, climate change, drought, fire, and grazing are both direct and indirect stressors, and that land user attitude is solely an indirect stressor. Participants identified indirect impacts of climate change as drought, invasive species, and insect outbreaks (especially grasshoppers).

It was noted that the Conservation Reserve Program should be considered as a subset of restoration projects and conservation easements, and that NRCS grazing management is a subset of the broad category of grazing management.

Participants shared that when an area of land receives “National Grasslands” designation, pre-established guidelines provide a management framework for all targets.

There was a discussion about regulation, specifically about voluntary and non-voluntary actions versus BMPs. Participants noted that much of prairie grasslands are privately owned so there is less control over them and more reliance on private landholders for enforcement of conservation actions.

Participants also differentiated between restoration efforts, which are voluntary and/or voluntary with incentives, and reclamation efforts, which are regulatory and mandatory. It was noted that grazing management is mandatory on all public lands.

The group discussed the need to identify key ecological attributes. They concluded that while they did not know of any groups monitoring invasive species in the state, there are designated lists for noxious weeds and pests.

6.0 Indicator Selection

6.1 Overview

The use of indicators to assess performance of wildlife management programs is not a luxury – it is a necessity. Given resource constraints, only a relatively small number of wildlife species and ecosystem parameters can be monitored, assessed, or measured.

Monitoring efforts typically include data collection activities that target a subset of the species, habitat attributes, landscape features, and vegetation conditions of conservation concern. Monitoring requires identification of a subset of candidate ecological features that are useful surrogates for - or indicators of - the greater array of organisms and other environmental attributes and processes that wildlife action planning seeks to manage. We are searching for reliable, cost-effective measures of the status or trend of wildlife and environmental phenomena that are scientifically or logistically challenging to measure directly.

For example, population of a given species (a well-defined, measurable variable) can be a good indicator of habitat quality (which is more abstract and harder to measure). If you have a population that is maintained at or above objective, then the habitat is generally in good condition. Whereas long term population decline would be an indicator of poor habitat condition.

Similarly, species can serve as indicators for one another. For example, raptor populations are responsive to the abundance of small animals.

An effective indicator species is recognized here as a species “so intimately associated with particular environmental conditions that its presence indicates the existence of those conditions” (see Patton 1987). Indicator species more generally meet the definition from Fleishman and Murphy (2009) as a “scientifically reliable, cost-effective measure of the status or trend of an environmental phenomenon, which is not scientifically or logistically tractable to measure directly.”

Bringing necessary rigor to the indicator selection process is challenging; it requires a clear articulation of the reasons for identifying an indicator or indicators, the assumptions used in the indicator selection process, and the purpose for which the indicator will be used. While an indicator is an incredibly useful tool for managers, it requires substantial effort to design and develop. When considering a potential indicator, potential reasons for acceptance or rejection may include the number of managers who will find it useful, whether or not it captures information about a priority species or ecosystem, and the availability of data to inform the indicator.

An emphasis on direct measures of wildlife abundances and habitat conditions will inevitably dominate monitoring in wildlife action planning. A comprehensive monitoring program will use some limited number of wildlife species for purposes of guiding management actions targeting a larger group of species. Likewise it will include indicators that collectively measure compositional, structural, and functional attributes of vegetation and other components of ecological systems at a variety of spatial scales (see Lindenmeyer et al. 2000, Noon and Dale 2002). The monitoring parameters that are directly measured may include aspects of the demography, life history, or behavior of an indicator species. These indicator measures are prototypical “fine-filter” measures of ecosystem health or integrity (Hunter et al. 1988, Haufler et al. 1996, Noon 2003).

Some species selected for measurement are intended as "coarse filters" - or broad measures - to provide insights into the status or trends of species that are not measured. ***Structure-based indicators*** are measured at local and landscape scales. Structure-based indicators include ecosystem elements, such as vegetation structural complexity, inter-patch heterogeneity, and connectivity at the landscape level. ***Function-based indicators*** rely on direct measures of processes and their rates, including primary productivity, nutrient cycling, water flows, and similar ecosystem process parameters. Both structure and function indicators serve as “coarse filter” measures of ecosystem condition.

6.2 Purpose

Indicators can be viewed as serving at least three essential functions:

1) ***Early warning indicators***, which provide early warning of specific stressors that are impacting key ecosystem processes;
2) ***Population surrogate indicators***, drawn from species whose status and trends are indicative of the status and trends of other species; and
3) ***Biodiversity indicators***, a species or taxonomic group that serves as a surrogate for multiple other taxonomic groups, and to the general health of a given ecosystem or geographic area.

Characteristics of effective indicator species include: sensitivity to environmental change, variability in responses, degree of ecological specialization, residence status, and population dynamics (Landres et al. 1988).

6.3 Process

Several sequential steps are necessary to inform a defensible indicator selection process, and are employed in developing a target-directed monitoring program:

1) **Define programmatic goals and planning criteria**; from the overarching goals, **identify explicit, quantifiable objectives**.

2) **Build conceptual model(s)** describing the target ecosystem and its wildlife, illustrating the species involved and the essential ecosystem attributes that affect those species, with an emphasis on stressors (both natural and human-generated) which impact the targeted species and their habitats and will require management responses.

3) **List opportunities and options for management actions**.

4) **Create a comprehensive list of candidate indicators** drawn from the list of wildlife species that are supported by the targeted ecosystem, and from the landscape features and ecological attributes of the system that contribute to habitat for those species. Candidate indicators are drawn from available ecosystem attributes at multiple spatial scales. These are inclusive, such as physical environmental parameters and biotic parameters, including potential structural, compositional, and process variables.

5) **Choose indicator measures** using explicit criteria that are consistent with assessment goals. These measures are those for which a causal chain can be identified that link the parameter to the environmental phenomenon of immediate concern. Measures can be found in any component (e.g., drivers, linkages, outcomes, and endpoints) of the conceptual models.

6) **Develop a sampling scheme** using estimates of expected values (or trends) of selected performance measures to assess the state of those measures following management actions.

Monitoring program designers identify indicator measure values that will trigger management responses, and fully consider issues of spatial context (including heterogeneity), temporal resolution and extent, and sample size and units of measure. Monitoring design elements reference back to program and project goals, and conceptual models are necessary tools for developing a sampling scheme that will detect pertinent changes in performance measure and ecosystem attributes. Sampling frequency and replication needed to detect trends in indicators should be based on historical data where possible and power analyses that interrelate the percentage change that can be detected, variance of the parameter, and replication in space and time.

6.4 Exercise: Selecting Indicators in Wyoming

In this workshop exercise, Wyoming stakeholders identified potential indicators (e.g., key rates, states, or processes) that could be monitored by managers in “real time.” These indicators would allow managers to track the condition of each priority conservation target, the effects of the threats

and stressors on the target, and the effectiveness of various conservation activities intended to benefit the target.

For each box in the conceptual model (i.e., threat/stressor, conservation action), as well as for each of the system's desired conditions, the stakeholder working groups brainstormed lists of potential indicators (e.g., metrics of status, trends, or key processes and rates).

To launch this exercise, an initial question was posed to the group: "What would you want to know about this target/stressor/action in an ideal world?" The result was a lengthy list of potential indicators.

The group reached a consensus on which information best conveys the status of a species. In ranked order they selected:

1) young-to-female ratios
2) population
3) harvest data

For each of the potential actions, we also asked whether or not there was anyone in the state actually pursuing that course of action, and listed the names of agencies and/or programs engaged in the specific types of activities identified in the conceptual model.

For each potential indicator, participants had a brainstorming session to identify individuals or group(s) (e.g., state agencies, federal agencies, tribes, NGOs, or academic biologists) that are currently collecting pertinent data within the state at appropriate temporal and spatial scales to adequately inform land and wildlife managers about the condition of the target or the effects of stressors and the effectiveness of conservation activities.

The Heinz Center used information gathered during this brainstorming session to create a chart for each system listing potential indicators for sagebrush, riparian, and prairie grassland communities (see Appendix 4). The charts also include information about monitoring programs that are currently collecting data associated with these indicators. None of the participants were actively engaged in fish monitoring, so these programs are not well represented in the charts.

For the sagebrush and riparian systems, small working groups were encouraged to narrow their selection to five or six "provisional" indicators. (These indicators may require further clarification and definition.) To guide them, participants were provided with parameters suggesting that the indicators should:

1) Be well-defined (e.g., presence/absence, population trend);
2) Measure/reflect an important aspect of the system;
3) Consider a variable for which monitoring is already being done; and
4) Incorporate existing data/collection efforts.

Each group member was also asked to rank them in order of which they felt were most important. Below are the provisional indicators selected by the small groups, in rank order, as well as notes from their discussions:

Sagebrush Systems

1. Sage Grouse	Potential metrics included population size, presence or absence studies, distribution, reproductive success/fitness measures, and male bird attendance at leks. WGFD is currently collecting data on the average number and percent of disturbance per 640 acres of high quality habitat, tying these data to the population of leks. Using this information they create a GIS footprint of disturbance, although this is not characterized by disturbance type (e.g., oil or gas well). The development of this disturbance layer began in the study areas over the last few months, and they plan to take follow-up orthophotos every two years.
2. Other Wildlife Species	The group discussed other potential indicator species including pronghorn, ferruginous hawk, and native birds (e.g., Brewer's sparrow, sage thrasher, sage sparrow). It was noted that bird community composition can be used as an indicator of habitat condition (e.g., vegetation composition, understory structure), since some bird species have specific habitat needs and their presence or absence represents the plant/shrub composition in a particular area. In addition, the Rocky Mountain Bird Observatory's Integrated Monitoring of Bird Conservation Regions (IMBCR) Program collects some habitat information (e.g., vegetation composition, structure) along the same transects used to collect bird data.
3. Fragmentation/Condition	Potential metrics include patch size/heterogeneity, heterogeneity within patches, habitat condition, connectivity/corridors/fences, and disturbance patterns.
4. Invasive Species	Potential metrics include species presence/absence and extent.
5. Climate	Potential metrics include timing of precipitation, the Palmer Drought Index, and temperature.
6. Local Sage Condition	Potential indicator species include the white-tailed prairie dog, pygmy rabbit, and pocket gopher.

Riparian Systems

1. Measures of riparian area intactness	Possible metrics include the percent of area affected or altered (e.g., habitat loss) by anthropogenic development, which would be measured primarily through GIS. The Nature Conservancy may have this type of data.
2. Bird Community Demographics	Metrics suggested include: species presence or absence, abundance, diversity, evenness, analysis of trends, changes in reproduction, and survivorship. Participants recommended the use of a reference site for this study. Multiple agencies may already have existing multi-species data (depending on the scale), including some long-term data, however the monitoring techniques may be limited in some cases. Participants suggested monitoring specific SGCN as well (e.g., willow flycatcher, great blue heron), taking into consideration external influences on their presence or health (e.g., exposure to other habitats through migration or life cycle patterns).
3. Invasive species (both plant and animal)	Possible measures include: species presence or absence, abundance, diversity, analysis of trends, and prevalence.
4. Proper Functioning Condition (PFC) rank compared to desired condition of a functional system	The PFC measure may combine several indicators including: water quality, woody species, flow rates, channelization, standing and flowing water, and so forth. PFC is meant to provide an overall picture of the system's condition, to understand the habitat state in light of existing development. This in turn also allows managers to deduce species health.
5. Water quality for the stream class	The Wyoming Department of Environmental Quality has existing programs that capture water quality by stream class, with federal agency involvement.
6. Similarity of existing stream hydrograph compared to historic	Participants suggested using existing U.S. Geological Survey data.
7. Mammal, herpetiles, and aquatic (e.g., mollusk, fish, crustaceans) community demographics	Participants stated there is existing retrievable data (e.g., species composition, species presence/absence) housed within the appropriate departments at WGFD. Participants

	also recommended considering use of a reference site for these studies.
8. Vegetation species composition, structure, and cover	These variables could be compared to intact reference site and over time. Some of this information can be found through PFC (see above).

7.0 Review of Existing Monitoring Efforts in Wyoming

A variety of agencies and organizations in Wyoming use different methods for wildlife management and monitoring activities. The data captured through these activities is ideally meant to inform management in an adaptive management context. Although multiple initiatives take place throughout the state of Wyoming, it can be difficult to assemble a complete picture of the data being captured by various wildlife agencies and their partners.

During the Wyoming workshop, participants described a number of data collection efforts around monitoring activities in sagebrush, riparian, and prairie grasslands systems. The workshop provided several opportunities for participants to discuss the monitoring programs their agencies engage in throughout the state. For instance, during an opening presentation by Dennis Saville (WY BLM) and Glenn Pauley (WGFD), a number of programs and activities relevant to the three target ecosystems were mentioned. Later, a large group discussion that included a brainstorm of desired conditions, threats/stressors, and conservation actions for each ecosystem also included an opportunity for participants to list the monitoring programs associated with each system.

As the workshop progressed, both small group and large group discussions led to the creation of a **comprehensive (but not exhaustive) list of relevant monitoring programs within the state of Wyoming, which can be found in Appendix 5.** This spreadsheet includes the species type, area/spatial scale, and frequency, and reflects edits made by the large group during the final session of the workshop. Note: additional information on some monitoring programs can be found in Appendix 4.

7.1 Monitoring in the Sagebrush

One of the areas where WGFD and BLM are collaborating most actively is in monitoring of sage grouse and the sagebrush habitat. During the workshop, participants spent some time discussing species-specific monitoring in the Sagebrush. When considering long-term monitoring, it was concluded that the only species monitored consistently over the long-term are: sage grouse, antelope, and mule deer. Below are notes from the workshop discussion related to monitoring of these and other sagebrush species. This information can be used to supplement the comprehensive list of relevant monitoring programs mentioned in Section 7.0 and found in Appendix 5.

Sage Grouse	Sage Grouse monitoring in Wyoming is conducted cooperatively by both WGFD and BLM. Together they measure an area of about 25% of the state and about 60% of original sage grouse range, looking at variables like presence/absence and number of males on leks. The study is tied to science and population, looking at removals, alterations, and changes

	in habitat. It tracks all anthropogenic activity disturbing to birds, disturbed ground/habitat, and man-made unsuitable habitats. To measure these variables, they use GIS tools and aerial photos of digital plots, taken every two years and every time there is a new proposed development project. Lek surveys are done statewide, with particular emphasis on areas impacted by development and other disturbances. Not all leks are surveyed three times per season; there are localized priorities. All WGFD biologists participate in sage grouse surveys every spring. Hunter harvest surveys are completed for sage grouse as well. Through telemetry studies, thousands of birds have been monitored in the state. This is true especially in conjunction with a variety of development (e.g., energy, suburban). The information is housed in publically accessible databases hosted by WGFD. Though historical information varies by area, in some places the data dates back to around 1940. Data is consistently available for all monitored areas for approximately ten years.
Antelope	Monitoring techniques for antelope have changed from ground based to almost totally air based. WGFD conducts annual aerial antelope surveys done with line transects, gathering population estimates of hunt areas and presence/absence data. Hunter harvest surveys are also completed annually. Antelope are also radio collared, but this is considered less organized than sage grouse collaring. Long-term antelope monitoring data exists, however line transects used today were developed over the last five years.
Mule Deer	Classification surveys are conducted annually on mule deer, a species now monitored mostly by air. Hunter harvest surveys are also completed on mule deer. Population estimates from mule deer surveys are less reliable than for antelope; with mule deer it is mostly a modeling exercise allowing room for error. Participants discussed barriers to mule deer migration, such as fencing, and whether population could be estimated in places where underpasses have been created as corridors from winter to summer range.
Pronghorn	Telemetry studies are conducted on pronghorn. Pronghorn surveys are conducted via line transects to gauge population estimates. Pronghorn fawn-to-doe ratios are good indicators for pronghorn. Each herd is surveyed every third year by aerial survey. Movement of pronghorn is monitored, especially their population in Jackson Hole. They are also monitored in relation to energy development in the Upper Greene River Basin, and for their response to ongoing impacts from oil and gas development.
Prairie Dogs	Both white-tailed and black-tailed prairie dogs are surveyed similarly. Aerially surveys are conducted every three years on the estimated occupied acres in Wyoming, plus presence/absence data in 500 x 500 meter quadrants. Field staff map a portion of the quadrant that is occupied by a colony (600 colonies approximately, randomly selected), and revisit the same plots every three years. 40-50% may no longer have prairie dogs as they and other species come and go.

Elk	Elk are surveyed in much the same way as mule deer. Winter range surveys are also conducted on elk. This species occurs less frequently in sagebrush than in other systems.
Ferruginous hawk	Ferruginous hawks are monitored statewide to create a nesting population estimate and maintains a database on nest locations statewide. WGFD is currently in the process of refining and developing a new hawk monitoring approach that hasn't been finalized.
Swift fox	To monitor swift fox, WGFD uses scent stations with cameras. Each station camera records for five days. They record occupancy: one photo equals one occurrence. Station sites are randomly selected and stratified with habitat modeling.
Bat	Bat surveys have varied over the years. Some routes are communal for multiple species, and most often site specific monitoring has been done (re: development) to detect audible signals.
Small mammals	WGFD does limited monitoring of small mammals (e.g., mice, gophers). However specific studies, including distribution studies, have been done on Preble's Meadow jumping mouse and Wyoming pocket gopher. Similarly, there is no regular frequency of pygmy rabbit distribution monitoring, although some genetic studies have been done.

8.0 Future Directions in Monitoring

In Wyoming, the Bureau of Land Management, Wyoming Game and Fish Department, and their partners already have a number of monitoring efforts directed at particular species or taxa of conservation interest. Such efforts could potentially serve as building blocks for a more integrated approach. However, many monitoring programs were generally designed to assess status and population trends in individual species or suites of closely related species, or in specific locations (e.g., new energy development sites). Thus there may be incompatibilities between the individual monitoring programs (for example having different temporal or spatial sampling schemes) which could in turn lead to problems with comparing data across multiple monitoring programs. To build a more robust picture of ecosystem health and environmental condition, managers will want to improve coordination across the existing programs and move towards compatible data collection efforts.

Though improving coordination may seem like a daunting task to agencies already limited in their capacity, the process can be made easier by using systems already in place. The literature on integrated sampling suggests that the following series of steps can help integrate multiple disparate monitoring activities across a broad landscape.

- ***Define the landscape of interest.*** Generally the landscape of interest can be defined by a large-scale vegetation community, ecosystem or watershed, or by a unit of human geography such as a county, region, or major municipality.
- ***Map the existing monitoring activities.*** The agency and its partners can map the localities at which data are currently being collected using paper maps or, better yet, Geographic Information Systems (GIS). For each point, sampling transect, or sampling array, it is useful to know what data are being collected at that site and at what frequency.
- ***Identify areas of overlap where monitoring activities might be combined or integrated.*** Look for areas on the map where monitoring activities are already occurring within close physical proximity. Determine whether or not there might be efficiencies in combining monitoring efforts at these sites.
- ***Identify the desired temporal sampling frequency and ideal spatial sampling density for each element, and for the system as a whole.***
- ***Identify and take the specific steps needed in order to bring activities into a standard temporal and spatial sampling frame.***

Putting these steps into action will require mapping existing monitoring in Wyoming, identifying areas of overlap, identifying desired spatial and temporal scales, and finally (if possible) putting all the elements together in a site-specific integrated sampling design for multiple taxa and ecosystem variables.

As monitoring programs in the state of Wyoming continue to develop, program managers will undoubtedly have opportunities to build stronger connections with the ongoing monitoring programs of partners at the state, federal, and local levels, thereby enhancing their own sampling efforts in a variety of ways. This may include:

- Identifying opportunities for collaboration and coordination across existing monitoring programs;
- Using statistical methods to identify under-sampled areas within the broader landscape;
- Adding sites along elevational and latitudinal gradients to track the effects of environmental change on wildlife and other important natural resources;
- Investing in permanent “sentinel sites” where long-term monitoring can occur; and
- Adding new monitoring targets sparingly and only when there is a clear management imperative or other compelling reason to do so.

When possible, managers should be encouraged to explore creative ways such as these to enhance and expand existing monitoring efforts.

9.0 Workshop Outputs, Outcomes and Future Directions

9.1 Outputs

The discussions and break-out sessions during the May 2011 workshop yielded extensive information about the three "target" ecosystems (i.e., sagebrush, riparian areas, and prairie grasslands) identified as shared priorities of the Bureau of Land Management and Wyoming Game and Fish Department.

For each ecosystem, workshop participants produced: a list of desired conditions, a list of threats and stressors, and lists of conservation activities and monitoring programs (including information found in the SWAP or BLM planning documents). Participants also built conceptual models for each of the three systems, and discussed how each of the threats and stressors could be measured on the landscape. Finally, they developed a list of provisional indicators for each system that integrates varied ecosystem processes, population status and trends for a suite of species, and different types of metrics (e.g., remote sensing, water quality, species population monitoring).

9.2 Outcomes

In addition to the tangible products developed, the workshop also enabled the Bureau of Land Management and Wyoming Game and Fish Department to achieve progress on some longer-term goals regarding wildlife monitoring within the state. Based on feedback received by Heinz Center facilitators, the interactive, collaborative workshop process was perceived by participants as having:

- Improved communication and discussion across participating agencies;
- Increased awareness of the types and kinds of data that are available for wildlife and ecosystem monitoring in the state; and
- Helped partners move towards a more robust monitoring approach for Wyoming ecosystems and wildlife.

9.3 Next Steps

During the final session of the workshop, participants were invited to discuss potential post-workshop activities, particularly those which utilize available data and existing protocols.

9.3.1 Data Sharing

Because available data are often localized within particular agencies or program offices, several key data sharing questions emerge. Among the issues which require further investigation are: who houses the data; what type of data is needed; how comparable are the data collection protocols across sites and agencies, and could they be put together in a useful way; do obvious patterns emerge across the data sets; and how do the data relate to pristine or reference sites?

Similar considerations also arise when looking at the individual monitoring programs. Opportunities for integrating data or data collection activities certainly exist in many cases. Some important questions raised by the group include: whether there are related or similar programs across agencies, whether there is some practical value in integrating those data across data sets, and whether (and under what circumstances) there might be value in integrating biotic with abiotic data?

Finally the group agreed that data-sharing agreements bring additional value to their agencies and others in the conservation community, and discussed what types of data-sharing protocols make the most sense for data collection and analysis across agencies.

9.3.2 Priority Follow-on Activities

Three main ideas emerged from the large group discussion of possible follow-on activity from this workshop:

1. ***Conduct focused research to validate the use of sage grouse as an indicator species for overall condition of sagebrush ecosystems.*** This work would build on the incredible amount of information available in historical research and existing data from ongoing monitoring. The potential of sage grouse as an indicator for application in adaptive management would be clarified, particularly how to detect problems at a smaller scale when sage grouse are mobile and use a large portion of the habitat. Participants felt momentum and useful tools exist, but there is no one place to combine, structure, and analyze data so it can be used in management decisions. They also consider Wyoming Geographic Information Science Center (WyGISC), BLM, USFWS, USGS, WGFD, researchers (e.g., University of Wyoming, Montana State University), cooperative units, and other key stakeholders (e.g., landowners and industry) important to this discussion.
2. ***Develop a GIS disturbance layer for core areas to show what is happening on the landscape (i.e., to move beyond a piecemeal approach); identify undisturbed areas which may merit conservation; and answer questions about specific areas.***

Participants mentioned that a sage grouse effort is underway to map patterns of sagebrush habitat and landscape disturbance in a single GIS layer, which will be applicable for other species in the system as well. If pristine areas can be identified through that process, they may be earmarked and protected. The development of this layer would be advanced by:

- Obtaining resources for field validation, database development, and maintenance.
- Defining specific parameters for the disturbance layer based on best available science, which will benefit from gathering broader input. Technical questions may include: what qualifies as a "disturbance;" for how long has it been occurring; why are certain stressors, such as pipelines, considered a disturbance; what are the unique considerations of a vertical disturbance or a fragmentation; and at what spatial scale does a disturbance impact a given ecosystem or species.
- Designing and constructing sustainable systems for ongoing data streams and data stewardship. To date, no single agency has been identified to maintain, house, and staff the development of this data layer; it is currently being created on a project-by-project basis.

Workshop participants suggested the Powder River Basin (PRB) in Northeast Wyoming as a possible **test site** for the disturbance layer. A PRB Initiative is underway in an area where coal bed methane development is transitioning to a reclamation phase. The initiative currently engages WGFD, NRCS, conservation districts, energy developers, and BLM. A disturbance layer could be used to inform on the reclamation phase by showing development in the area. The site also provides an opportunity to monitor whether and how fast reclamation activities achieve species recovery, and apply the results to future projects.

3. ***Explore strategies for communicating with key constituencies and the public about consequences of development, how it impacts wildlife and ecosystems, and trade-offs with other social values*.** Wyoming was described as a state with "high-level threat and low-level concern." As a result, participants felt it is imperative to translate species and/or habitat loss information for the public, in order to inform them of the consequences and tradeoffs of decisions. Although a lead agency still needs to be chosen, potential activities mentioned include:

   - Using the indicators identified through the

workshop to demonstrate outcomes from public expenditures on wildlife conservation (e.g., how well projects move species and habitats toward desired condition).

- Developing future scenarios, using indicators identified through the workshop, to illustrate the most likely outcomes of current and alternative development and conservation activities, with attention to economic and social indicators in addition to wildlife-related indicators.
- Demonstrating economic consequences of inadequate conservation funding and activities (e.g., costs to industry, government, and society when species are listed as threatened or endangered; realistic costs required to achieve species recovery). The scientific and management community was noted to play a key role in this type of activity, although they are cautious about becoming involved in such public debates. It was suggested that the workshop participants may want to develop partnerships and activities to demonstrate the scenarios. An example was cited in the state not allowing wind development in sage grouse corridors (despite a lack of data articulating the impact of development on the species).

Participants also felt the response to a reporting mandate on performance expectations must include communicating the consequences, on a broader level, of low investments in wildlife conservation and management, and the scale of species recovery.

Among the western states, Wyoming is a leader in wildlife monitoring and conservation activities. Within the state, the rich legacy of historical monitoring data complements ongoing collection activities for a number of flagship species and ecosystems. There are established and highly-functioning relationships between the leading conservation partners, who have already identified a set of shared priorities. Wyoming wildlife managers have the tools and the momentum needed to build a more robust, integrated monitoring system that can respond to ever-growing demands, and leads the way to a future where wildlife and ecosystems thrive.

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Appendices

Appendix 1:
List of Stressors, Threats, and Conservation Actions
(Sagebrush, Riparian, and Prairie Grasslands Systems)

WYOMING PIONEERING PERFORMANCE MEASURES WORKSHOP

Complete List of Threats/Stressors and Conservation Actions (Sagebrush, Riparian, and Prairie Grasslands Systems)

May 2011

[Note: this list was generated by the large group and may not reflect changes made by the small working groups for each system, as shown in the conceptual models and the Indicator/Monitoring Program spreadsheets.]

Sagebrush

Threats/Stressors:

- Incompatible energy development and mining practices
- Rural subdivision
- Off-road vehicle use
- Incompatible grazing management practices
- Conifer encroachment
- Drought
- Climate change
- Fences
- Power lines
- Roads (main arteries as well as two-track/lesser used roads)
- Fire
- Insects
- Control projects
- Invasive species (e.g., plants, invertebrates, red fox)
- Disruption of disturbance regimes
- Feral horses

Current Conservation Actions:

- Easements
- Corridor preservation
- Grass banks
- Habitat treatments
- Fences (removal, marking)
- Grazing management
- Big game population management
- Small game population management
- Fire response (immediate, reclamation)
- Development approval processes
- Education
- Invasive species control (e.g., cheatgrass, invertebrates)
- ORV management and regulation

Riparian

Threats/Stressors:

- Water development / altered flow regimes
- Drought and climate change
- Invasive species (e.g., New Zealand mud snail)
- Ungulate grazing / browsing
- Rural subdivision / development
- Incompatible energy development practices
- Barriers
- Channelization
- Water pollution / low water quality / erosion / sedimentation
- Flood plain development
- Illegal dumping
- Bank stabilization
- Levees

Current Conservation Actions:

- In-stream flow conservation efforts / Water rights to ensure fisheries
- Fish habitat structures
- Bank stabilization
- 404 permitting (under CWA)
- Fencing / Managed grazing
- Working with highway department to minimize impacts
- Riparian easements
- Best Management Practices (BMPs) (watershed, agriculture)
- Invasive plant control (e.g., Russian olive, tamarisk)
- Riparian habitat restoration / treatments
- Ox Bow restoration
- Fishing easements
- Development buffers (BLM, USFS)
- Wetland restoration / mitigation
- Beaver reintroduction

Prairie Grasslands

Threats/Stressors:

- Energy development
- Invasive plant species
- Off-road vehicle use
- Altered disturbance regimes change
- Rural subdivision and development
- Conversion to agriculture
- Improper use of pesticides and herbicides
- Land user attitude

- Overgrazing
- Fragmentation (roads, power lines)
- Insect outbreaks
- Ecosystem conversion

Current Conservation Actions:

- Invasive species control
- Grazing management
- Prescribed burns
- Conservation easements
- Reclamation (oil, gas, coal)
- Harvest management
- Conservation Reserve Program (CRP)
- Grassland restoration projects
- Prairie dog management (colonies on private land, incentive payments)
- National grassland designation
- NRCS grazing management plans

Appendix 2:

Wyoming BLM Sensitive Species/
WGFD Species of Greatest Conservation Need
(Sagebrush, Riparian, and Prairie Grasslands Systems)

WYOMING BLM SENSITIVE SPECIES/WGFD SPECIES OF GREATEST CONSERVATION NEED
SAGEBRUSH, RIPARIAN, AND PRAIRIE GRASSLAND ECOSYSTEMS
May 2011

I. Sage and Sagebrush Ecosystems

Mammals
Eastern Red Bat
Great Basin Pocket Mouse
Idaho Pocket Gopher
Olive-backed Pocket Mouse
Pallid Bat
Plains Pocket Gopher
Preble's Meadow Jumping Mouse
Pygmy Rabbit
Sagebrush Vole
Spotted Bat
Spotted Ground Squirrel
Swift Fox
Townsend's Big-eared Bat
White-tailed Prairie Dog

Key
Blue = WGFD SGCN
Green = WY BLM Sensitive Species
Red = Shared Priority

Birds
Brewer's Sparrow
Columbian Sharp-tailed Grouse
Greater Sage-grouse
Ferruginous Hawk
Loggerhead Shrike
Sage Sparrow
Sage Thrasher
Swainson's Hawk

Amphibians
Plains Spadefoot
Great Basin Spadefoot

Reptiles
Great Basin Skink
Greater Short-horned Lizard
Midget Faded Rattlesnake
Northern Tree Lizard
Plains Hog-nosed Snake

II. Prairie Grasslands Ecosystems

Mammals

Black-footed Ferret
Black-tailed Prairie Dog
Hispid Pocket Mouse
Idaho Pocket Gopher
Olive-backed Pocket Mouse
Plains Harvest Mouse
Plains Pocket Mouse
Plains Pocket Gopher
Silky Pocket Mouse
Spotted Ground Squirrel
Swift Fox
Wyoming Pocket Gopher

Birds

Baird's Sparrow
Bobolink
Burrowing Owl
Chestnut-collared Longspur
Dickcissel
Ferruginous Hawk
Grasshopper Sparrow
Lark Bunting
Long-billed Curlew
McCown's Longspur
Mountain Plover
Peregrine Falcon
Short-eared Owl
Upland Sandpiper

Amphibians

Great Plains Spadefoot
Great Plains Toad
Plains Spadefoot

Reptiles

Great Plains Earless Lizard
Greater Short-horned Lizard
Northern Many-lined Skink
Ornate Box Turtle
Plains Black-headed Snake
Plains Hog-nosed Snake
Prairie Lizard
Prairie Racerunner

III. Riparian Ecosystems

Mammals
American Water Shrew
Big brown bat
Fringed Myotis
Hayden's Shrew
Little Brown Myotis
Long-eared Myotis
Long-legged Myotis
Meadow Jumping Mouse
Moose
Northern Myotis
Pallid Bat
Preble's Shrew
Preble's Meadow Jumping Mouse
Pygmy Shrew
River Otter
Spotted Bat
Townsend's Big-eared Bat
Vagrant Shrew

Birds
Bald Eagle
Barrow's Goldeneye
Greater Sandhill Crane
Harlequin Duck
Lesser Scaup
Swainson's Hawk
Trumpeter Swan
White-faced Ibis
Willow Flycatcher
Yellow-billed Cuckoo

Amphibians
Boreal Toad
Columbia Spotted Frog
Great Plains Toad
Northern Leopard Frog
Plains Spadefoot
Great Basin Spadefoot
Wood Frog
Wyoming Toad

Reptiles
Plains Gartersnake
Red-sided Gartersnake
Smooth Greensnake
Valley Gartersnake
Wandering Gartersnake
Western Painted Turtle
Western Spiny Softshell

Fish
Bigmouth Shiner
Bluehead Sucker
Bonneville Cutthroat Trout
Brassy Minnow
Burbot
Central Stoneroller
Colorado River Cutthroat Trout
Common Shiner
Finescale Dace
Flannelmouth Sucker
Flathead Chub
Goldeye
Hornyhead Chub
Iowa Darter
Kendall Warm Springs Dace
Mountain Whitefis
Northern Leatherside Chub
Northern Plains Killifish
Orangethroat Darter
Pearl Dace
Plains Minnow
Plains Topminnow
Roundtail Chub
Sauger
Shovelnose Sturgeon
Snake River Cutthroat Trout
Sturgeon Chub
Suckermouth Minnow
Western Silvery Minnow
Yellowstone Cutthroat Trout

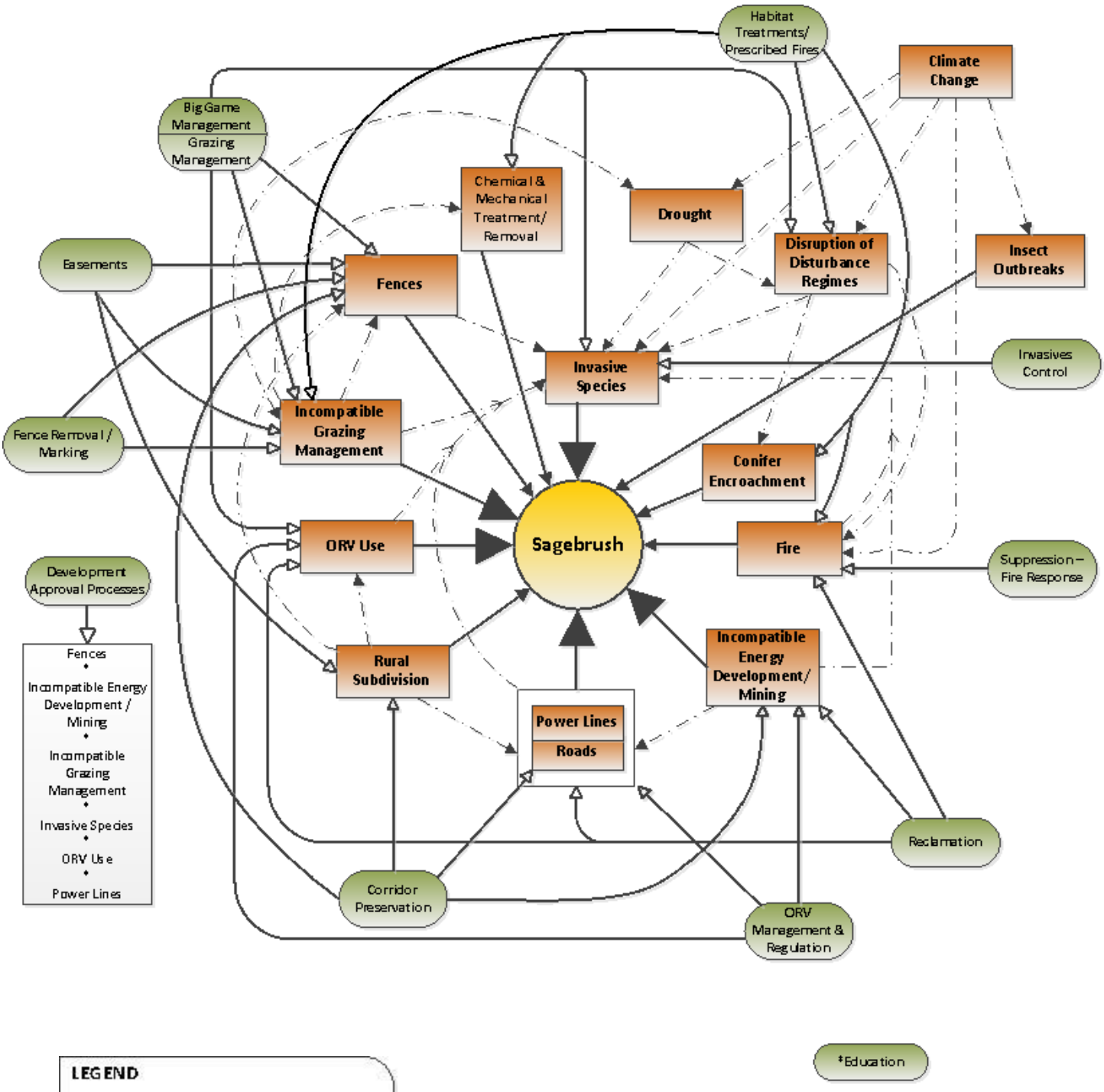
Crustaceans
Calico Crayfish
Devil Crayfish
Pilose Crayfish
Ringed Crayfish

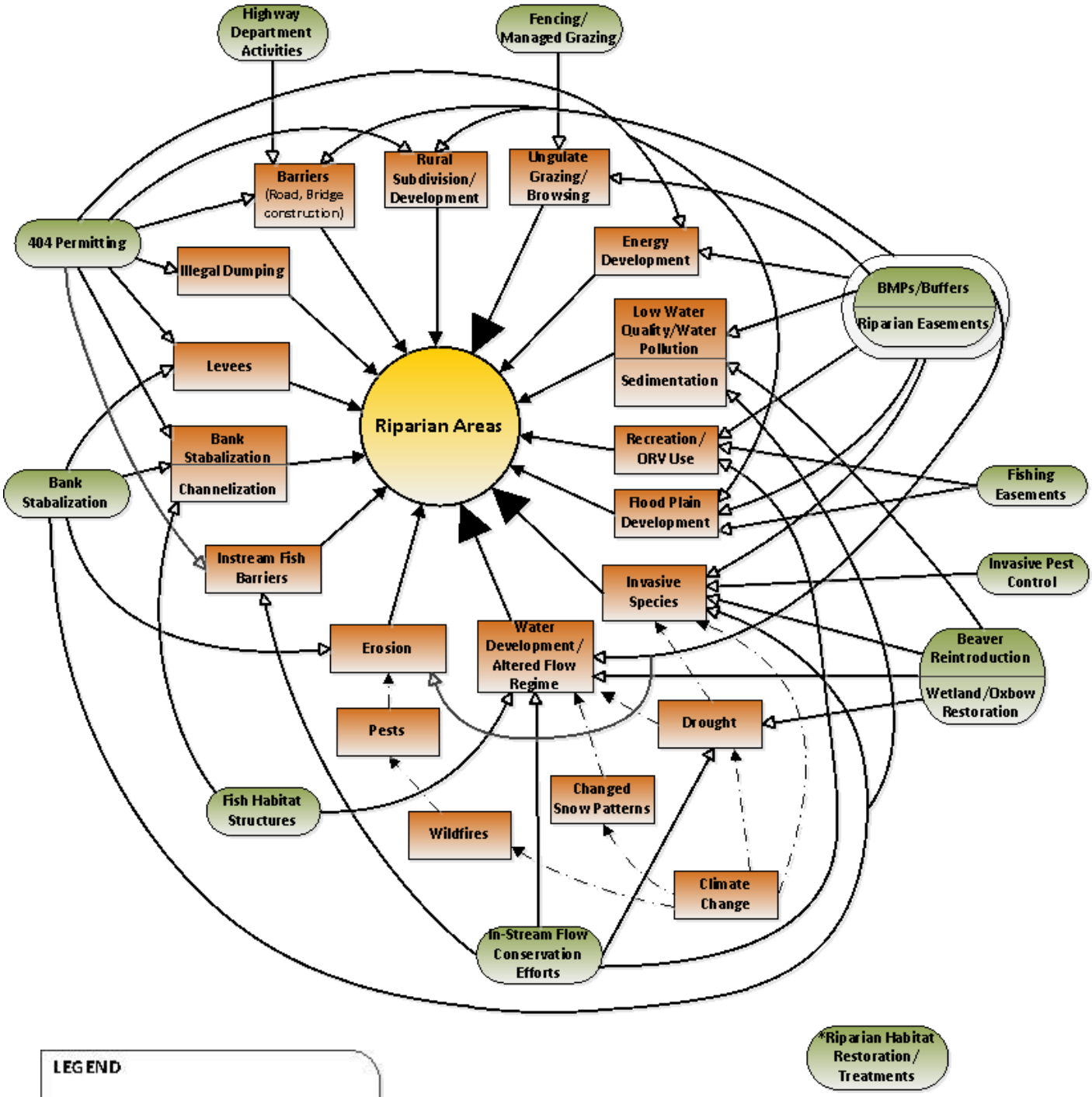
Mollusks
Aquatic Snails
California Floater
Cylindrical Papershell
Fatmucket
Giant Floater
Jackson Lake Springsnail
Pill Clams
Plain Pocketbook
Stagnicola Pondsnails
Western Pearlshell
White Heel Splitter

Appendix 3:

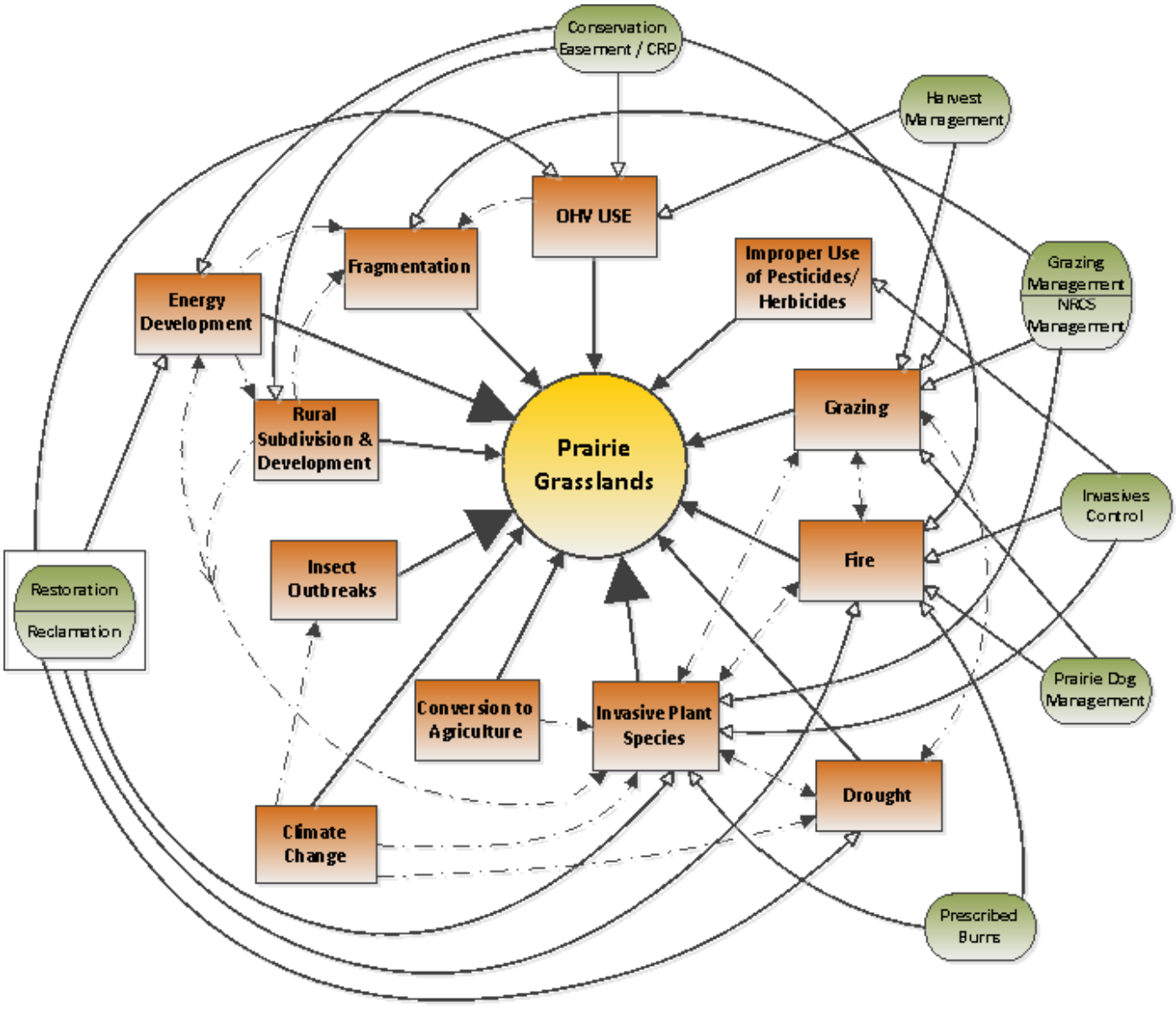
Conceptual Models
(Sagebrush, Riparian, and Prairie Grasslands Systems)

Note: Please refer to Section 5.4 for further descriptions of the models and their components


Habitat Treatments/ Prescribed Fires
Climate Change
Big Game Management
Grazing Management
Chemical & Mechanical Treatment/ Removal
Drought
Disruption of Disturbance Regimes
Insect Outbreaks
Easements
Fences
Invasive Species
Invasives Control
Incompatible Grazing Management
Fence Removal / Marking
Conifer Encroachment
ORV Use
Sagebrush
Fire
Suppression – Fire Response
Development Approval Processes
Fences
Incompatible Energy Development / Mining
Incompatible Grazing Management
Invasive Species
ORV Use
Power Lines
Rural Subdivision
Incompatible Energy Development/ Mining
Power Lines
Roads
Reclamation
Corridor Preservation
ORV Management & Regulation
*Education
LEGEND
Conservation Action
Stressor/Threat
Direct Stressor/Threat
Priority Direct Stressor/Threat
Indirect Stressor/Threat
Conservation Action
* Affects all stressors/threats



NOTE: This conceptual model differs from the others in this report. The *indirect* interactions between the threats/stressors that *directly* affect riparian areas are not shown. The focus instead is on the conservation actions, those management activities that WGFD and other agencies may make to improve or maintain the health of the system.


Conservation Easement / CRP
Harvest Management
OHV USE
Fragmentation
Improper Use of Pesticides/ Herbicides
Grazing Management
NRCS Management
Energy Development
Rural Subdivision & Development
Prairie Grasslands
Grazing
Invasives Control
Fire
Insect Outbreaks
Restoration
Reclamation
Prairie Dog Management
Conversion to Agriculture
Invasive Plant Species
Drought
Climate Change
Prescribed Burns
LEGEND
Conservation Action
Stressor/Threat
Direct Stressor/Threat
Priority Direct Stressor/Threat
Indirect Stressor/Threat
Conservation Action
* Affects all stressors/threats
*Land User Attitude
*Implementation Strategies
*National Grasslands Designation
* Land Use Permitting

Appendix 4:

Potential Indicators and Monitoring Programs
(Sagebrush, Riparian, and Prairie Grasslands Systems)

List of Potential Indicators and Monitoring Programs:
Sagebrush Communities in Wyoming

May 2011

Desired Condition	Indicator(s)	Monitoring Programs		Notes
		Agency	Program Name	
Lack of disturbance	Sage grouse	Wyoming BLM, TNC, WyGISC, WGFD		Sage grouse analysis in core area (25% of state and 60% of original sagegrouse range) by WGFD and BLM; will have fairly complete statewide coverage by this fall, focus on highest-quality habitat areas, with orthophoto taken every two years. Analysis also available on local scale specific to oil and gas activity areas & housed in a database. Hunter harvest surveys conducted as well. Some sagegrouse data available to 1940, with at least 10 years of consistent data across all areas.
Lack of fragmentation	Same as Lack of disturbance			
Natural landscape mosaic (including grass/forb understory, diversity of age classes, multiple successional stages, appropriate patch sizes)				
-grass/forb understory	shrub/grass height, amount of sage cover, overstory/canopy cover, lack of invasive species	BLM	Rangeland Health Assessment, allotment basis	
-seral states/age classes		Inter-agency	LANDFIRE	
-vegetation composition / structure		RMBO and partners (in Wyoming: WGFD, BLM, FS, WYNDD, Audubon)	Integrated Monitoring in Bird Conservation Regions (IMBCR)	Vegetation data are collected as part of the program, in addition to bird density and population estimates, and occupancy estimates for low-density species. Birds can also be a good indicator of habitat composition and structure, particularly Brewer's sparrow, sage sparrow, sage thrasher. Some data on other taxa are collected on the same grid (e.g., bat population data collected by the Forest Service). 197 total transects.
-appropriate patch sizes				Would need to define "appropriate"; patch sizes are species-specific and in some cases aren't known or overlap.

List of Potential Indicators and Monitoring Programs:
Sagebrush Communities in Wyoming

May 2011

Resilience and recovery from natural events	lack of invasive species (quantify acres if data available [depends on county]; presence/absence)	Wyoming BLM, County Weed & Pest Control agencies, all Federal agencies, weed groups?		Justin Williams may be aware of weed groups/councils.
	bird species composition (density, population estimates)	RMBO and partners	IMBCR	See above
No invasive plants (e.g., cheatgrass)	lack of invasive species (quantify acres, presence/absence)	Wyoming BLM, County Weed & Pest Control agencies, all Federal agencies, weed groups?		
No vertical structures	Powerline mapping	Rural electric co-ops		Two tiers of vertical structures - above or below 30 feet. Smaller stature structures (e.g., pipelines) won't show up.
	fences	BLM		
	wind turbines	TNC?		
Natural fire/disturbance regimes	departure from natural regime (pre-settlement)	Inter-agency	LANDFIRE	
Intact riparian areas		USFWS	National Wetlands Inventory	What is "intact" - would need to define
Representative wildlife assemblages	presence/absence, diversity, or occupancy metric of potential species (see Notes); can also look at variables such as % fragmentation, % sage cover, % canopy overstory	WGFD (bats, antelope, sage grouse, swift fox, mule deer, white-tailed prairie dog, ferruginous hawks in future); BLM (elk, desert herpetiles, sage grouse); FWS (pocket gophers)		Potential species mentioned included birds, white-tailed prairie dog, swift fox, mountain plover, bats, sage grouse, antelope, mule deer, ferruginous hawk, elk, desert herps, pocket gophers. Sage grouse, mule deer, and antelope are only long-term, ecosystem-wide monitoring programs - other programs not as consistent. Antelope monitored with line transects (over last 5 years), hunter harvest surveys, and aerial surveys annually. White-tailed prairie dog surveyed aerially every 3 years with presence/absence surveys in 500x500 meter quadrants. Elk surveyed same as mule deer, also with hunter harvest and winter range studies. Fawn ratios are most sensitive index related to deer and pronghorn.

Migration corridors	Pronghorn movements; mule deer underpass monitoring	WGFD		Pronghorn - aerial surveys, line transect surveys, population monitoring, harvest surveys, fawn-to-doe ratios. Herds are monitored every third year. Their population is an indicator of the habitat quality. Some site-specific data for bird and bat migration also exists.
Abundance of sage grouse		Wyoming BLM, TNC, WyGISC, WGFD		Sage grouse analysis in core area by WGFD and BLM; analysis on local scale specific to oil and gas activity areas, focus on highest-quality habitat areas, orthophoto is taken every two years.
Presence of obligate species	Brewer's sparrow	RMBO and partners		See above
	herps (presence/absence, range, distribution)	WGFD		Program is just starting, no trend data yet.
Adequate soil crust				Talk to Eve Warren (Fire ecologist, BLM-Warland office)
Presence of insects / "Natural" insect regime				Food for sage grouse; only know of individual studies on insect diversity
Threats/Stressors	**Indicator(s)**	**Monitoring Programs**		**Notes**
		Agency	**Program Name**	
Incompatible energy development and mining practices	Same as Prairie Grasslands	Energy Development: Oil & Gas Commission, Industrial Siting Council or RICO (wind), AWEA, pipeline authority within state government. Mining: DEQ permitting, BLM, USFS, State Lands Office (esp. bentonite).		Bed rock mining; coal, oil, and natural gas development; mineral extraction (bentonite, trona, uranium)
Rural subdivision	Same as Lack of disturbance			
Off-road vehicle use		BLM, Wyoming state parks		BLM travel management planning areas (rough estimates); Wyoming state parks may have data (via state trails association, focuses on users)

Incompatible grazing management practices				No one really tracking. BLM has grazing allotments; state land allotments also tracked. Imagery data may highlight the worst effects, although would also be covered in other disturbance measures at that level.
Conifer encroachment (pine, juniper)				No good mapping effort exists; maybe through ReGAP
Drought	Palmer Drought Index (PDI)	State climate office, NOAA, WGFD incorporates the PDI, NWS, USGS snowfall data?		
Climate change		State climate office, NPS, USGS, NOAA		Climate modeling also conducted by USGS, TNC, and some modeling facilitated by the LCCs
Fences		BLM		
Power lines		Electric co-ops		
Pipelines				
Roads (main, 2-track)		Main: Interagency led by USGS; DOT, state, counties. Two-track: varies depending on land ownership (TNC tracks some of this data).		Wyoming-specific estimate is being created as a disturbance layer for sage grouse (completion Fall 2011). Also, TIGER database maintained by Census Bureau (does not cover roads associated with oil & gas wells).
Fire	Acres burned	National Interagency Fire Center		Each BLM district also has annual fire layer, as does FS - presumably wrapped up into NIFC data. No good data on private land fires.
Insect outbreaks		APHIS, WY Department of Agriculture, maybe NRCS		
Control projects (see Chemical/mechanical treatments)				
Invasive species (e.g., plants, invertebrates, red fox)	See No invasive plants, above (plants only were discussed)			

Disruption of disturbance regimes	See Natural fire / disturbance regimes, above			
Feral horses		BLM, FS (MT/WY)		
Chemical/mechanical treatments		Conducted by BLM, NRCS, WGFD, industry		USGS is evaluating some industry treatment projects; WLCI may also have some data.
Conservation Actions	**Agency/Organization**	**Program Name**	**Notes**	
Easements		CRP		
Reclamation		CRP		
Corridor preservation				
Grass banks	TNC, FS (SW Wyoming), WLCI			
Habitat treatments				
Fences (removal, marking)				
Grazing management				
Big game population management	WGFD		mule deer, antelope population studies state-wide; also elk	
Small game population management	WGFD		sage grouse population studies	
Fire suppression	FS, BLM, County fire departments, Stat land board (through counties)			
Prescribed fire	FS, BLM, NRCS, WGFD, RMEF			
Development approval processes	Power lines: rural electric companies; ORV use - travel management planning areas information			
Education				
Invasive species control (e.g., cheatgrass, invertebrates)				
ORV management and regulation				

List of Potential Indicators and Monitoring Programs:
Riparian Communities in Wyoming
May 2011

Desired Condition	Indicator(s)	Monitoring Program		Notes
		Agency	Program Name	
Support native assemblages of breeding birds	Presence/absence of obligate species (e.g., house wren, red-breasted merganser, yellow-billed cuckoo, wood duck, bald eagle, red headed woodpecker, willow flycatcher, sandhill cranes, trumpeter swans, harlequin ducks (indicator of water quality).	Wyoming Game and Fish Department (WYGFD)	Breeding Bird Survey	
		RMBO (WGFD, BLM, Partners in Flight, etc.)	Monitoring Wyoming Birds (throughout summer)	
		Audubon Society	Bird surveys	
		Forest Service (FS) WGFD	Harlequin duck surveys	
Intact Watershed (i.e., buffer zone)	Proper Functioning Condition (PFC) (e.g., water, chemical and vegetation structure.	Bureau of Land Management	PFC	
		BLM, FS	Watershed Associations	
		Conservation Districts, EPA, DEQ	Watershed Planning	
	Agriculture operations implementing BMPs/Conservation practices (e.g., contour plowing, buffer strips)	NRCS	WRP (Wetland Restoration Program) Equip (irrigation)	
		Conservation Districts	Non-point source pollution Program	
		DEQ, EPA	319 toward TMDL	
	Urban BMPs/Watershed Plans (e.g., septic tank)	Municipality Conservation Districts	Planning	
Adequate Flow Regime	Flow Rates Presence/absence of macro invertebrates	Irrigation Districts USGS	Flow rate measurement	
		WY State Engineering Department	Permit program for water use	
		WYGFD Fisheries Department	Fisheries Program (flow, etc.)	
		Bureau of Reclamation (BOR)	Water budgeting/ monitoring	
	Presence/absence of fish (e.g., Trout)	WGFD - Fish Division	Fish surveys	
	Climatological Information (e.g., precipitation, rain)	WY water dev. Con.; State climatologist; NRCS; USGS	Climatological monitoring	

List of Potential Indicators and Monitoring Programs:
Riparian Communities in Wyoming
May 2011

No Invasive Species	Presence/absence of certain invasive species (e.g., Tamarisk, Russian Olive, Purple Loosestrife, Eurasian Millfoil) Presence/absence of aquatic plant/animal species (e.g., quadra mussels, zebra mussels)	Collaboration between Federal and State (BLM, BOR, county, WPD, FS, NPS)	MISMs	
		WGFD	Aquatic Invasives Program (specifically mussels)	
		Wyoming Dept of Ag.	CRM (Coordinated Res. Management) - weeds	
High Water Quality	Meets EPA Water Quality Standards for Livestock/Wildlife Meets water quality standards for class of stream	Wyoming DEQ Conservation Districts	Water Quality Monitoring Programs	
PFC of Riparian Zone (e.g., appropriate shade, lack of erosion)	PFC	BLM	PFC	
		BLM, FS	Watershed	
		Conservation Districts, EPA, DEQ	Watershed Planning	
Woody components	PFC (e.g., woody debris, etc.) Recruitment/reproduction in tree species	BLM, FS	PFC program	
	Condition of non-tree woody species (shrubs etc..)	WGFD	Wildlife Division willow monitoring as it pertains to moose herd units	
	Presence/absence of appropriate assemblages of vegetation			
Multi-layered herbaceous species	Presence/absence of appropriate species (e.g., cottonwood, aspen)	BLM, FS	PFC	
	Species composition, diversity, Cover classes	NRCS	WHIP	
	Grazing (e.g., amount of cover, utilization)	Federal agencies NRCS		
Connectivity (floodplain, in-stream fish passages)	Contiguous healthy riparian zone (percent coverage) Adequate flow regime (e.g., flow rates, presence/absence of macro invertebrates; presence/absence of fish; climatological information)	WYGISC		
Full compliment of appropriate wildlife	Presence/absence of beavers, otters, minks, water shrews, water voles, native fish, amphibians, herpetiles	WGFD	Beaver take	
		WYGIS Fish Division	Fish surveys	
Absence of structural modifications	Presence/absence of structural modifications	Army Corps of Engineers BOR Countries Municipalities	Permitting	
Resilience to natural events	PFC	BLM, FS	PFC	

List of Potential Indicators and Monitoring Programs:
Riparian Communities in Wyoming
May 2011

Threats/Stressors	Indicator(s)	Monitoring Program		Notes
		Agency	Program Name	
Water development/altered flow regime	Presence/absence of structural modifications Connectivity (Contiguous healthy riparian zone (percent coverage) Adequate flow regime (e.g., flow rates, presence/absence of macroinvertebrates; presence/absence of fish; climatological information) Shift in vegetation type/structure Stream channel dynamics	FS, BLM, etc.	PFC Transects as part of permitting data collection	
	Water depletions (e.g., Green River, Platte River)	USFWS		
Drought	Stream flow gauges Snowpack Climatological information Desiccation/loss or riparian zones	NRCS USGS State climatologist State engineer		
Climate change	Stream flow gauges Snowpack Climatological information Desiccation / loss or riparian zones	NRCS USGS State climatologist State engineer		State climatologist pulling information sources together
	Presence/absence of certain invasive species (e.g., Tamarisk, Russian Olive, Purple Loosestrife, Eurasian Millfoil) Presence/absence of aquatic plant/animal species (e.g., quadra mussels, zebra mussels)	Collaboration between Federal and State (BLM, BOR, county, WPD, FS, NPS)	MISMs	
		WGFD	Aquatic Invasives Program (specifically mussels)	
		Wyoming Dept of Ag.	CRM (Coordinated Res. Management) - weeds	
Invasive species	Presence/absence of certain invasive species (e.g., Tamarisk, Russian Olive, Purple Loosestrife, Eurasian Millfoil) Presence/absence of aquatic plant/animal species (e.g., quadra mussels, zebra mussels)	Collaboration between Federal and State (BLM, BOR, county, WPD, FS, NPS)	MISMs	
		WGFD	Aquatic Invasives Program (specifically mussels)	
		Wyoming Dept of Ag.	CRM (Coordinated Res. Management) - weeds	

List of Potential Indicators and Monitoring Programs:
Riparian Communities in Wyoming
May 2011

Ungulate grazing/browsing	Grazing /browsing utility Shift in species composition Hoof damage to saturated soils (e.g., rootmats in saturated soils)	BLM, FS	PFC Grazing management	
		WGFD	Big game programs (especially moose)	
Rural subdivision/ Development	Number of permits Number of acres (in relation to the percentage of riparian habitat)	County Zoning Department WYGISC, etc. (counties, department of revenue, etc.)	Zoning GIS tracking	
Energy development/mining	Coal bed methane plant discharge Percentage of riparian area Trends in wildlife/aquatic sensitive to, particularly nesting raptors, sage grouse, bats, etc. Cottonwood-willow presence/absence (i.e., presence/absence of flow)	DEQ Federal agencies Oil and gas companies	Permitting	
	Colonial nesting water birds (e.g., herons, cormorants)	Federal agencies WYGFD	Surveys	
Fish barriers	Presence/absence of fish barriers	BLM/FS Trout Unlimited	Inventory of fish passage barriers on federal lands (has occurred over the last 3 years)	
Other barriers (e.g., roads, bridge construction)	Channel modifications Acres of distribution as percentage of riparian area Loss of riparian habitat (vegetation)/constriction of riparian zone Downcuts, deposition, headcuts Accelerated erosion	WYGISC Federal agencies WYGFD NRCS	Aerial imagery	
Channelization	404 permits issued	Army Corps of Engineers		
	Stream channel profile Percent loss/reduction of riparian zone	Irrigation Districts	PFC (on Federal lands)	
Water pollution/decreased water quality/ sedimentation/ erosion	TMDLs, salinity, turbidity, and other water quality measurements	DEQ Conservation districts Federal agencies (BLM, FS, etc.) (evolves out of DEQs stream ratings)		
	Presence/absence of macroinvertebrates	DEQ WYGFD (sporadic) Conservation districts		
Flood plain development (transmission corridors, pipelines, etc.)	Number of permits Number of acres developed (percentage of riparian habitat developed) Also other indicators from Energy development/mining above	County Zoning Department WYGISC, etc. (counties, department of revenue, etc.)	Zoning GIS tracking	

Illegal dumping	Presence/absence of dumping	Municipalities	Opportunistic observations	
Bank stabilization	Presence of bank stabilization structure (riprap, etc.) Fluvial geomorphology (sand bar building, channel shifting, etc.)	BLM, FS, Conservation Districts	PFC	
	Permitting	USACE	Permitting program	
Levees	Loss of fluvial process Loss of riparian vegetation (because there is a lose of overland floods) Presence of levee structure	USACE BOR (as part of building)	Permitting of levees	

Management Activities	Program	Agency/Organization
In-stream flow conservation efforts	In-stream Flow Conservation Program In-stream flow modeling for threatened and endangered species (e.g., razorback suckers)	WYGFD USFWS
Fish habitat structures		WGFD Federal Agencies (BLM, FS, etc.) on Federal lands Trout Unlimited
Bank Stabilization (non-destructive)		Private landowner participation through agency programs WGFD Highway Department
404 Permitting		USACE (CWA)
Fencing/Managed Grazing	Miscellaneous Programs Rangeland Health Assessments CRM	WYGFD BLM and related other Federal Agencies NRCS Private landowners Conservation districts Department of Agriculture
Decrease impact of roads by working with the highway department		WGFD (with Highway Department) Federal Highway Administration regulations for State Highway Department BLM (when on Federal land) FS (when on Federal land) State land board

List of Potential Indicators and Monitoring Programs:
Riparian Communities in Wyoming
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Riparian Easements		The Nature Conservancy WGFD (using funding from WWNRT, etc.) Partners for Fish and Wildlife Other NGOs (Green River Trust, Trout Unlimited, etc.)
Best Management Practices (watershed, agricultural)	Section 310 Outreach	EPA DEQ
	Technical assistance	NRCS Other Federal Agencies Conservation Districts WYGFD
Riparian Habitat Restoration/Treatments (Oxbow restoration)	Grazing management Wetland/Ox Box restoration work Partners for Fish and Wildlife	Federal agencies (BOR, FS, BLM) NRCS (some on private lands) FWS (national parks managed with riparian areas), including work with local partners WGFD
Fishing easements	Fishing easement program PLPW (Private land, Public Wildlife)	WGFD
Development buffers	Regulatory As part of BMPs	Federal agencies (BLM, etc.) State Land Boards Utility and Gas Commissions WGFD FS (buffers for timber sales) DEQ NRCS
Wetland restoration/ mitigation	Wetland and riparian mitigation work	WYDOT
	404 permitting process (avoidance or mitigation requirement)	USACE
	Wetland Restoration Program (restorations, easements) Partners for Fish and Wildlife	NRCS WYGFD Ducks Unlimited USFWS
	Fund projects	Joint Ventures
Beaver Re-introduction		WGFD

List of Potential Indicators and Monitoring Programs:
Prairie Grasslands in Wyoming
May 2011

Desired Condition	Indicator(s)	Monitoring Program		Notes
		Program Name	Agency	
Functioning unfragmented vegetation blocks	Remote sensing/GIS		TNC WYGISC WYBLM	
Native grassland birds	Trends and population estimates		Rocky Mountain Bird Observatory BLM USFS WYGFD	
Complement of native species, especially:				
Swift fox	Presence/absence, trend data		WYGFD	
Black tailed prairie dog	Presence/absence, acreage/trend		WYGFD BLM	
Mountain Plover	Project specific presence/absence information		BLM	
Ferruginous Hawk	Presence/absence		WYGFD GBO	
Sandpiper	Presence/absence		BLM	
Burrowing owl	Presence/absence	Breeding Bird Survey	WYGFD, BLM	
Black footed ferret	Presence/absence, trend, extent, distribution, area	Surveys (annual)	WYGFD	
Buffalo herds				Livestock class in most of Wyoming except the northwest.
Toads (e.g., Wyoming Toad, Spadefoot)	Presence/absence		WYGFD	
Intact Natural Disturbance Regimes	Fire frequency Grazing		Landfire	
Absence of invasive species	presence/absence, density estimates		Country Weed and Pest council Fed agencies (DOI, USDA) National Invasive Species Information Management System (NISIMS)	
Low impact from cultivation	Acres with past cultivation	GIS, Range Assessment, Aerial Photos ReGap	BLM	

List of Potential Indicators and Monitoring Programs:
Prairie Grasslands in Wyoming
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Absence of man-made structures (e.g., roads, wells, turbines, transmission lines, subdivisions, fencing)	acres converted/acres disturbed by man-made structures		American Farmland Trust	
		Development projections	TNC	
Threats/Stressors	**Indicator(s)**	**Monitoring Program**		**Notes**
		Program Name	**Agency**	
Energy development	Presence of development (e.g., active well sites, wind, etc.) via permitting and tracking of activity/production		Wyoming Oil and Gas Commission BLM American Wind Energy Association (AMEA)	
Invasive plant species (e.g., cheatgrass)	presence/absence, density estimates		Country Weed and Pest council Federal agencies (DOI, USDA) NISIMS (multi-agency)	
ORV Use	Permitting, road surveys, GIS/remote sensing		USFS BLM	
Rural subdivision and development	GIS tracking Project permitting information Number/acreage of plots		Municipalities TNC	
Fragmentation	Mapping/GIS	Landscape Conservation Cooperatives	USFWS	
		migration corridors, connectivity	NatureServe Ducks Unlimited	
Conversion to Agriculture			USDA	
Altered disturbance regime	Fire frequency Grazing		Landfire	
Overgrazing	Monitoring information of condition classes		BLM USFWS	
	Leases, permits, agriculture statistics		State of Wyoming NRCS (if farm bill funded)	
Management Activities	**Program**	**Agency/Organization**		
Invasive species control		Municipality weed and pest control Private entities Oil and gas companies State of Wyoming Federal weed management		

List of Potential Indicators and Monitoring Programs:
Prairie Grasslands in Wyoming
May 2011

Management Activities	Program	Agency/Organization
Grazing management		Federal landowners
	Grazing management plans, Farm Bill	USDA, NRCS, Ag extension
	Habitat programs	WYGFD
Prescribed Fire		USFS BLM Other federal agencies private entities (NRCS promotes)
	Air quality permitting for private burning	WY DEQ
Conservation easements		BNRCS TNC Land trusts Rocky Mountain Elk Foundation WGFD Wyoming Wildlife and Natural Resource Trust (WNRT)
	Wetland Preserve Program (WRP)	USDA
Reclamation (oil, gas, goal)		State and Federal permitting agencies State oil and gas commission Energy companies (per requirements)
Harvest Management		WGFD USFWS
Conservation reserves	Conservation Reserve Program	Farm Service Agency NRCS
Grassland restoration	Habitat improvements and grassland restoration projects	WGFD
	Grassland Reserve Program	NRCS
Prairie Dog Management		Private landowners Federal agencies
National Grassland Designation		USFS

Appendix 5:

Current Monitoring Activities
(Sagebrush, Riparian and Prairie Grasslands Systems)

Wyoming Pioneering Performance Measures Workshop:
Current Monitoring Programs
Sagebrush, Riparian, Prairie Grasslands Systems
May 2011

Monitoring activity	Sagebrush	Riparian areas	Prairie grassland	Agencies, partners	Area / spatial scale	Measures	Frequency	Possible relevance for indicators
MAMMALS								
AMPHIBIANS & OTHER AQUATIC ANIMALS								
Bat surveys	☐			WGFD	Specific studies	Distribution (mist nets), trend, nesting, communal roosts	Before / after wind development	Have protocols which could be applied more broadly
Beaver harvest		☐		WGFD		Harvest data (by individual warden)		Confounding factors (e.g., permits limit the number of beavers harvested)
Big game surveys (all major game species including pronghorn, mule deer)	☐	☐	☐	WGFD	Statewide	Population (area line transect estimates) Aerial surveys	Annual	(1) Fawn-to-doe ratio; (2) Population estimates, herd classification; (3) Harvest
Black footed ferret monitoring	☐		☐	WGFD, (Thunder Basin, USFS)	Core areas / currently occupied	Population estimates, trend data, extent, distribution (mark / recapture)	Annual (alternate between trend data and distribution data)	[note: expanding area due to success and reintroduction]
Black-tailed prairie dog survey	☐		☐	WGFD, BLM	Statewide	Acreage estimates, trend data; aerial survey	Every 3 years	
Cottontail surveys	☐	☐		WGFD	Statewide	Harvest		Generalist species. High take limit. Long season. Well-correlated to sage

Monitoring activity	Sagebrush	Riparian areas	Prairie grassland	Agencies, partners	Area / spatial scale	Measures	Frequency	Possible relevance for indicators
								grouse.
Desert elk surveys	▯			WGFD (BLM?)	Localized herds			
Feral horses	▯			BLM, FS (MT/WY)				
Fish Division Database						Sportfish monitored intensively (e.g., stream trout, lakes / reservoirs). Data on nongame species (e.g. prairie fish).		
Fish surveys		▯		WGFD				
Herpetological surveys	▯			WGFD, WYNDD (BLM?)	Southwest and southeast	Distribution for 15 species		
Mollusk surveys		▯		WGFD	Technique developed	Distribution		
Mule deer surveys	▯		▯	WGFD		Underpass monitoring; focused on tracking use at specific sites		
Pocket gopher surveys	▯			WGFD, WYNDD, FWS	Specific studies			
Pronghorn movements	▯			Wildlife Conservation Society	Upper Green River; Jackson area	Aerial surveys, population monitoring		
Pronghorn surveys	▯		▯	WGFD	Statewide	Population (aerial line transect surveys for each herd)	3 year intervals	
Pygmy rabbit surveys	▯			WGFD, WYNDD	Specific studies			
Spadefoot surveys (2 species)		▯	▯	USFWS, WGFD	Initial surveys	Presence / absence	[low density]	
Swift fox monitoring	▯		▯	WGFD	Grasslands, some sagebrush	Trend data (new statewide technique)	1 year of data so far (ongoing)	
White-tailed prairie dog monitoring	▯		▯	WGFD, Weed & Pest Council Districts	Statewide	Acreage estimates, trend data; aerial survey	Every 3 years	Status of ferrets, other predators
Wildlife Observation System	▯			WGFD		Observation database		
Wyoming Natural				Run by University of WY;				

Monitoring activity	Sagebrush	Riparian areas	Prairie grassland	Agencies, partners	Area / spatial scale	Measures	Frequency	Possible relevance for indicators
Diversity Database (WYNDD)				contributed to by various state and federal agencies and other partners				
Wyoming Toad surveys				USFWS, WGFD, PARC - interagency groups & WYNDD (various toads)	One location near Laramie	Trend	[low density]	
BIRDS								
Bald eagle nest sites				WGFD				
Breeding Bird Survey				WGFD, coordinated with National BBS effort	Statewide	More abundant avian species	Annual	
Colonial waterbird surveys (e.g., Bittern, Ibis)				WGFD	Specific study sites (unstructured)	Roadside surveys		
Duck breeding pair surveys				WGFD			Historic data to 1999	
Ferruginous hawk				GBO, WGFD (trying to develop a monitoring approach…still 1-2 years out; best in Rawlins)	Specific nest monitoring	Nest sites		
Harlequin ducks				WGFD (FS?)	Northwest WY	Number of breeding pairs	Every 5 years	
Integrated Monitoring in Bird Conservation Regions (formerly Monitoring Wyoming Birds, Partners in Flight)				RMBO (houses data), WGFD, BLM, USFS, WYNDD, Audubon; link to Avian Knowledge Network at Cornell	throughout summer	Consistent protocol across states, region. Multi-site sampling frame, stratified by management units. Transects. Density, population, occupancy.		
Long-billed curlew survey				WGFD	Pinedale, Sublett County	Roadside survey		
				RMBO (houses data), WGFD, BLM, USFS, Audubon, link to Avian Knowledge Network at Cornell	throughout summer	Consistent protocol. Multi-site sampling frame, stratified by management units. Transects. Density, occupancy.		

Monitoring activity	Sagebrush	Riparian areas	Prairie grassland	Agencies, partners	Area / spatial scale	Measures	Frequency	Possible relevance for indicators
Mountain plover survey				WGFD, BLM, RMBO? Weed & Pest Council Districts?	Project-specific		Annual	
Sage grouse surveys				WGFD, BLM, University of Wyoming, TNC	Statewide with higher intensity in core areas, near oil & gas activity	Lek surveys; also hunter harvest surveys	Increasing frequency; 3 x / season	Also sage thrasher, Brewer's sparrow?
Sandpiper				BLM		Presence/Absence		
Sharp-tailed grouse survey				WGFD	Mostly in the east	Lek surveys (on lek routes)		
Trumpeter swan surveys				WGFD, USFWS	Primarily NW; on refuges	Individual counts		
Waterfowl surveys				WGFD (game)		Sandhill crane, Canada goose (overwintering), and mid-winter surveys of all birds. Historic data on bird pairs.		
PLANTS								
BLM green line monitoring (long-term vegetation monitoring)				BLM (fits in with PFC, but is specific to Riparian areas)	Riparian areas	Many plants; density; species composition		
Colorado butterfly plant surveys				USFWS, WYNDD	SE WY (2-3 counties)			
Grass-forb understory				BLM rangeland health assessment	Allotment basis (i.e., leases come up every 10 years)			Wildlife habitat and clean air/clean water indicators
Multi-layered herbaceous species				Programs: PGC, WHIP. Agencies: BLM, USFS, NRCS				
Plants on BLM's sensitive species list				BLM, WYNDD	Site clearances	Ex: desert yellowhead; penstemon		
Shrub communities				WGFD, BLM, USFS, NRCS (private lands?)	Statewide	Transects. Forage utilization / productivity.		

Monitoring activity	Sagebrush	Riparian areas	Prairie grassland	Agencies, partners	Area / spatial scale	Measures	Frequency	Possible relevance for indicators
Ute Lady's Tresses survey			☐	USFWS, WYNDD	East-Central Wyoming	Occasional site-specific surveys in potential habitats (species only found in a few places)		
Vegetation monitoring			☐	Thunder Basin Grassland Prairie Ecosystem Association	Thunder Basin			
Willow monitoring		☐		WGFD	Mostly in Western WY	Productivity and utilization; condition of non-tree woody species (e.g., shrubs)		Relative to moose morbidity [Ask regional biologists for more information]
LANDSCAPE / HABITAT / SITE								
AIM project (low/ high intensity frameworks)	☐			BLM				
BLM Renewable Energy Coordination Office (RECO)			☐	BLM	Public lands			Active wells
Habitat assessment framework for sage grouse	☐		☐	WGFD, BLM	Fine-scale			
LANDFIRE	☐		☐	USGS, BLM?	Federal lands [not enough contiguous land]	Seral states; age classes		Disturbance regimes (fire)
Mapping of sagebrush structure	☐			WGFD, USGS	Specific studies (large scale)	Intention to map sagebrush in WY (what attributes?); aerial images		
Monitoring at energy development projects	☐		☐	Oil and gas companies	Local area	Ex: invasive species		
Monitoring of mine reclamation projects			☐	Mining companies	Local area			
National Wetlands		☐		USEPA	10 sites in WY	National wetland	5 year cycle	

Monitoring activity	Sagebrush	Riparian areas	Prairie grassland	Agencies, partners	Area / spatial scale	Measures	Frequency	Possible relevance for indicators
Condition Assessment						assessment. Data intensive / many metrics.		
National Wetlands Inventory				USFWS			Beginning in 2012	
NatureServe						Migration corridors, disturbance fragmentation, connectivity layers		Conversion to agriculture
Photo-point studies				Various agencies		Ex: fenceline contrast, conifer encroachment	Ongoing	
Proper Functioning Condition monitoring				BLM (USFS?); WHIP (NRCS)		Presence / absence; species composition / diversity; cover classes; grazing (amount of cover, utilization)		Ex: water, chemistry, vegetation structure, appropriate shade, lack of erosion, woody debris, recruitment/ reproduction in tree species, cottonwood, aspen
REGAP				BLM-WY w/ GIS (shrub, grass), NatureServe, USGS, University of Idaho	Regional	Range assessment, aerial photos. Gap analysis.		Areas with past cultivation
Remote sensing/GIS				USGS, WyGISC, WYBLM, TNC, USFS (road surveys)	Various activities			Unfragmented vegetation blocks. ORV use.
Riparian easements				TNC, WGFD, others		More pristine areas. Circumstances around riparian easements		Reference sites?
Surveys related to coal mining				Coal mine operators	Local area	Raptors (occupancy, success, prey base). Sage Grouse leks. Big game. Lagomorph (rabbits, hares; numbers per mile).		

Monitoring activity	Sagebrush	Riparian areas	Prairie grassland	Agencies, partners	Area / spatial scale	Measures	Frequency	Possible relevance for indicators
Transect data on livestock permits				USDA? WY Dept of Ag?				
OTHER								
Aerial imagery				WY GISC, WGFD, NRCS other federal agencies				
In-stream flow monitoring				WGFD		Flow rates;		
Invasive species inventories/monitoring				Weed & Pest Council Districts; Invasive Coordinated Resource Management; National Invasive Species Information Management System (NISIMS) coming online soon, involving DOI, USDA, WGFD, WY Ag Dept); Aquatic Invasives program - mussels (WGFD)		Pest density estimates; presence / absence		Ex: Tamarisk, Russian Olive, purple loosestrife, millfoil, zebra mussel
Inventory of fish passage barriers				BLM, USFS, Trout Unlimited, WGFD	Federal lands		Last 3 years	
Stream monitoring				Permit program for water use (WY Engineering Dept); Fisheries program (WGFD); water budgeting / monitoring (Bureau of Reclamation); Coordinated Resource Management - weeds(CRM)		presence of macroinvertebrates; fish		
Water depletion monitoring				USFWS	Green and Platte River systems	Outtake by significant water users		Habitat for T&E species
Water quality				WY DEQ, Conservation Districts; EPA		Water quality standards for stream class		

MANAGEMENT ACTIVITIES								
Agricultural BMPs, conservation practices				Watershed Association (BLM, USFS); Watershed planning (Conservation Districts, EPA, WY DEQ); Non-point source pollution program 519 toward TMDL (EPA, WY DEQ); Wetland Restoration Program (NRCS); EQUIP - irrigation (NRCS)				Ex: contour plowing, buffer strips
Urban BMPs, watershed plans				Municipal planning offices; Conservation Districts				Ex: septic tanks

NOTES:

- RMBO, BLM, USFS and WGFD are designing a statewide bird monitoring program. Data collection since 2002.
- Buffalo are considered livestock (except in national parks and Teton corridor) – check Durham offices.
- 'Natural' disturbance regimes: Interaction of prairie dogs, buffalo, fire. Totally unattainable today (except perhaps on some large ranches).
- Fire: NIFC (BLM, USFS). Fire regimes: LANDFIRE. Suppression: FS, BLM, county fire departments, state land board (through counties).
- Historical cultivation: many attempts in early 1900s were unsuccessful (See REGAP)
- Human structures (e.g., acres converted / acres disturbed by): aerial photos? Development records? American Farmland Trust? TNC mapping roads, projecting future development?
- Energy development (wind turbines): American Wind Energy Association (AWEA); Industrial Siting Council or RICO. Wind tracked on public and federal lands. State industrial siting commission (permitting) – tracked by production.
- Energy development (active wells): WY Oil & Gas Commission, WY BLM (database 5-7 months behind)
- Wind farms: tracked on public lands; state permitting for private lands (above threshold of industrial citing)
- ORVs: USFS, BLM ; State parks? Potentially gathering information on vehicle permits, satellite imagery (GIS/remote sensing), permitting, road surveys.
- Rural subdivision / development: counties (GIS, plats); TNC
- Fragmentation: Joint Ventures, Ducks Unlimited, LCCs (large-scale mapping…climate focus?)
- Conversion to agriculture: NatureServe (migration corridors, fragmentation, connectivity)

- Overgrazing: BLM, USFWS (monitor condition classes), State lands (leases, permits, agriculture statistics), NRCS (if Farm Bill funded; grazing management plans), Agricultural Extension (on private land in conjunction with funding). Little tracking on private lands.
- Prescribed fire: USFS, BLM, WY DEQ (air quality, permits for private burning). Private lands: NRCS promotes.
- Conservation easements: NRCS, TNC, land trusts, Rocky Mt Elk Foundation, WGFD, WNRT, WRP
- Reclamation (oil, gas, coal): permitting agencies, state oil and gas commission. Energy companies.
- Mining: State Lands Office, DEQ (permitting), BLM
- Roads: Disturbance layer for sage grouse (completion fall 2011); also see TIGER database (Census Bureau, although does not include roads associated with oil/gas wells)
- Harvest management: WGFD, USFWS
- CRP: FSA, NRCS
- Grassland restoration: Extension biologists (funded by WGFD, NRCS) mission is habitat improvement including grass restoration. Grassland Reserve Program.
- Prairie dog management: private landowners. Some protection on federal lands.
- Structures in riparian areas: Army Corps of Engineers, Bureau of Reclamation
- Structures in sagebrush: rural electric coops; BLM (fence); TNC (turbines)
- Connectivity (including floodplain, instream, fish passage): WY GISC
- Climate change (temperature, precipitation, drought): State Climatologist, NOAA, NPS, USGS, WGFD. Climate modeling by USGS, TNC, and LCCs.
- Channelization: Army Corps of Engineers, Irrigation districts
- Levees: USACE, BOR
- Soil crust: Eve Warren, Fire Ecologist in Warland Office
- Insect outbreaks: APHIS, WY Department of Agriculture, NRCS?
- Chemical / mechanical treatments (sagebrush): BLM, NRCS, WGFD, industry. USGS is evaluating some industry treatment projects.
- Grass banks (sagebrush): TNC, USFS (SW Wyoming), WLCI

Appendix 6:

Workshop Participants List

Pioneering Performance Measures Workshop
Cheyenne, Wyoming
May 2011

Workshop Participants List

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