WYOMING GAME AND FISH DEPARTMENT

STATE WILDLIFE ACTION PLAN 2010

Foreword

State Wildlife Action Plans (SWAPs) are comprehensive wildlife conservation strategies to maintain the health and diversity of wildlife within a state, including species with low and declining populations. Plans are intended to be coordinated with other wildlife and natural resource agencies and organizations, as well as receive public input during their development and implementation.

Wyoming's abundant wildlife, native habitats, and outdoor recreational opportunities are defining features of the state. Wyoming is home to 120 species of mammals, 426 species of birds, 12 species of amphibians, 27 species of reptiles, 78 species of fish, probably several thousand species of invertebrates, and well over 13,100 species of plants (Wyoming Game and Fish Department 2005, NRCS Plant Database). Some of the largest migratory populations of big game animals in North America are found within the state (Sawyer et al. 2005). Wyoming also has among the highest participation rates in wildlife related recreation in the country. About 48% of Wyoming residents engage in wildlife viewing and about 28% of its population fishes or hunts (U.S. Fish and Wildlife Service 2006). The state's natural splendor is a major attraction for visitors who annually spend approximately $2.25 billion (The Conservation Fund 2007).

During the late 19th and early 20th century, North America experienced one of the greatest wildlife conservation success stories in history with the enactment of wildlife laws, which brought back many wildlife species from the brink of extinction as a result of unregulated harvest, commercial exploitation, and habitat loss. Concurrently, the establishment of wildlife agencies, a funding system for wildlife conservation and management through license sales and taxes on hunting and fishing equipment, wildlife and natural resource professions, and a host of non-profit conservation organizations combined to create arguably the most effective wildlife conservation system in the world.

In order for this success story to continue throughout the 21st century, new challenges must be met. Many past advancements occurred through improvements in understanding and application of wildlife conservation principles. In the future, the availability of suitable habitat will increasingly become the most limiting factor for maintaining viable wildlife populations as the human population grows and natural resource demands increase. Developing strategies to effectively address this concern will involve engaging partners and disciplines outside the traditional wildlife management field.

Accordingly, issues addressed and recommended conservation actions within Wyoming's SWAP frequently cross jurisdictional boundaries and involve a variety of interests and diverse natural resource users. Implementation of recommendations within the plan will require commitment and dialogue among numerous government agencies, landowners, industry, and the public. Wyoming's SWAP is planned to be revised every five years and will certainly evolve overtime as successes are expanded, shortcomings corrected, new information becomes available, threats change, and new partners become engaged.

Many organizations and individuals were involved in the 2010 revision of Wyoming's SWAP. Their names can be found at the end of the sections of the SWAP where they contributed. The Wyoming Game and Fish Department is grateful for their time and expertise. Special recognition goes to:

Wyoming Game and Fish Habitat Technical Advisory Group

Wyoming Game and Fish Department Nongame Section

Wyoming Game and Fish Department Habitat Section

Wyoming's State Wildlife Action Plan Inter-agency Advisory Team

Wyoming Natural Diversity Database

Amanda Losch and Judie Petersen

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Acronyms Used throughout the SWAP

AIS	Aquatic Invasive Species
ATV	All Terrain Vehicle
AWVED	Assessment of Wildlife Vulnerability to Energy Development
BCT	Bonneville Cutthroat Trout
BLM	Bureau of Land Management
BMP	Best Management Practices
BTU	British Thermal Unit
CCT	Colorado Cutthroat Trout
CCVI	Climate Change Vulnerability Index
CER	Categorical Exclusion Review
CEQ	Council on Environmental Quality
COA	Conditions of Approval
CRM	Coordinated Resource Management
CRP	Conservation Reserve Program
CSU	Controlled Surface Use
CWCS	Comprehensive Wildlife Conservation Strategy
DEQ	Department of Environmental Quality
DSS	Decision Support System
DU	Ducks Unlimited
EIS/EA	Environmental Impact Statement/Environmental Assessment
ENSO	El Niño-Southern Oscillation
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
EQIP	Environmental Quality Incentives Program
ES	Ecological Systems
ESA	Endangered Species Act
FONSI	Finding of No Significant Impact
FOOGLRA	Federal Onshore Oil and Gas Leasing Reform Act
FRPP	Farm and Ranchland Protection Program
FSA	Farm Service Agency
GIS	Geographic Information Systems
GRP	Grassland Reserve Program
GYE	Greater Yellowstone Ecosystem
HACCP	Hazard Analysis and Critical Control Point
HTAG	Habitat Technical Advisory Group
HUC	Hydrologic Unit Code
IAT	Interagency Advisory Team
IBI	Index of Biotic Integrity
IPCC	Intergovernmental Panel on Climate Change
ISC	Industrial Siting Council
IWJV	Intermountain West Joint Venture
JIO	Jonah Interagency Office
LCC	Landscape Conservation Cooperative
LSC	Leatherside Chub
MDWG	Mule Deer Working Group
MICD	Modified Index of Centers of Density
MMS	Mineral Management Services
MOU	Memorandum of Understanding
MW	Megawatts
NAWCA	North American Wetlands Conservation Act
NEPA	National Environmental Policy Act

NFHAP	National Fish Habitat Action Plan
NFMA	National Forest Management Act
NGO	Non-governmental Organization
NGPJV	Northern Great Plains Joint Venture
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Services
NREL	National Renewable Energy Lab
NSO	No Surface Occupancy
NSS	Native Species Status
NWGAP	Northwest Gap Analysis Project
NWPCP	National Wetlands Priority Conservation Plan
PEIS	Programmatic Environmental Impact Statement
POD	Plan of Development
RCRA	Resource Conservation and Recovery Act
RMP	Resource Management Plan
ROW	Right-of-way
SARA	Superfund Amendments and Title III Reauthorization Act
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SGCN	Species of Greatest Conservation Need
SHC	Strategic Habitat Conservation
SHP	Strategic Habitat Plan
SRC	Snake River Cutthroat Trout
SWAP	State Wildlife Action Plan
SWG	State Wildlife Grant
TNC	The Nature Conservancy
UNEP	United Nations Environment Programme
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USNVC	United States National Vegetation Classification
WAFWA	Western Association of Fish and Wildlife Agencies
WGA	Western Governors' Association
WGFD	Wyoming Game and Fish Department
WGFC	Wyoming Game and Fish Commission
WHIP	Wildlife Habitat Incentives Program
WISC	Wyoming Industrial Siting Council
WJVSC	Wyoming Joint Ventures Steering Committee
WLCI	Wyoming Landscape Conservation Initiative
WMO	World Meteorological Organization
WOGCC	Wyoming Oil and Gas Conservation Commission
WOS	Wildlife Observation System
WREZI	Western Renewable Energy Zones Initiative
WRP	Wetlands Reserve Program
WSA	Warmwater Stream Assessment
WWDC	Wyoming Water Development Commission
WWNRT	Wyoming Wildlife Natural Resource Trust

WYBWG	Wyoming Bat Working Group
WyGISC	Wyoming Geographic Information Science Center
WYNDD	Wyoming Natural Diversity Database
YNP	Yellowstone National Park
YSC	Yellowstone Cutthroat Trout

Activities since the 2005 Comprehensive Wildlife Conservation Strategy

Wyoming's first Comprehensive Wildlife Conservation Strategy (CWCS) was adopted by the Wyoming Game and Fish Commission in July 2005 and was approved by the U.S. Fish and Wildlife Service (USFWS) in September 2005. Developing a CWCS is required in order to receive funding through the federal State Wildlife Grants (SWG) program enacted by Congress in 2001. The purpose of the CWCS is to establish a coordinated strategy to maintain the health and diversity of wildlife within Wyoming, including those species with low and declining populations. Not only is the CWCS intended to guide the Wyoming Game and Fish Department's (WGFD) activities for this purpose, but it also serves as a guide for the combined efforts of government agencies, conservation organizations, academia, tribes, and individuals in conserving Wyoming's Species of Greatest Conservation Need (SGCN). The CWCS is the first plan of its kind for Wyoming, and also part of an unprecedented national framework of similar plans established in all U.S. states and territories.

Implementation Plan for Wyoming's Comprehensive Wildlife Conservation Strategy

The WGFD Habitat Technical Advisory Group (HTAG) developed an *Implementation Plan for Wyoming's Comprehensive Wildlife Conservation Strategy* in February 2008. The implementation plan was intended to help prioritize WGFD SGCN conservation efforts until the revision of the CWCS in 2010. The plan placed the highest priority on collecting biological information (i.e., distribution, abundance, life history, habitat requirements, genetics, method development, research, etc.,) for SGCN for which there is insufficient data. Secondary emphasis was placed on habitat projects including conservation easements and property acquisitions.

The implementation plan included additional criteria for evaluating SWG and other sensitive species grant proposals. Emphasis was placed on projects that:

1. Implemented conservation strategies for SGCN that are federally listed under the Endangered Species Act;
2. Addressed the needs of multiple SGCN;
3. Incorporated human, financial, or technical resources of partners outside the WGFD;
4. Involved SGCN for which Wyoming represented a large percentage of their continental range; and
5. Displayed the ability to be cost effective.

The importance of GIS work and public outreach to the future success of the CWCS was noted. Lastly, the implementation plan contained a timeline and task list for the next revision of the CWCS.

New Sensitive Species Funding Sources

The WGFD has received more than $3,050,000 from the SWG program for fiscal years 2005–2009.

The budget for the 2009–2010 biennium provided general fund appropriations to the WGFD for the first time for all aspects of its nongame/sensitive species program. The Wyoming Legislature awarded $1.2 million to the department for maintenance and operations, including existing personnel and administrative support, and $609,000 in direct general fund appropriations for each of the two years for specific SGCN project work. This appropriation was later reduced by $40,000 to $569,000 as part of the Governor's directive to all agencies to reduce general fund budgets due to revenue shortfalls. This funding, in conjunction with $1.3 million from the Governor's Endangered Species Account, has aided the WGFD with inventory work to fill data gaps for SGCN and has resulted in status

reclassifications for some species in the revised CWCS. These dollars are also important for matching SWG program funds, which require a 50% contribution from the state for most projects.

In December 2007, Region 6 of the USFWS entered into a five-year memorandum of agreement with the State of Wyoming and the WGFD to facilitate coordination on sensitive species projects, including projects on current or potentially listed threatened or endangered species. Projects initiated through this collaboration include researching the potential impacts of wind energy development on wildlife, restoring native fish populations, and surveying prairie dogs and goshawks, among other. The WGFD has received a total of $548,000 through this agreement and is expecting additional allocations in fiscal years 2011–2013.

Lastly, in 2005, the Wyoming Legislature created the Wyoming Wildlife and Natural Resource Trust (WWNRT) to "enhance and conserve wildlife habitat and natural resource values throughout the state." The WWNRT is funded by donations, legislative appropriations, and the interest earned on a permanent account. It functions as an independent state agency governed by a board of directors composed of nine citizens appointed by the Governor. Since 2006, 160 projects have been funded by WWNRT throughout the state, which has resulted in the allocation of more than $14 million from the trust itself and over $105 million when matching dollars from sponsoring agencies and organizations are included. The WGFD and the Wyoming Game and Fish Commission have been able to use WWNRT grants to augment SWG funding to support various SGCN monitoring and recovery efforts.

Strategic Habitat Plan

In early 2009, the WGFD revised its Strategic Habitat Plan (SHP) in response to intensified habitat threats across Wyoming, including accelerated energy development, insect epidemics, proliferating invasive species, drought stress, and the apparent role of climate change in wildlife management. The recent revision of the SHP incorporates SGCN into the planning process and includes SGCN considerations in identifying "crucial" and "enhancement" areas. Moreover, the mitigation policy developed by the Wyoming Game and Fish Commission for species and habitats that are being unavoidably impacted by growth, development, and land use changes includes SGCN. The WGFD Habitat Technical Advisory Group's role in developing both the SHP and CWCS allowed for coordination between the two plans.

SGCN Projects

More detailed information about CWCS-related projects conducted since 2005 can be found in this plan within individual species accounts and in the "Conservation Initiatives" topic heading of the specific sections on aquatic basins and, to a lesser extent, terrestrial habitat types. Annual Reports are completed for all bird and mammal CWCS projects and can be found at http://gf.state.wy.us/wildlife/nongame/AnnualCompletionReport. The following are examples of some, but not all, CWCS-related projects since 2005.

Birds and Mammals

Baseline and trend data was collected on the American white pelican and other colonial nesting water birds, bald eagle, Columbian sharp-tailed grouse, common loon, greater sage-grouse, sandhill crane, long-billed curlew, peregrine falcon, trumpeter swan, American bittern, mountain plover, upland sandpiper, and goshawk. SWG program funding also helped to develop survey and inventory methods for harlequin ducks. Sage-grouse habitat-use studies, including investigations into brood rearing locations, summering and wintering habitats, and seasonal movements, have been completed. Research has also been conducted on the risk of nest abandonment by raptors due to human disturbances. The effects of energy development, including from wind power, on birds is being studied. Sage-grouse, golden eagles, and ferruginous hawks are receiving special attention for this research.

SWG grants have also supported baseline data collection and surveys on black- and white-tailed prairie dog, several species of bats, Canada lynx, pygmy rabbit, swift fox, and wolverine. Annual surveys were completed on black-footed ferrets to determine their status and distribution at reintroduction sites, to map ferret habitat, and to make additional reintroductions. A wolverine study in the Yellowstone ecosystem researched wolverine densities and population viability, habitats important to wolverine persistence, travel corridors between isolated mountain ranges, effects of human recreation, reproductive and survival rates, and mortality factors. Similarly, a study on the effects of winter recreation trails on small- and mid-sized mammals, including lynx and wolverine, was conducted. Enhanced manpower and materials have been provided to reduce grizzly bear–human conflicts in the Yellowstone Ecosystem. Remote cameras were used to document females with cubs as a potential technique to estimate grizzly bear population. A study investigating the effects of beetle kill on forest SGCN has also been established.

Fish

Considerable survey work was completed on Wyoming native fish populations. Notable projects were conducted on the main stem and tributaries of the Green, lower Bighorn, and Powder rivers, as well as eastern Wyoming prairie streams. This work greatly enhanced knowledge about the size and distribution of a significant proportion of Wyoming native fishes and contributed to the reclassification of the SGCN status of 15 species in the revised CWCS. Completion of this survey work will help to target future native fish conservation and restoration efforts.

Projects to remove nonnative fishes were completed to conserve endemic populations of Colorado River and Yellowstone cutthroat trout. SWG program funds were also used to describe the spawning movements and habitat of Snake River cutthroat trout in the Salt River watershed.

The effects of habitat fragmentation on native roundtail chubs, bluehead suckers, and flannelmouth suckers were researched in the Little Sandy River and on Colorado River cutthroat trout in the north fork of Little Snake river watershed. Research into the movement and migration of sauger and shovelnose sturgeon was completed.

Reptiles and Amphibians

The WGFD hired a Herpetological Coordinator in May 2008. Amphibians and reptiles including turtles (six taxa), amphibians (five taxa), snakes (six taxa), and lizards (two taxa) were surveyed in the Powder River basin. The study helped to refine survey methods for these species groups that can be applied statewide. Data on road mortality for snakes and turtles was collected as part of this research. Abundance and distribution information on midget faded rattlesnakes, ornate tree lizards, Great Basin gopher snakes, and Northern Plateau lizards was collected in Sweetwater County. This area was prioritized due to proposed natural resource development. SWG funds were used to conduct boreal toad surveys in all portions of southern Wyoming and throughout the Green River watershed in south-central Wyoming. The department's Herpetological Coordinator was also active in recovery efforts for the endangered Wyoming toad.

Mollusks and Crustaceans

A project has been established to look into the distribution and ecology of Wyoming freshwater mussels and freshwater gastropods of western Wyoming. Surveys of crayfish were conducted to increase knowledge about their distributions in all Wyoming drainages.

Data Systems

SWG funding helped to employ a WGFD GIS Analyst, who worked to compile SGCN datasets from before and after the writing of the 2005 CWCS. This information was imported into a geodatabase that allows for visualization and both spatial and non-spatial queries. The GIS Analyst played a leading role in creating SGCN priority area maps for the 2010 State Wildlife

Action Plan (the new name for the CWCS), and in responding to numerous requests from WGFD employees for SGCN maps and map analyses. An additional GIS Analyst was hired to focus on sage-grouse work.

Public Outreach
The WGFD frequently featured articles about the CWCS, CWCS projects, leading conservation issues, and SGCN, using its *Wyoming Wildlife* magazine (~33,000 subscribers), the bi-monthly *Wyoming Wildlife News* newsletter (~30,000 printed), and the weekly email news releases (~15,000 subscribers). Featured SGCN have included harlequin duck, trumpeter swan, yellow-billed cuckoo, black-footed ferret, pygmy rabbit, midget faded rattlesnake, and Colorado River cutthroat trout. In 2006, the *Species of the Season Challenge* program was established to enhance awareness about SGCN and to engage the public in collecting information on their distribution and relative abundance (see SWAP Public Involvement).

Preparation and Completion of 2010 CWCS Revision

Preparations for the revision of the CWCS began with the development of a revision timeline and task list for the *Implementation Plan for Wyoming's Comprehensive Wildlife Conservation Strategy*. Among the tasks recommended and completed was the hiring of a CWCS Coordinator to assist with the 2010 revision of the plan. This coordinator was hired by the WGFD in July 2008.

The first task in the revision process was for the Habitat Technical Advisory Group (HTAG) to review the CWCS and CWCS implementation plan for needed improvements. Next, WGFD employees and representatives from other agencies who participated in the development of the 2005 CWCS were interviewed regarding their perceptions of the plan and suggested changes. Key stakeholders for the future implementation of the CWCS, including individuals from agriculture and energy industry trade associations, were also contacted. CWCSs from surrounding states and those from states noted for being particularly innovative or effective were reviewed for ideas and to facilitate future cross-border coordination.

An outline and timeline for the revised plan was completed by HTAG and approved by the WGFD Administration in January 2009. Goals for the 2010 CWCS were presented and adopted by the Wyoming Game and Fish Commission on April 24, 2009. These goals included:

1. Creating a more structured approach for meeting the conservation needs of SGCN at the state, habitat, and species level;
2. Including a section that addressed Wyoming's leading wildlife conservation issues;[1]
3. Increasing the habitat focus of the plan by including a section that divided SGCN habitats into 11 terrestrial habitat types and 6 aquatic basins. Non-SGCN wildlife species of high ecological, economic, or social importance were identified within each terrestrial habitat type and aquatic basin;
4. Providing greater prioritization of SGCN for conservation actions;
5. Establishing an Interagency Advisory Team to improve interagency coordination on the revision and future implementation of the CWCS (see Wyoming's 2010 SWAP Conservation Approach); and
6. Developing prioritization criteria for future SWAP funding which incorporated the above goals.

At this time, the name of the Comprehensive Wildlife Conservation Strategy was changed to State Wildlife Action Plan (SWAP) to reflect the most common name by which these plans were being referred.

[1] For the 2010 CWCS, Wyoming's leading wildlife conservation challenges were identified as rural subdivision and development, energy development, invasive species, climate change, and disruption of natural disturbance regimes.

In order to receive public input on the plan, a quarterly *SWAP Newsletter* was initiated in May 2009. Revision topics and developments were featured within the *SWAP Newsletter* as they occurred along with contact information for the WGFD SWAP Coordinator for receiving questions and comments (see SWAP Public Involvement).

Information collection for the revised SWAP began in May 2009. Input was received from leading wildlife and natural resource conservation experts by personal interview, focus groups, and written submissions. Experts were identified by HTAG and the SWAP Inter-agency Advisory Team (see Wyoming's 2010 SWAP Conservation Approach).

From this stage, the 2010 SWAP revision proceeded as follows:

1. The first drafts of SWAP sections were finished in May 2010 and were made available for review and comment by individuals who had contributed information. This review period lasted until the end of July.
2. The WGFD HTAG groups reviewed SWAP conservation and monitoring recommendations in early August 2010.
3. A draft of the completed SWAP was delivered to the WGFD Administration for approval on August 17 and submitted to the Wyoming Game and Fish Commission at their September 8, 2010 meeting.
4. A presentation on the revised SWAP was provided to Wyoming Game and Fish Commission members at the September 8 commission meeting.
5. The revised SWAP, with the recommendations of Wyoming Game and Fish Commissioners included, was posted on the WGFD website for public comment on October 1, 2010. The public comment period ended October 31, 2010. During this time public meetings were held in four locations around the state—Green River, Lander, Casper, and Laramie—to provide the public with an overview of the revised SWAP and to receive feedback on the plan (see SWAP Public Participation).
6. The SWAP, with revisions based on public comments, was presented to and approved by the Wyoming Game and Fish Commission during their January 28, 2011 meeting.
7. The revised SWAP was submitted to the USFWS for approval in February 4, 2011. Approval was received on July 1, 2011.

The next revision of the SWAP is currently scheduled for 2015.

Wyoming's 2010 SWAP Conservation Approach

In 2001, the U.S. Congress created the State Wildlife Grant (SWG) Program and charged each state and territory with developing a Comprehensive Wildlife Conservation Strategy (CWCS) as a condition of receiving federal funds through the program. Wyoming completed its first CWCS in 2005.

CWCSs, now referred to as State Wildlife Action Plans (SWAPs), are intended to be broad-based strategies to maintain the health and diversity of wildlife within a state, including preventing the need for additional species to be listed under the Endangered Species Act. Special emphasis is given to addressing wildlife species that have received less conservation attention in the past, including those that are not hunted or fished. All 50 states have developed SWAPs, providing a comprehensive framework for planning and coordination on wildlife issues that cross state boundaries.

In the legislation defining SWAPs, Congress outlined eight requirements (Table 1). Beyond these requirements, Congress and the U.S. Fish and Wildlife Service (USFWS), the agency that reviews and approves SWAPs, provide substantial flexibility for each state to develop approaches that fit their unique wildlife, habitats, management context, and local issues.

Table 1. Eight Required Elements for SWAPs

1. Information on the distribution and abundance of species of wildlife, including low and declining populations as the state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the state's wildlife;
2. Descriptions of extent and condition of habitats and community types essential to the conservation of species identified in (1);
3. Descriptions of problems which may adversely affect species identified in (1) or their habitats, and priority research and survey efforts needed to identify factors which may assist in restoration and improved conservation of these species and habitats;
4. Descriptions of conservation actions proposed to conserve the identified species and habitats and priorities for implementing such actions;
5. Proposed plans for monitoring species identified in (1) and their habitats, for monitoring the effectiveness of the conservation actions proposed in (4), and for adapting these conservation actions to respond appropriately to new information or changing conditions;
6. Descriptions of procedures to review the plan at intervals not to exceed 10 years;
7. Plans for coordinating the development, implementation, review, and revision of the plan with federal, state, and local agencies and Indian tribes that manage significant land and water areas within the state or administer programs that significantly affect the conservation of identified species and habitats; and
8. Broad public participation is an essential element of developing and implementing these plans, the projects that are carried out while these plans are developed, and the species in greatest need of conservation.

While state wildlife agencies are responsible for developing and implementing SWAPS, many issues necessary for their success are beyond their jurisdiction and resources. Accordingly, SWAPs are required to be coordinated with other state, federal, and local natural resource organizations and agencies. The U.S. Forest Service, U.S. National Park Service, and the Bureau of Land Management have all signed an instructional memorandum for cooperation in developing and implementing SWAPs. In addition, many of Wyoming's most valuable wildlife habitats occur on private land, which

requires both developing conservation strategies that respect private property rights and nurturing strong functional partnerships with the private landowners in question.

Accomplishing the SWAP's purpose is no small task. Wyoming's waters and landscapes support over 800 species of wildlife (Wyoming Game and Fish Department 2005). Specifically, there are 120 species of mammals, 426 species of birds, 12 species of amphibians, 27 species of reptiles, 78 species of fish, arguably several thousand species of invertebrates, and well over 13,100 species of plants (Wyoming Game and Fish Department 2005, NRCS Plant Database).

Conserving Wyoming's wildlife species is heavily dependent upon the future quantity and quality of available habitat, both terrestrial and aquatic. The amount and condition of wildlife habitat is influenced by the success in developing strategies to address the issues which are having the greatest impact on wildlife and habitat resources. With this in mind and to most effectively focus conservation efforts and organize information within this plan, Wyoming's revised SWAP is organized by a three-tiered approach:

Statewide	Leading Wildlife Conservation Challenges
Habitat	Terrestrial Habitat Types and Aquatic Basins
Species	Species of Greatest Conservation Need

As the reader moves through the SWAP, the identified threats and conservation actions progress from general statewide issues and actions to habitat-specific issues and actions, and finally to conservation strategies for individual Species of Greatest Conservation Need (SGCN), which are presented within each species account.

Each level of conservation is addressed in a separate chapter which is further broken down into sections. Within each section, the eight required elements for SWAPs are addressed (Table 2). Exceptions are elements 6 and 8, dealing with public involvement and plans for revising the SWAP, which are both addressed in separate chapters. Various sections are frequently cross-referenced throughout the SWAP to provide the reader with additional information on a given topic, but each section is also composed to function as a standalone document. This format was adopted because it is anticipated that Wyoming's SWAP will most frequently be accessed through the Internet for information on specific subjects, as opposed to being accessed as a single document in its entirety. Additionally, it is likely that individual sections of the SWAP will be duplicated and distributed.

The revision of Wyoming's SWAP extensively utilizes the expertise and feedback of wildlife and natural resources conservation experts. The broad scope of the SWAP and associated time and resource limitations made it impractical to conduct independent scientific analyses on each topic for this revision. Additionally, SWAPs are required to be developed using broad professional and public involvement and to discuss and address not only scientific issues, but also social, economic, and administrative considerations. Two committees assisted in the coordination of internal and external comment and feedback:

The WGFD Habitat Technical Advisory Group

The WGFD Habitat Technical Advisory Group (HTAG) facilitated the coordination of intra-agency expertise in the SWAP's revision, as well as linking SWAP efforts to existing department activities and priorities. In revising the SWAP, HTAG helped to develop the plan's outline, identify experts within the WGFD to contribute information, evaluate various conservation and prioritization strategies, review draft sections, and provide a forum for discussing revision-related issues and making recommendations to the WGFD's administration. HTAG also has a central role in the implementation of the plan through recommendations for the approval of SWG projects and other SWAP-related funds. A list of HTAG members can be found in Appendix A.

The SWAP Interagency Advisory Team

The SWAP Interagency Advisory Team (IAT) was created to support the involvement of other wildlife and natural resource agencies in developing and implementing the SWAP. Their role includes communicating respective agency expertise and concerns, identifying common priorities and opportunities, minimizing the duplication of efforts, facilitating information-sharing, and conveying SWAP issues and activities to agency employees and constituencies. IAT contributed to the revision of the SWAP by providing input on the plan's outline, identifying leading issues and conservation actions, soliciting input from experts within their organizations, and reviewing draft documents. A list of IAT members can be found in Appendix B.

With the help of these two committees, input for the chapters on Leading Wildlife Conservation Challenges and Terrestrial Habitat Types was solicited from the personnel of agencies and organizations which have significant jurisdictional authority, financial resources, and/or technical expertise on each subject. Information was received either through focus groups or through individual written submissions to questions based on the subject headings of each section. This approach was considered to be both time-efficient for gathering information, as well as encouraging the involvement of entities whose participation is important for the implementation of the SWAP. Near the end of each section within these chapters is a list of individuals who reviewed the document and provided feedback on the subject matter. The input of contributors was compiled and then further supported by independent research. Existing conservation initiatives pertaining to Wyoming's wildlife and natural resources were consulted and referenced throughout the revision process. Most notable among these initiatives is the WGFD's Strategic Habitat Plan (2009).

Information for individual species accounts was provided by WGFD biologists most familiar with the species, and all accounts were reviewed by the WGFD Fisheries Management Coordinator and the Supervisor of Biological Services. Species accounts were also made available to the Wyoming Natural Diversity Database for review. Scientific names for each SGCN can be found in the comprehensive list of these species within the SGCN chapter.

The SWAP should not be viewed as providing an exhaustive overview of each subject. Rather, it is intended to identify threats and conservation actions that are considered most important throughout the state, on which there is general consensus among experts consulted, and which have some degree of short-term or long-term attainability. The breadth of information in each section and the specificity of conservation actions vary, based upon existing knowledge, the availability of information, and the input provided by contributors. This reduced the consistency of identified threats and conservation recommendations between sections according to the priorities of the contributors. With this in mind, and with the knowledge that many listed conservation actions cross jurisdictional boundaries, the intent of many conservation recommendations is more to provide strategic guidance than to set specific courses of action. Agencies and organizations helping to implement the SWAP will need to select and adapt recommendations to fit their individual mandates and priorities. To this end, the WGFD is planning to develop an implementation strategy for the SWAP, including identifying performance indicators, beginning in the spring of 2011.

The content of this SWAP only reflects conditions and issues from one snapshot in time. It is the intent of the WGFD to formally revise its SWAP every five years with interim updates likely (see Reviewing and Updating the SWAP). Items and priorities addressed in this SWAP will change as new information becomes available, conditions change, and additional agencies, organizations, and individuals become engaged.

Table 2. Road Map to Required SWAP Elements

Required SWAP Element	Location in SWAP
Element 1. Information on the distribution and abundance of wildlife including SGCN.	• Species accounts for each SGCN contain information on rangewide and statewide abundance, as well as Wyoming range and distribution maps. (Page IV- 1 - 1 to IV– 7 -35) • Terrestrial habitat types and aquatic basins have lists of associated SGCN and information on wildlife diversity. (Page III – 1 – 1 to III - 11 - 28)
Element 2. Descriptions of extent and condition of habitats essential to SGCN.	• SWAP habitat types and aquatic basins contain information about their distribution throughout Wyoming and physical and biological conditions. (Page III – 1 – 1 to III – 17 - 28) • Maps found within habitat types and aquatic basins show their locations within Wyoming. (Page III – 1 – 1 to III – 17 - 28) • SWAP SGCN priority area maps evaluate level of habitat intactness based upon 8 habitat disturbances. (Explanation and Map: Page III – i - 6 to III – i - 8) • Species accounts describe habitat requirements for each SGCN. (Page IV -1 - 1 to IV – 7 - 35)
Element 3. Descriptions of problems that may adversely affect SGCN and their habitats.	• The SWAP Leading Wildlife Conservation Challenges chapter addresses the five statewide threats that are most significant to SGCN and their habitats including climate change. (Page II 1 - 1 to II – 5 – 21) • Leading threats to each terrestrial habitat type and aquatic basin are listed within these sections. (Page III – 1 – 1 to III – 17 - 28) • Each species account lists threats to SGCN. (Page IV -1 - 1 to IV -7 -35) • Priority research and survey efforts are identified within the individual sections on leading wildlife conservation challenges, terrestrial habitat types, aquatic basins, and species accounts. (Page II 1-1 to II – 5 – 21, Page III – 1 – 1 to III – 17 - 28, Page IV -1-1 to IV -7-35)
Element 4. Descriptions of conservation actions to conserve SGCN and their habitats.	• Conservation actions needed to conserve SGCN and associated habitats and to address the most significant statewide wildlife conservation issues are found within individual species accounts,

	terrestrial habitat types, aquatic basins, and leading wildlife conservation challenges. (Page II 1 - 1 to II – 5 – 21, Page III – 1 – 1 to III – 17 - 28, Page IV -1 - 1 to IV - 7 - 35)
Element 5. Proposed plans for monitoring SGCN, their habitats, and the success of conservation actions.	• Existing and needed monitoring is included within the Monitoring/Research and Conservation Actions sections found within species account. The introduction to the SGCN chapter has information on the WGFD plans to complete surveys on all SGCN. (Page IV -1-1 to IV -7 - 35, Page IV – i - 5) • Terrestrial habitat types and aquatic basins include monitoring recommendations. Existing monitoring is addressed within the Current Conservation Initiatives section. (Page III – 1 – 1 to Page III – 17 - 28) • Each of the five leading wildlife conservation challenges contains a section on recommended monitoring to track impacts and evaluate the success of conservation actions. (Page II 1- 1 to II – 5 – 21) • The chapter on Reviewing and Updating the SWAP has information on adapting conservation actions to respond to new information or changing conditions. (Page V – 1 - 1 to V – 1 – 3)
Element 6. Descriptions of procedures to review the SWAP.	• These procedures are found in the Reviewing and Updating the SWAP chapter. (Page V – 1 - 1 to V – 1 – 3)
Element 7. Plans for coordinating the development and implementation of the SWAP with other agencies.	• The role of the SWAP Interagency Advisory Team in developing and implementing the SWAP is described in the chapter on Conservation Approach. This chapter also explains how information was collected from various agencies, organizations, and experts in developing the SWAP. (Page I – 2 - 2 to I – 2 – 3) • A list of individuals from various agencies/organizations who contributed information or reviewed the SWAP is found at the end of each section within the Leading Wildlife Conservation Challenges and Habitat chapters. (Page II 1-1 to II – 5 – 21, Page III – 1 – 1 to III – 17 - 28) • The revised SWAP external review process is described within the chapter on Public

	Participation. . (Page VI – 1 – 1 to VI – 1 – 4)
Element 8. Public participation.	• Public Participation chapter. (Page VI – 1 – 1 to VI – 1 – 4)

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Appendix A

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Wyoming's Leading Wildlife Conservation Challenges

Introduction

Wildlife conservation in Wyoming is influenced by a wide range of issues. A few issues, however, have defining roles in determining the future health, abundance, and diversity of species throughout the state. When wildlife and natural resource professionals were surveyed during the 2010 revision of Wyoming's State Wildlife Action Plan (SWAP), the following five issues were consistently identified as the most significant challenges facing Wyoming's wildlife:

- rural subdivision and development
- energy development
- invasive species
- climate change
- disruption of historic disturbance regimes

Further, these issues, or issues related to them, were most commonly listed as concerns within individual SWAP terrestrial habitat types, aquatic basins, and species accounts.

The exclusion of other challenges from this chapter does not imply they are unimportant to Wyoming's wildlife and habitat resources. Other important wildlife conservation issues include such concerns as disease, off-road vehicle recreation, certain agricultural practices, and pollution, among others. In comparison to the challenges identified above, however, these problems may not be as widespread, may not have the same level or scope of impact, or may be closely related to other issues, including the five leading challenges. Issues such as restoring and maintaining habitat connectivity for the movement of wildlife, while important, are better discussed as conservation strategies, typically in response to broader threats. These conservation concerns, and others not covered in this chapter, are addressed in the sections for the terrestrial habitat types, aquatic basins, and species accounts where they have the greatest impact.

Focusing attention on the five leading wildlife conservation challenges is not intended to be an indictment of any industry or group. Wildlife is one of many considerations in managing Wyoming's land and natural resources to meet society's current and future needs. Instead, the emphasis placed on the issues discussed in this chapter is meant to encourage appropriate and timely planning so that benefits for all interests, wildlife and other, can be maximized. Accordingly, the recommended conservation actions within this chapter tend to apply to a greater number of stakeholders, and often must be addressed at the policy level.

Rural subdivision and development, energy development, invasive species, climate change, and disruption of historic disturbance regimes are five important conservation issues that extend across a majority of Wyoming's habitat types and wildlife species. Addressing these issues as separate chapters in the SWAP provides in-depth background to supplement other sections of the SWAP where they are discussed. It also eliminates redundancy.

These conservation challenges are interrelated. For example, the spread of invasive species is commonly facilitated by broken and bare ground associated with new roads and construction from rural subdivision and energy development. In turn, the establishment of invasive species, cheatgrass for example, can alter historic disturbance regimes such as fire, to the detriment of indigenous plant communities (Whisenant 1990). A warmer, more variable climate, which some predict for Wyoming, may provide a competitive advantage for cheatgrass over native plants, further facilitating its spread (Bradley et al. 2008).

Leading wildlife conservation challenges addressed within the SWAP will likely change over time as new challenges emerge, as government agencies are encouraged to evaluate the potential impacts of issues that are considered national priorities, or as existing threats diminish or are mitigated. The issues addressed within this chapter will be re-evaluated with each revision of Wyoming's SWAP.

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Rural Subdivision

Photo courtesy of WGFD

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The following individuals reviewed or contributed information to the Rural Subdivision and Development section of the SWAP: 13

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Background

Wyoming is internationally known for its scenic beauty, abundant wildlife, numerous recreational opportunities, and friendly small-town atmosphere. These qualities are increasingly desirable to telecommuters and retiring baby boomers alike, and to both state residents and non-residents seeking rural lifestyles.

Trends in housing development patterns reflect these desires. Lot sizes are increasing, as is development outside of incorporated city boundaries. Rural development on exurban lots (i.e., land that is beyond suburban development) and rural lots (1.7 to 40 acres) has been growing at a rate of 10–15 % per year, exceeding urban and suburban expansion rates (U.S. Department of Agriculture 2006).[1]

By 2100, the population of the United States is expected to nearly double to 571 million (Hulme et al. 2009). Wyoming has had a steady, positive growth rate for the past few decades. Its population growth rate over the 10-year period from 1990 to 2000 was 8.9% (Lieske and Taylor 2002), and from 2000 to 2009 was estimated to be 10.2% (U.S. Census Bureau 2010). For the 12-month period ending July 1 2009, it had the nation's fastest population growth rate, at 2.12%, bringing the state's population to a total of 544,270 people (US Census Bureau 2009).

The majority of rural subdivision and development in Wyoming is occurring on privately owned ranchlands. Forty-three percent of Wyoming is privately owned land, of which 93% is in agricultural production (Taylor 2003).[2] Cropland in Wyoming is limited, due to a relatively arid climate, and most agricultural lands are large tracts of rangelands used for grazing. The average size of farms or ranches in Wyoming is over 3,600 acres, with more than 80% operating on 5,000 acres or more (U.S. Department of Agriculture 2004).

Wyoming receives many benefits from population growth and development, which are important components of the state's present and future economic prosperity. Enjoying wide open spaces and living close to nature are attributes that define Wyoming and the character of its people. However, the location, design, and rapid rate of rural subdivision and development in some areas can have negative consequences for wildlife and wildlife habitat.

Privately owned ranchlands in Wyoming contain disproportionately high amounts of crucial wildlife habitat. Historically, ranches were established along valleys and waterways. These lands are not only the most agriculturally fertile, but also the most biologically productive and diverse. While Wyoming contains a significant amount of public land, many wildlife species, including big game, tend to inhabit or migrate through public lands during the summer and fall and spend the winter at lower elevations on private lands.

Today, private ranchlands provide crucial winter range, travel corridors, and birthing sites for many of Wyoming's wildlife species. Fifty percent of the winter habitat for Wyoming's major big game species is located on private land (Coupal et al. 2004). Additionally, more than 80% of wildlife in Wyoming relies on riparian zones (McKinstry et al., 2002), which are frequently located on private agricultural lands.

Rural development and subdivision can reduce both the quantity and quality of wildlife habitat.

[1] Many of the statistics and background information for this section are taken from the University of Wyoming William D. Ruckelshaus Institute of Environment and Natural Resources publication *Wyoming's State of the Space: A Comprehensive Review of Land Use Trends in Wyoming.* For a copy of this publication or more information on strategies to address rural subdivision and development, visit: http://www.uwyo.edu/enr/.

[2] Fifty-four percent of Wyoming is public land that is managed by either the state or federal government. Tribal lands represent just over 3% (Hulme et al. 2009).

The amount of wildlife habitat is reduced as natural vegetation is replaced by homes, roads, out-buildings, and other infrastructure. As barriers to wildlife movement, such as roads and fences, increase, habitat quality may decline. Invasive species spread, and animals avoid areas with greater human and pet activity. Additionally, water quality may decline from increasing sedimentation levels and contamination from pesticides, herbicides, fertilizers, and other chemicals found in runoff from nearby roads and lawns. Urban sprawl is the second leading causes of decline of federally listed threatened and endangered species (Mealor 2007).

Scope and Challenges of Rural Subdivision and Development and Wildlife Conservation

Wyoming's growth in the last 15 years has primarily fit into the "rural" category, with much of rural housing having a density of one unit per 35 to 40 acres (Hulme et al. 2009). Locations that offer many natural amenities such as scenic views, outdoor recreational opportunities, and clean air and water tend to attract more residential growth, which has led to a flow of people out of municipalities and into rural areas in some parts of Wyoming. A study by the American Farmland Trust (2002) found that Sublette, Park, Uinta, Big Horn, and Fremont counties were among the top 25 counties in the Rocky Mountain region in terms of the potential for conversion of prime ranchland to residential development.

Wyoming State Engineer's Office records indicate that nearly 100,000 acres of land were subdivided into lots of 35 acres or less between 1998 and 2006. This trend could result in 80% of new developments in Wyoming being on lots of 10 to 40 acres by 2020. This would total 7.1 acres of residential development per new household or 2.9 acres of residential development per new resident (Theobald 2003).

Because of agriculture's predominance on the land base, the fate of much privately owned wildlife habitat in Wyoming is closely tied with the future of the agricultural and livestock industries. Low profit margins from agriculture, the lure of large financial returns from the sale of ranchlands, the increasing number of agricultural producers entering retirement age, and low recruitment of new farmers and ranchers are leading factors contributing to the sale and conversion of ranchlands to residential uses.

After a high in 1993 of almost $200 million, the net proprietor income for agriculture in Wyoming has averaged less than $40 million per year through 2006, and was negative in 2002 (-$16.5 million) and 2006 (-$63.2 million) due to drought (U.S. Department of Commerce 2007). Additionally, the future of federal grazing leases is uncertain, due to competing uses of federal lands, such as energy development and recreation, as well as court challenges over the valuation and environmental impacts of public land grazing. Agricultural operations with federal land grazing permits control 20.4 million acres of private land in Wyoming, or 60% of Wyoming's total private land base (Hulme et al. 2009). Continued access to public land grazing is central to the profitability of most of these agricultural operations.

The price of agricultural land in Wyoming continues to rise and is driven in part by an increasing demand for natural and outdoor recreational amenities. The average price of a ranch in Wyoming increased by more than three times on a production-unit basis from 1993 to1995 and again from 2002 to 2004, and the average price for irrigated meadowland in Wyoming has nearly doubled (Taylor 2003).

Currently, about 8.7 million acres of agricultural land in Wyoming are managed by operators aged 65 and older (Hulme et al. 2009). One study found that the percentage of Wyoming agricultural operators of 65 and older had more than doubled between 1959 to 2002, from less than 12% in 1964 to nearly 26% in 1997, while the percentage of Wyoming agricultural

operators under 35 years of age had declined by two-thirds, from more than 15% in 1982 to less than 5% in 2002 (Foulke et al. 2000). The future of ranchlands held by retiring agricultural producers remains uncertain.

Accordingly, State of Wyoming Board of Equalization records indicate there was a 600,000-acre decrease in the amount of land classified as agricultural between 2003 and 2006. This is an area similar in size to the state of Rhode Island (Hulme et al. 2009). A study from the American Farmland Trust (2002) predicts that up to 2.6 million acres of Wyoming's most productive ranchlands are at risk of conversion to residential development by 2020.

In addition to the reduction of habitat quantity and quality, subdivision and rural development have other impacts on the state's ability to effectively manage and conserve wildlife. Human wildlife conflicts frequently increase in areas with high rural development. Deer in particular can damage lawn and garden plants, and high densities often lead to increased road collisions. Bears, skunks, raccoons, and other unwelcome wildlife visitors are often attracted to human food and garbage.

Controlling wildlife numbers through hunter harvest often becomes more difficult as the land becomes fragmented and many properties are too small or do not allow hunting. Revenue for state wildlife agencies can decline as hunting license sales diminish. Excessively large big game herds can over-utilize their habitat, decreasing its quality for other wildlife species and increasing damage to nearby agricultural crops. Additionally, some historic habitat management techniques needed to sustain native plant communities, such as periodic fire, are no longer feasible with rising safety and liability concerns as a result of growing numbers of people and structures. Water conflicts may also become more common as demand for water resources increases. Population growth heightens the need for water storage and diversion structures which can be detrimental to the movement of some aquatic species and the continuation of natural flow regimes required to sustain native riparian vegetation and aquatic communities.

Current Initiatives Related to Addressing Rural Subdivision and Development

The proliferation of rural subdivisions has become an issue in Wyoming relatively recently, especially when compared to other regions of the United States. This may be partly explained by Wyoming's small population and a population growth rate that has lagged behind other western states. Most efforts to mitigate the negative impacts of accelerated rural subdivision and development fall into five categories:

- increasing the profitability of land uses that maintain wildlife habitats
- enhancing the effectiveness of land planning
- improving the design of rural developments
- working directly with landowners to conserve land through voluntary land purchases and land use agreements
- increasing public and landowner awareness about rural land management issues including wildlife needs

Increasing the Economic Viability and Profitability of Land Uses that Maintain Open Spaces

The Sonoran Institute's booklet Preserving Working Ranches in the West features methods and examples of ways ranchers have diversified their agricultural operations to increase profitability and retain the natural values of their land. Copies of the booklet can be obtained and training courses scheduled by contacting the Wyoming office of the Sonoran Institute, Partnership for Wyoming's Future (see Additional Resources). The Sonoran Institute also offers a one-day training seminar on this subject geared for agricultural producers.

The Wyoming Business Council's Agribusiness Division has a variety of programs that assist farmers and ranchers with strategies to increase profits and provide added value to their businesses. The Business Council works one-on-one with farmers and ranchers to identify new marketing opportunities, develop agricultural diversification strategies, and enhance their business and marketing skills. The Business Council also has a workbook available for agricultural producers interested in assessing their current operations to better utilize their existing resources to sustain their operation.

Some ranchers have established side businesses related to hunting/fishing outfitting, eco-tourism, and dude ranching to bring in extra income. More recently wind development is being explored as a means to add to the profitability of some agricultural operations, but this type of renewable energy development may also alter wildlife habitat and impact hunting access.

Enhancing the Effectiveness of Land Planning

Wyoming law requires that both municipal and county governments develop a comprehensive land use plan (Hulme et al. 2009). Unincorporated cities or towns may develop a land use plan, but are not obligated to do so. Local entities responsible for land use decision-making include county commissioners, planning and zoning commissions (city and county), and municipalities.

There have been a number of efforts in Wyoming to increase the knowledge levels of county commissioners, town councils, and planning/zoning commission members about land planning issues and techniques. The Sonoran Institute, Wyoming Association of County Commissioners, and Wyoming Planning Association all provide workshops on topics related to rural development including methods of minimizing negative environmental impacts and potential land use conflicts.

The Wyoming Rural Development Council *Community Assessment* program supports the creation of locally-driven development strategies and provides long-term support in helping to achieve community development goals. The Council has facilitated community assessments in almost 80 towns and cities and is now expanding the program to the county level. Similarly, the *Building the Wyoming We Want initiative* (BW3), a nonprofit organization that originated from a governor-sponsored 2008 conference, intends to provide process and resource assistance for local efforts to plan for growth while retaining residents' core values of open spaces, ability to recreate in the great outdoors, and safe, friendly communities for their children and grandchildren. Currently, the BW3 High Plains Initiative is conducting a pilot project that includes Platte and Goshen counties. The goal of the initiative is to explore growth-related issues and future planning options based on community vision, involvement, and a formal values study. Cheyenne, with its *PlanCheyenne*, along with Teton and Sheridan counties are examples of counties and municipalities that have developed comprehensive land use plans that included considerable public involvement and take into account wildlife habitat conservation issues.

Until recently, Wyoming counties did not have authority to review the subdivision of land where parcel size was 35 acres or more. Counties were able to use zoning, however, to regulate the minimum parcel size to exceed 35 acres if desired. This lack of subdivision review encouraged the creation of very large tracts without public comment or governmental oversight. In 2008, the Wyoming legislature passed legislation allowing counties, through resolution, to regulate subdivisions between 35 and 140 acres (Wyoming Statute § 18-5-316/7, et seq. 2008). The legislation included exemptions for parcels existing prior to July 1, 2008, and for the division of up to 10 parcels of 35 or more acres to be created without undergoing subdivision regulation review (Wyoming Statute § 18-5-316/7, et seq. 2008).

Improving the Design of Rural Developments

The concept of conservation or cluster development is to minimize negative impacts to the environment and maximize residents' enjoyment and use of the natural amenities of the land. This type of development is often approached by increasing housing densities and allowing common open space to be shared by all residents of the subdivision. Developers can benefit by selling more lots clustered on a portion of the development as compared to selling a smaller number of large parcels. As long as cluster developments are not located too far from town and city service centers, they can potentially lower the net costs of service and save money for local governments. Generally speaking, it is cheaper to provide services to houses located in a confined area as compared to residences that are scattered across the landscape.

In 2009, the Wyoming Legislature passed HB0009 to provide incentives for conservation design and cluster development in rural areas. Incentives allow an exemption for subdivision application requirements for housing developments that use density bonuses to preserve open space. Preserved lands should contribute to the protection of wildlife habitat or the enhancement and maintenance of the rural character of land that is contiguous to agricultural lands. To qualify, two-thirds of the total area of the parcel being divided must be retained in open space and remain under this designation for at least 65 years. After 65 years, there must be a process by which the owners of the lots in the development can renew the designation. Each board of county commissioners has authority to allow this exemption.

Voluntary Land Purchases and Land Use Agreements

Conservation easements are voluntary agreements that limit the amount and type of development that can occur on a property with the purpose of maintaining its natural open space value, wildlife and habitat value, or productive features (e.g., agricultural uses). Most conservation easements are placed on the land title in perpetuity. This means the development restrictions run with the land regardless of landownership. Landowners typically receive tax incentives and/or direct payments for entering into a conservation easement. In 2007, an estimated 389,000 acres of land across Wyoming was under conservation easement agreement, or approximately 1.45% of the privately owned land in Wyoming. In 2005, Wyoming ranked third of northwestern states in land area in conservation easements (Hulme et al. 2009).

Conservation easements have become the predominant method of land conservation in the West because they are voluntary and incentive-based, they retain land in private ownership and on local tax rolls, and they do not require future upkeep costs since land management responsibilities are typically retained by the landowner. Land trusts are organizations that typically hold and monitor conservation easements. Land trusts may be either government or non-profit organizations. Some of the more active organizations in Wyoming that hold conservation easements are: Ducks Unlimited, Wyoming Land Trust, Jackson Hole Land Trust, National Wild Turkey Foundation, Rocky Mountain Elk Foundation, Sheridan County Land Trust, The Nature Conservancy, The Conservation Fund, Wyoming Game and Fish Commission, and the Wyoming Stock Growers Agricultural Land Trust.

In recent years, the use of conservation easements has been further incentivized by increased federal tax incentives[3] and new state

[3] Federal tax incentives for conservation easements were increased in 2006. New incentives raise the maximum deduction a donor can take for donating a conservation easement from 30% of their adjusted gross income (AGI) in any year to 50%; allow qualified farmers and ranchers to deduct up to 100% of their AGI; and increase the number of years over which a donor can take deductions from 6 to 16 years. If not renewed or made permanent, increased tax incentives will expire at the end of 2009. As of July 2010, House and Senate have both passed one-year extension, but changes elsewhere in the bill will require additional action by the House. If passed, the extension would last through

funding sources. The Wyoming Wildlife and Natural Resource Trust was established by the Wyoming Legislature in 2005 with the purpose of enhancing and conserving wildlife habitat and natural resource values throughout the state. Annual interest from this account is available for habitat improvement projects including conservation easements. The corpus of the account in July 2010 was approximately $91 million (Budd, personal communication, July 2010). Funds established to enhance planning and offsite mitigation for energy development have also been used to purchase conservation easements. Examples include the Jonah Interagency Office, Pinedale Anticline, and Wyoming Land Conservation Initiative.

In Wyoming, land purchases to conserve wildlife habitat have been limited due to expense and political opposition to reductions in the private land base. Land purchases may have the added wildlife management benefit of allowing public access, which while possible with conservation easements, is typically not part of the terms of easement agreements.

Increasing Public and Private Landowner Awareness

There are several initiatives within Wyoming designed to inform policy-makers, landowners, developers, and the general public about rural subdivision issues and habitat conservation options. One of the most notable is the University of Wyoming's William D. Ruckelshaus Institute of Environment and Natural Resources' (Ruckelshaus Institute) *Open Space Initiative*. Established in 1993, the Ruckelshaus Institute has conducted research, disseminated information, and facilitated public dialogue on a number of topics associated with land-use change and the impacts of that change within Wyoming. Some of the topics addressed through the *Open Spaces Initiative* include: public opinion on land conservation and open space, private land and big game habitat, residential development and the cost of community services, conservation easements, population growth and land use trends, and big game migration corridors (see Additional Resources for Open Space Initiative publications).

The Sonoran Institute is currently conducting surveys of county and community land use planners, county commissioners, mayors, town councils, and planning and zoning commission members to encourage a dialogue about regulatory changes that would make growth planning more effective, to create incentives for developments that conserve natural areas, and to identify future educational needs.

Lastly, the University of Wyoming's Cooperative Extension Services program *Barnyards & Backyards: Rural Living in Wyoming* focuses on providing information to small acreage landowners, new landowners, or backyard enthusiasts on rural landownership issues including pasture management, wildlife habitat, and invasive species.

Federal land management agencies have also taken steps to educate and train agency personnel to work more effectively with local land planners and private landowners in order to conserve the quality of lands that are adjacent to publicly managed lands and help promote conscientious development. Privately held land that is within public land boundaries (i.e., private inholdings) and land that borders national parks and national forests are at high risk for development due to their desirable locations. Additionally, these publicly managed lands, many of which provide essential habitat for Wyoming's wildlife, are also vulnerable to human-caused disturbances such as predation by domestic pets and invasive species used in residential landscaping. The Sonoran Institute has collaborated with the Bureau of Land Management to develop the *Desktop Reference Guide to Collaborative Community Based Planning* (2000), and has worked with the National Park Service in hosting workshops to discuss the strategies, goals, and successes of community partnerships. More recently, the U.S. Forest Service has worked with the Ruckelshaus Institute to develop a toolkit for Wyoming's

December 31, 2010 and be retroactive to the beginning of the year.

public land managers that compiles information on many of the technical and financial resources that are available for the conservation of private land. The goal of the toolkit is to aid Wyoming's public land managers in becoming more involved in local land planning efforts.

Current Challenges to Conserving Private Wildlife Habitat and Mitigating the Potential Negative Impacts of Rural Subdivision and Development

Growth planning and land conservation efforts can be contentious.
Individual freedom and avoidance of excessive government intrusion are strongly held values in Wyoming. Many mechanisms to address growth planning limit future land uses, resulting in an inherent tension between balancing the protection of individual and private property rights with providing public benefits. The controversial nature of growth-planning issues often causes public officials to be reluctant to address them.

Uncertainty about the future profitability of agriculture, access to federal grazing leases, and land use regulations can make farmers and ranchers unwilling to enter into agreements which place long-term development restrictions upon their land.
While many landowners have a desire to retain wildlife habitat on their land and continue to farm or ranch, uncertainty about the future economic viability of agriculture may cause some to be reluctant to enter into conservation agreements in perpetuity or support land use planning which would prevent them from selling their land for alternative land uses.

Wyoming's large public land base may decrease the perception that conservation of wildlife habitat is necessary.
Fifty-four percent of Wyoming's land is owned by either the state or the federal government (Hulme et al. 2009). Much of this land has some level of protection against future subdivision and housing development. However, relying solely on public land to provide habitat for Wyoming's wildlife discounts the disproportionate amount of crucial habitat, especially winter range, birthing sites, and migration corridors located on private land. Some habitat types, including lowland riparian areas and shortgrass prairie, are predominately found on private land in Wyoming.

There is a need for a greater number and diversity of tools available for landowners to retain wildlife habitat.
Many landowners, particularly those who rely on agriculture for their livelihood, do not have the earnings to take advantage of income tax incentives for entering into conservation easements. The number and type of incentives for entering into land conservation agreements should be expanded and include incentives supporting sustainable land uses which maintain open spaces in addition to land use restrictions.

For subdivisions outside of municipal boundaries, fewer administrative hurdles exist and development is typically cheaper.
Rural development is currently encouraged because it is often cheaper and less administratively burdensome than developments inside incorporated municipal boundaries. Connecting to municipal infrastructure such as water, sewer, and electricity can add to development costs. Wyoming statutes make it easy to develop rural areas since few counties have chosen to opt for review and permitting of parcels which are 35 acres or larger. Additionally, relatively few county building codes and development standards may reduce costs of rural developments. Current difficulties with municipal annexation have been identified as discouraging developments within city and town limits in favor of rural subdivision. Also, sales tax revenue is often allocated between counties and cities based on the number of residences. This has led to a perception among some counties that large numbers of residents will enhance county revenue; although costs for

providing services to rural residents may exceed financial gains.

Landowners, developers, and local governments need to be provided with more options for growth planning supported by examples based in Wyoming.
Many people involved with land use decisions and designing developments are unaware of the options to address growth planning and habitat conservation. Additionally, although a diversity of techniques have been used throughout the country, Wyoming examples are lacking.

Raise awareness about the potential benefits of planning for growth and habitat conservation.
Growth control and land conservation efforts often encounter the belief that all growth is beneficial and development limitations are generally disadvantageous. Effective wildlife habitat conservation efforts can support traditional land uses and local economies through activities such as agriculture, tourism, hunting, and angling. Conserved properties can increase property values, save tax dollars, and retain community features most valued by residents and sought-after by businesses. A study conducted in Wyoming in 2001 found that to provide community services such as trash collection, emergency services, and road maintenance, it costs a statewide average of 54 cents in expenditures per dollar of tax revenue collected for lands under agricultural production, compared to $1.13 for rural residential lands (Coupal et al. 2002).

Limited coordinated, statewide Geographic Information System (GIS) mapping capacity.
Currently, Wyoming lacks statewide tracking of subdivisions and rural residential developments to quantify land use changes and guide habitat conservation planning. Some counties in Wyoming have GIS departments and websites, but coordination among all 23 counties is limited and data is not uniformly available. GIS maps for wildlife and crucial habitats often lack specificity and are limited in the number and diversity of wildlife species incorporated.

Difficulty of land conservation and growth planning efforts keeping pace with development rates.
Limited staff for municipal and county land planners as well as for land trusts can make it difficult for the development review process and habitat conservation efforts to keep pace with high rates of rural subdivisions.

Recommended Conservation Actions

Increase funding for habitat conservation projects.
Organizations that conserve private wildlife habitat frequently have more interest from landowners than project funding will support. It is particularly difficult for many of Wyoming's land trusts to achieve the matching funding required to access state and federal conservation dollars, which are available through sources such as the Wyoming Wildlife and Natural Resource Trust Fund and the U.S. Department of Agriculture's Grassland Reserve and Farm and Ranchland Protection Programs. Mechanisms that other states have used to increase funding for land conservation include lodging and recreational user fees, bonding initiatives, state lottery funds, and a real estate transfer tax, which applies when land is sold and changes from an agricultural use to another use. Energy development mitigation money should continue to be available for habitat conservation projects. It is recommended that the Wyoming Wildlife and Natural Resource Trust be fully funded to its $200 million limit during the next five years.

Wildlife habitat conservation efforts should be linked to maintaining ranching and other sustainable land uses.
The majority of privately-owned, crucial wildlife habitat in Wyoming is found on working ranches. Polls have shown that the loss of working family farms and ranches is the number one conservation concern for Wyoming voters (Hulme et al. 2009). Linking habitat

conservation efforts to retaining agricultural operations may increase landowner involvement and public support.

Because the value of ranchland for development vastly exceeds the land's agricultural productive value, efforts that enhance the economic viability of agricultural operations may diminish incentives for ranchers to sell their land for alternative uses. Such initiatives may be popular with landowners and are not constrained by government budgets if they are linked to free markets. Examples of efforts that have been used to increase and diversify financial returns from agriculture include direct marketing, niche marketing, food cooperatives, and new product development. Many landowners have also established businesses that capitalize on the natural amenities of their land including outfitting for wildlife viewing, hunting, and fishing.

Similarly, increased regulation may also discourage landowners from remaining in agriculture. Continued access to grazing leases on federal land is central to the economic sustainability of many Wyoming ranching operations.

Future monitoring and stewardship expenses should be eligible for habitat conservation grant funding.
Wyoming land trusts are acquiring an ever-increasing number of conservation easements. Money to monitor and enforce conservation easements is a growing percentage of a land trust's operating budget. Most conservation easements are perpetual agreements. Research has shown that conservation easement violations typically occur after the land transfers from the original landowner who entered into the conservation easement agreement to a new owner (Danskin 2000). A portion of grants for habitat conservation projects should be eligible for long-term conservation easement stewardship expenses.

A resource portal of wildlife-friendly planning options should be created for landowners, developers, and land use planners.
A web-mediated resource guide of wildlife-friendly development and land planning tools should be created and hosted in an easily accessible location. The Building the Wyoming We Want initiative has a stated goal of creating such a resource portal. Emphasis should be placed on developing more Wyoming examples that highlight the successful use of various options. Research should be conducted to determine the financial and conservation value of less-than-perpetual conservation leases. The resource portal should include best management practices for land use, should be regularly updated and managed by the appropriate agency or organization, and should provide a resource section where readers can access additional related information.

Enhanced coordination, consistency, and accessibility of GIS mapping efforts should be a state priority.
Mapping information regarding the size and location of rural subdivisions and crucial wildlife habitat in Wyoming is often incomplete and not compatible between sources. Similarly, even for state agencies, requirements for mapping data storage at a central location is lacking.
Currently, Species of Greatest Conservation Need (SGCN) monitoring and inventory work is scattered among agencies, consultants, conservation organizations, and natural resource industries. Among other benefits, compiling data would help to identify data gaps.
Land use planners and developers would also benefit from more information on the locations of crucial wildlife habitat. Enhanced GIS capabilities would enable more investigation into the relationships among various types of land use. For example, the cumulative wildlife impacts from energy and housing development could be better understood and perhaps minimized. There should be particular emphasis on developing GIS mapping to quantify the amount, location, and rate of rural subdivision in the state for both public awareness and planning purposes.

GIS mapping information should be made more accessible and spatially consistent. This could include maintaining information on a centralized website, as well as enhancing GIS training for planners, county commissioners, and planning and zoning boards. GIS data should be accessible to the general public. Some private landowners may be reluctant to reveal the locations of sensitive species and habitats on their property because of the fear of being the target of future regulations, which could result in the loss of land values and land uses. To reduce these concerns, investigations should be made into methods of providing safe-guards for future access and use of this information.

Increase awareness about the potential negative impacts of wildlife habitat fragmentation and the benefits of habitat conservation and growth planning.
Rural development and subdivision can reduce both the quantity and quality of wildlife habitat. Some impacts such as the spread of invasive species, increased wildlife conflicts including vehicle collisions and damage to crops and landscaping, and decreasing water quality may not be anticipated or well understood by those designing and reviewing rural subdivision plans.

Accordingly, knowledge levels should be improved about the benefits and relationship between wildlife habitat conservation and maintaining agriculture and other traditional land uses, attracting businesses, preserving clean air and water, providing outdoor recreational opportunities, and reducing the cost of providing community services. Proactive, incentive-based habitat conservation efforts can be effective in reducing the need for future listing of species under the Endangered Species Act.

Training workshops on habitat conservation and rural development issues should be enhanced and made available to larger audiences. Important stakeholder groups include landowners, developers, realtors, businesses, county and community land-use planners, county commissioners, mayors, town councils, planning and zoning commission members, and the general public. The Wyoming County Commissioners Association, The Sonoran Institute, University of Wyoming Department of Agriculture Cooperative Extension Service, and Wyoming Planning Association currently offer training and facilitation on development issues and growth planning. Plan-IT Wyoming (www.planitwyoming.org), a partnership between the Ruckelshaus Institute, University of Wyoming GIS Center, and the Wyoming Rural Development Council, can offer training in planning technology tools. Educational material should also be made available through websites and informational CDs.

A common terminology for discussing growth planning and land conservation issues should be developed.
For some, terms like "open space" can conjure images of beautiful vistas of natural areas and pastoral scenes; for others "open space" may mean urban greenways or even shopping center parking lots. Similarly, terms such as "conservation easements," "land use planning," and "zoning" carry with them considerable historically negative stigma and may elicit strong emotional reactions. Effort should be made to develop terms or clarify existing terms to discuss growth planning and habitat conservation issues that are broadly understood and facilitate discussions about both opportunities and limitations of various conservation options.

Clearly identify wildlife habitat priority areas.
Habitat priority areas, including wildlife corridors, need to be clearly identified in order to be effectively incorporated into development design and growth planning efforts. SWAP SGCN priority areas identified in the Habitat Section of this State Wildlife Action Plan should assist in achieving this objective. It is important to address all species, including SGCN and big game animals. Greater incentives and assurance should be provided to landowners who voluntarily participate in habitat GIS mapping

projects that data will not be used in future regulatory actions. Attention should be given to creating policies and programs that encourage landowners to view designation of their land as a wildlife priority area as an opportunity rather than a potential threat to its traditional uses.

Improve the knowledge of first-time landowners about wildlife and rural living issues and increase efforts to mitigate the negative impacts of rural subdivisions.
Many rural subdivisions exist in Wyoming and many more will be developed in the future. Programs that increase first-time landowners' knowledge of wildlife and rural living issues, such as Barnyards & Backyards: Rural Living in Wyoming headed by the University of Wyoming's Cooperative Extension Services, should be continued and expanded. Additionally, there are numerous opportunities including landscaping choices, grazing practices, pesticide use, and garbage storage to mitigate the negative wildlife impacts of rural subdivisions and even increase habitat quality. More attention can be placed on wildlife-friendly fencing. The Wyoming Game and Fish Department has a publication on wildlife-friendly fencing (http://gfi.state.wy.us/Wildlife/References/Fencing/WildlifeFence-MTPublication.pdf). WGFD also supports the Wyoming Land Trust's Corridor Conservation Campaign, which focuses on minimizing barriers to big-game movement in Sublette County, including installing wildlife-friendly fencing at no cost to landowners. Federal, state, and private landowner fence-design often lacks consistency. Landowners have the option to specify what type of fencing they prefer along Wyoming Department of Transportation rights-of-way. The state should assume a leadership role in providing examples of wildlife-friendly fencing for state projects.

Evaluating/monitoring Success

A centralized GIS database should be established to track rural subdivision and land conservation efforts in Wyoming.
Many Wyoming counties do not have the ability to electronically map subdivisions, so that rural subdivisions are not being mapped on a statewide basis. Establishing a statewide electronic database of rural subdivisions would help to guide future development and conservation efforts to minimize impacts to important wildlife habitats. This database would also be helpful in evaluating the cumulative impacts of rural subdivisions in relation to other habitat threats such as energy development or invasive species, assuming that these threats are also mapped. The location of conserved properties, including lands upon which conservation easements or management agreements exist, should also be tracked to assist in planning. This information could be used in evaluating success in reaching habitat conservation targets.

The availability of funding and technical information resources for addressing rural subdivision and development should be monitored and made accessible to land conservation organizations, private landowners, local governments, and developers.
There are diverse funding and technical information resources for completing land conservation projects and enhancing development planning. Keeping updated on all resources can be difficult. Increasing land values and fluctuating fund availability will likely require increased resources for completing habitat conservation projects in the future. The *Building the Wyoming We Want* website http://www.buildingwyoming.org/ may serve as an appropriate location for this information.

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Additional Resources

Building the Wyoming We Want
P.O. Box 634
Casper, WY 82602
www.buildingwyoming.org

Ducks Unlimited
Colorado/Wyoming Program
2926 East Mulberry Street
Fort Collins, CO 80524
Phone: (970) 221-9861
www.ducks.org

Jackson Hole Land Trust
P.O. Box 2897
555 East Broadway, Suite 228
Jackson, WY 83001
Phone (307) 733-4707
http://jhlandtrust.org/

National Turkey Foundation
1376 Harding Road
Burns, WY
Phone: (307) 547-3556
www.nwtf.org

Rocky Mountain Elk Foundation
Southern Wyoming
1291 Jones Road
Thermopolis, WY 82443
Phone: (307) 867-2613

Northern Wyoming
53 Albright Drive
Buffalo, WY 82834
Phone: (307) 684-5285
http://www.rmef.org/Conservation/WhereWeWork/Wyoming/

Sheridan County Land Trust
P. O. Box 7185
Sheridan, WY 82801
Phone: (307) 673-4702
www.sheridanclt.org

The Sonoran Institute
Partnership for Wyoming's Future
P.O. Box 20665
Cheyenne, WY 82003
Phone: (307) 635-1973
http://www.sonoraninstitute.org/

The Conservation Fund
P.O. Box 4441
Jackson, Wyoming 83001
Phone: (307) 733-2360
www.conservationfund.org/mountainwest/wyoming

The Nature Conservancy in Wyoming
258 Main Street, Suite 200
Lander, WY 82520
Phone: (307) 332-2971
Fax: (307) 332-2974
www.nature.org/wherewework/northamerica/states/Wyoming

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Wyoming Assoc. of County Commissioners
P.O. Box 86
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Cheyenne, WY 82003
Phone: (307) 632-5409
www.wyo-wcca.org

Wyoming Business Council – Agribusiness
214 Wes15th Street
Cheyenne, WY 82002
Phone: (307) 777-6589
www.wyomingbusiness.org

Wyoming Game and Fish Department – Lands Division
5400 Bishop Boulevard
Phone: (307) 777-4653
http://gf.state.wy.us

Wyoming Open Spaces Initiative
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University of Wyoming
Laramie, WY 82071
Phone: (307) 766-5080
http://www.uwyo.edu/openspaces/index.htm

Wyoming Land Trust
P. O. Box 1580
Pinedale, WY 82941
Phone: (307) 367-7007
http://wyominglandtrust.org/

Wyoming Planning Association
1001 Donegal Street
Casper, WY 82609
Phone: (307) 234-9442
www.wyopass.org

Wyoming Rural Development Council
214 West 15th Street,
Cheyenne, WY 82002
Phone: (307) 777-6430
www.wyomingrural.org

Wyoming Stock Growers Land Trust
P.O. Box 206
Cheyenne, WY 82003
Phone: (307) 772-8751
http://www.wsgalt.org/

Energy Development

Wind energy development in Wyoming (Tony Hoch)

Bottom two photos courtesy of WGFD

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Background

Wyoming has become the number one U.S. domestic exporter of energy over the last decade, supplying the nation with more than 10 quadrillion (thousand million million or 10^{15}) BTUs of energy per year (Surdam 2008). Wyoming domestic energy exports account for half of all energy exported by states within the U.S. and surpasses the exports of all major exporters including Canada, Mexico, Venezuela, and Saudi Arabia (Surdam 2008). Specifically, Wyoming is the nation's leading producer of coal (National Mining Association 2008), is ranked second in natural gas production (U.S. Energy Information Administration 2010), eighth in crude oil production (Lawrence 2007), and seventh for wind-power generating potential when factoring in land status and environmental constraints (Elliott et al. 1991). The minerals industry is by far the largest single contributor to Wyoming's economy. In 2009, the taxable valuation of oil, natural gas, coal, uranium, and natural gas pipelines was $20,078,022,930 or 69% of the state's total valuation (State of Wyoming Department of Revenue 2009).

Wyoming's role in supplying the nation's energy will likely increase even more in the future. Since 2000, the global energy environment has changed significantly. Global oil demand exceeded supply in 2005, with increasing needs from developing nations such as China and India. Stability in the Middle East has deteriorated, U.S. energy demands have increased, and refining capacity has failed to expand (Surdam 2008). At present, oil production exceeds the discovery of new reserves, with world oil reserves currently declining by four to five million barrels per day (Surdam 2008). Sustaining the economic growth and prosperity the nation has experienced for the last several decades will require an increase in electric power generation of slightly more than 1% per year, which equates to 25–30% more capacity in the next 25 years (Surdam 2008). As world demand for energy continues to exceed supply, the value of Wyoming's energy resources will increase.

Wyoming has some of the largest untapped energy resources in the country, with the most significant constraint on enhanced energy production being a lack of adequate transportation options, transmission lines, and pipeline capacity.

Based on a recent compendium of public land statistics, 175,980 acres of federal minerals are currently leased for coal extraction, and oil and gas leases total more than 8.8 million acres in Wyoming (Bureau of Land Management 2008). Natural gas production in Wyoming is projected to more than double from its current level by 2035 (Surdam 2005, 2008). Newly developed fields will remain in production for up to 40 years and longer (Wyoming Game and Fish Department 2010a).

Wind energy development is also increasing. Wyoming has approximately 50% of the highest potential on-shore wind energy sites in the U.S., and only 1% of the state's capacity has been developed (Bureau of Land Management 2010). Wind energy is an important focus of efforts to reduce national dependence on foreign oil and federal energy policy that emphasizes reductions in carbon emissions. Wind development in the U.S. increased by 46% in 2007, and at the end of 2007, the U.S. had the second-highest cumulative wind-generation capacity globally (Wyoming Game and Fish Department 2010b). The Wyoming Infrastructure Authority, in conjunction with transmission developers, is currently studying a conceptual design capable of collecting as much as 12,000 megawatts (MWs) of new electric generation within the state. The majority of this new generation is expected to come from wind turbines. Currently, only about 1,000 MWs of wind-generated electricity is produced in the state (Wyoming Game and Fish Department 2010b).

Increasing energy demands, diminishing fossil fuel reserves, and concerns over carbon emissions will likely lead to an increase in nuclear energy. Wyoming has the nation's largest uranium reserves (Department of Energy 2003). The World Nuclear Association estimates a 78% increase in uranium demand over the next 20 years. Uranium companies in

recent years have bought up thousands of mineral lease acres in the West and invested hundreds of millions of dollars to launch more than 30 new uranium mining projects. About two-thirds of the projects are in Wyoming (Casper Star-Tribune 2009).

Wyoming also has vast reserves of unconventional energy resources. It is estimated that oil shale found in the Green River Formation, located in northwest Colorado, southwest Wyoming, and northeast Utah, contains over two trillion barrels of oil, which is equivalent to one to two times the total world oil reserves (Bureau of Land Management 2010a). The Bureau of Land Management (BLM) instituted a moratorium on oil-shale development in the early 1980s, largely because the technology to extract the oil economically was lacking. Congress directed the BLM in 2006 to lift the moratorium and began accepting nominations for oil-shale research projects.

The state also has enormous potential to develop shale gas, deep gas, bypassed under-pressure gas, coal gasification, and coal-to-liquid energy sources (Surdam 2008) although this potential has been largely undeveloped despite existing technologies. Wyoming also has excellent geologic features to sequester carbon dioxide in the form of structural traps with saline reservoirs, depleted compartmentalized gas accumulations, and deep coal deposits (Surdam 2008). This availability will likely increase the development of new power plants in the region. If the U.S. eventually moves to a hydrogen-based economy, coal will be used to produce hydrogen, increasing the need for Wyoming coal reserves (Surdam 2008).

Wyoming has geothermal resources which could be commercially developed for energy production in a number of locations in the state, including the northwest, central, and southwest portions of the state Wyoming's solar energy development potential is also strong statewide, although both solar and geothermal energy sources remain largely undeveloped in the state at this time (Nielsen et al. 2002). A helium production facility, which will product up to 10% of the nation's helium when completed in 2011, is being built near Big Piney (Casper Star-Tribune 2010). The Wyoming State Geological Survey has conducted an inventory and prioritization of all Wyoming geologic sites capable of sequestering commercial quantities of CO_2. The research identified the Rock Springs Uplift as the most promising geological CO_2 sequestration site in Wyoming. A CO_2 sequestration project is also underway at Rands Buttes by Big Piney Wyoming.

Scope and Challenges of Energy Development and Wildlife Conservation

Access to affordable and reliable power is important to our nation's economy and security and contributes to the prosperity and quality of life of its citizens. Energy development is Wyoming's leading source of revenue and is responsible for about 28,000 jobs in the state (Wyoming Department of Employment 2010). Continued, well-planned energy development will play a central role in the futures of both Wyoming and the nation.

Like nearly all forms of disturbance, energy development, particularly during certain stages, has some level of impact on wildlife. The significance of the impact depends upon the amount, intensity, and duration of the disturbance; the specific locations and arrangements of the disturbance; and the ecological importance of the habitats affected (Wyoming Game and Fish Department 2010a). Small, isolated disturbances within less important habitats can often be of little consequence, however, larger-scale developments within habitats that are crucial to the survival or reproduction of wildlife can be significant if not mitigated.

Oil and gas development produces potential adverse effects. These include: direct loss of habitat, physiological stress to wildlife, disturbance and displacement of wildlife, habitat fragmentation and isolation, alteration of environmental functions and processes (e.g., stream hydrology, water quantity/quality),

introduction of competitive and predatory organisms, and secondary effects created by work force assimilation and growth of service industries (Wyoming Game and Fish Department 2010b). Concerns over air quality have also arisen in areas of intense oil and gas development (Jacus and DiLuigi 2010).

The collective area of disturbance from oil and gas development may encompass just 5–10% of the land; however, disturbances associated with each facility (well pad, road, overhead power line, etc.,) can cause stress and avoidance by wildlife in surrounding areas (Wyoming Game and Fish Department 2010a). Zones of avoidance may extend over a mile for mule deer (Sawyer et al. 2008), over half a mile for elk on open winter range (Brekke 1988, Hayden-Wing Associates 1990; Hiatt and Baker 1981; Johnson and Lockman 1979), and up to several hundred yards for some raptor species during egg laying and early incubation (Fyfe and Olendorff 1976, White and Thurow 1985). Declines in the use of leks by male sage-grouse have been associated with decreasing distance to natural gas related disturbances, increasing levels of disturbance and noise, and greater levels of traffic (Holloran 2005). Similarly, nesting females avoided areas with high densities of producing gas wells and brooding females avoided producing wells (Holloran 2005).

As densities of wells, roads, and facilities increase, habitats within and near well fields can become progressively less suitable for some species of wildlife, until most animals no longer use the area or animals that do use the affected areas are subjected to increased physiological stress (Wyoming Game and Fish Department 2010a). Areas of intensive activity or construction may become barriers to animal movement, including inhibiting animals from reaching crucial winter ranges and habitats important for reproduction (Sawyer 2010). Animal numbers can increase in areas surrounding development which may raise the risk of density-dependent effects, such as range over-utilization or disease transmission, which can lower survival and reproduction (Sawyer et al. 2006). Greater road numbers and densities may also increase both the legal and illegal harvest of wildlife.

Aquatic habitats can be impacted by energy development if roads and development sites affect the infiltration rate of water, through increasing the velocity and quantity of water running across the landscape, and potentially increasing erosion and sediment deposition into nearby waterways (Wyoming Game and Fish Department. 2010b). These changes may result in decreased pool depths, decreased riffle area, less diversity in channel substrate, and increased bank erosion. These changes along with direct effects from increased sediment loading can affect macro invertebrate populations and diversity and decrease fish habitat (Wyoming Game and Fish Department 2010b). A common impact is a decrease in gravel and cobble used by spawning fish (Wyoming Game and Fish Department 2010b). There is currently an incomplete understanding about surface to groundwater interaction and its impact on terrestrial and aquatic wildlife.

Some researchers have proposed similar impacts on wildlife from wind energy to those possible with oil and gas development (Becker et al. 2009). Wind power requires an amount of space per unit of power that is second only to that required by bio fuels (Kiesecker et al. 2009, Surdam undated). Unlike oil and gas development, bird and bat strikes are commonly associated with wind energy facilities. For other species of wildlife that inhabit open landscapes, such as pronghorn and sage-grouse, the behavioral and resulting population responses to wind energy development are currently unknown but being studied.

Wind towers range from 212 feet to over 260 feet tall with blade sweeps of between 328 to more than 400 feet above ground level (Wyoming Game and Fish Department 2010b). Injury and mortality to birds is known to occur from strikes during flight with wind turbine rotor blades, monopoles, power lines, guide wires, and other related structures (Kunz et al. 2007, Winegrad 2004). Most species of birds are at risk of collision, although studies have shown that specific groups of birds in particular

habitats, under certain weather conditions, or in large densities are more at risk than others, including raptors, migrating birds, wading birds, and waterfowl (Wyoming Game and Fish Department 2010b). Nearly 90% of bat fatalities occur in late summer and early fall, during the peak of fall migration (Keeley et al. 2001, Erickson et al. 2002, Johnson 2005). Migrating and commuting bats often follow linear features in the landscape, and may be drawn to ridges where wind energy facilities are commonly located (Erickson et al. 2002, Kunz 2004). The physical characteristics of wind turbines might also attract bats.

Energy development can also affect aquatic wildlife and ecosystems. The overall health of an aquatic habitat is a reflection of the condition of the entire watershed including the uplands, riparian corridor, and the stream channel. Disturbances to upland plant communities can impact wildlife by influencing water quantity and quality as well as associated flow regimes (Wyoming and Game and Fish Department 2010b). Also, changed physical conditions, such as stabilized flow regimes and reduced sediment loads, can create environments favorable for the establishment and spread of nonnative species which may be detrimental to native wildlife.

Energy booms are also often accompanied by human population growth in nearby towns and cities, which can lead to additional wildlife conservation challenges. These secondary effects arise from additional housing, service industries, transportation corridors, and other infrastructure (Wyoming Game and Fish Department 2010a). Private lands available for housing subdivisions are often located along valley bottoms and waterways that frequently provide crucial winter range, travel corridors, and reproductive sites for wildlife.

Further information about potential impact for energy development to wildlife, as well as mitigation and monitoring recommendations for individual and groups of wildlife species, can be found within the Wyoming Game and Fish Department's (WGFD) *Recommendations for Development of Oil and Gas Resources within Important Wildlife Habitats and Wildlife Protection Recommendations for Wind Energy Development in Wyoming*. Links to download copies of these documents are located in the Literature Cited section of this chapter.

Current Initiatives to Incorporate Wildlife Conservation into Energy Development

An overview of the regulatory framework for energy development in Wyoming as well as the agencies involved with energy development permitting and mitigation can be found on pages II – 2 – 19.

Sage-grouse Conservation

In Wyoming, 87% of the state's coal production, 83% of the natural gas production, 64% of the oil production, and 38% of the areas that would support commercially developable wind energy (Class 4 or higher) exist within sage-grouse range (Clark 2009). Greater sage-grouse have been petitioned to receive protection under the Endangered Species Act. Most recently, in March 2010, the U.S. Fish and Wildlife Service (USFWS) ruled the species status warranted, but precluded; meaning that the greater sage-grouse meets the criteria to be listed as threatened, but there are other species that have higher priority. The listing of the sage-grouse under the Endangered Species Act would have significant negative consequences for Wyoming's economy and future energy development within the state. Efforts to conserve the sage-grouse are at the forefront of energy-development wildlife conservation planning and mitigation efforts and will likely have a positive impact on other sagebrush-associated wildlife species. Associated science and management innovations could likely be applied to other wildlife species and habitats in the future.

The following section lists some of the most significant sage-grouse conservation efforts in Wyoming related to energy development. Additional information about sage-grouse and sagebrush habitat conservation work can be

found in the Sage-grouse Species Account and the Sagebrush Shrublands Habitat Type.

Sage-grouse Core Area Strategy
In 2007, in response to the possibility of listing the greater sage-grouse under the Endangered Species Act, Governor Freudenthal formed the Sage-grouse Implementation Team. First among the implementation team's recommendations was extensive statewide mapping of sage-grouse habitats and habitat enhancement efforts. In 2008, Governor Freudenthal issued Executive Order 2008-2 which constituted Wyoming's Core Area Strategy. New development within Core Population Areas would only be authorized when it could be demonstrated that the activity will not cause declines in greater sage-grouse populations. Incentives would be provided to encourage development outside Core Population Areas and to enhance reclamation in habitats adjacent to Core Population Areas. The Core Area Strategy was designed to demonstrate to the U.S. Fish and Wildlife Service that Wyoming had a mechanism in place to ensure the viability of the species.

Bureau of Land Management Instructional Memorandums on Sage-grouse
In 2009, the Washington D.C. Office of the BLM issued Instruction Memorandum WO-2010-071 to ensure environmentally responsible development within the range of the Gunnison and greater sage-grouse. The memorandum instructed that nominated oil and gas, oil shale and/or geothermal lease parcels would be withheld or deferred from sale as needed, pending additional land-use planning and/or further NEPA analysis. All new leases would include notices that more stringent restrictions may be required as future sage-grouse conservation needs are identified. Conditions of Approval (COAs) may be attached to new Applications for Permits to Drill (APD) that could be more stringent than restrictions identified in Resource Management Plans (RMPs) and existing lease stipulations if needed to protect sage-grouse habitats. In RMP revisions and amendments, areas could be excluded from energy development if they are identified as priority habitats necessary to support sage-grouse populations. New right-of-way applications for wind energy development would also be screened to alert applicants that authorization could be delayed until additional research on impacts for wind energy development on sage-grouse has been completed to demonstrate if development can occur without causing declines to affected populations. Lastly, transmission corridors would be rerouted to avoid high priority habitats necessary to support sage-grouse populations.

In January 2010, a follow-up instructional memorandum was issued by Wyoming's State BLM Director to field offices to provide additional guidance to help support WGFD sage-grouse population objectives and to ensure consistency with the Governor's Core Population Area Strategy. Ten policy statements were outlined to achieve these objectives, and a screening system was created to assist BLM field offices in determining appropriate recommendations for leasing federal minerals on lands in sage-grouse Core Areas.

The BLM has recently filed a notice of intent to amend six BLM RMPS to incorporate the sage-grouse protections into a regulatory framework.

Federal Energy Development Permitting
Bureau of Land Management Wind Programmatic Environmental Impact Statement (PEIS)
The BLM initiated the development of a Wind Programmatic EIS (PEIS) in the fall of 2003 for BLM lands in the 11 western states, including Wyoming, as part of a renewable energy resource assessment. A Programmatic EIS evaluates the environmental impacts of broad federal agency actions such as the setting of national policies or the development of programs. The final Wind PEIS was completed in 2005. Among the outcomes of the Wind PEIS was the development of best management practices, which address wind energy siting, construction, and mitigation activities to reduce adverse environmental impacts. These best management practices are being incorporated

into the BLM Wind Energy Development Policy as additional guidance for BLM field offices for wind project-specific Plans of Development (PODs) and/or as right-of-way (ROW) authorization stipulations. Copies of the final Wind PEIS can be found at http://windeis.anl.gov/documents/fpeis/index.cfm.

Bureau of Land Management Leasing Reform
In May 2010, the BLM issued Instruction Memorandum 2010-117 which made modifications to existing leasing policy in order to ensure environmental protection of important natural resources on BLM lands while also aiding in the orderly leasing and development of oil and gas resources. The BLM will develop Master Leasing and Development Plans that consider important natural resource values prior to leasing in areas where intensive new oil and gas development is anticipated. Each potential lease sale will undergo increased internal and external coordination, public participation, and interdisciplinary review of available information. Appropriate mitigation measures will be identified. Additionally, there will be confirmation of Resource Management Plan (RMP) compliance. When needed, site visits will occur to supplement or validate existing data.

Furthermore, the BLM issued interim draft guidance to its field offices on the implementation of Section 390 of the Energy Policy Act of 2005. Under NEPA, federal agencies may use categorical exclusions to approve projects on federal land without conducting extensive environmental reviews if it is determined that the projects will not have significant environmental impacts. The draft guidance establishes a process for considering individual actions that normally would be categorically excluded, but are of a nature or intensity that they warrant further environmental analysis before permitting.

U.S. Fish and Wildlife Service and Wyoming Game and Fish Department Energy Pilot Offices
Section 365 of the Energy Policy Act (EPAct) of 2005 established a Federal Permit Streamlining Pilot Project with the intent of improving the efficiency of processing oil- and gas-use authorizations on Federal lands. Pursuant to EPAct, WGFD and USFWS have placed staff in BLM pilot offices in Buffalo and Rawlins, Wyoming. By involving USFWS and WGFD biologists early in project planning, projects can be designed to avoid or minimize impacts to wildlife resources including addressing Endangered Species Act issues and state recommendations. Biologists streamline projects by working proactively to identify wildlife issues early in the project development, develop conservation measures to address those concerns, and follow through with monitoring guidance to direct on-the-ground activities.

Best Management Practices and Development Guidelines

Wyoming Game and Fish Department Energy Development Recommendations
In 2004, the WGFD produced *Recommendations for Development of Oil and Gas Resources within Important Wildlife Habitats* to identify thresholds of oil and gas development that could impair important wildlife habitats, recommend planning and management considerations to avoid or minimize impacts, and recommend mitigation activities to offset or compensate adverse effects. This document has been revised and updated several times, most recently in April 2010. Recommendations are intended to be applied to important wildlife habitats including big game winter ranges, sage-grouse habitats, priority watersheds, and others identified on maps available from the WGFD website at http://gf.state.wy.us/habitat/index.asp. A similar document, *Wildlife Protection Recommendations for Wind Energy Development in Wyoming*, was approved by the Wyoming Game and Fish Commission in 2010. Sage-grouse habitat protection recommendations for uranium and bentonite mining as well as other significant surface-disturbing activities are addressed in the Sage-grouse Core Area implementation recommendations available on the WGFD website.

U.S. Fish and Wildlife Service Voluntary Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines
First released in 2003, the USFWS Interim Guidelines are intended to assist USFWS staff in providing technical assistance to the wind energy industry to avoid or minimize impacts to wildlife and their habitat through: 1) evaluation of potential wind energy developments on wildlife, 2) proper location and layout of turbines, and 3) pre- and post-construction monitoring to identify or assess impacts to wildlife. Implementation of the guidelines by the wind industry is voluntary, but does not limit or preclude the USFWS' regulatory authority. Copies of the guidelines can be obtained at http://www.fws.gov/habitatconservation/wind.pdf. Wyoming-specific USFWS guidelines are also being created and are expected to be available in late 2010. A USFWS Wind Federal Advisory Committee Act group finished a set of wind development guidelines in the summer of 2010 and has submitted them to the Secretary of Interior for adoption. Until these are approved by the Secretary, the 2003 guidelines should be consulted.

Bureau of Land Management Wind Energy Program Policies and Best Management Practices (BMPS)
In June 2005, the BLM established policies and BMPs regarding the development of wind energy resources on BLM lands. The policies provide guidance for how wind energy development activities are administered and indicate required stipulations, best management practices, and mitigation measures that are to be incorporated into project-specific PODs and ROW authorizations.
http://www.blm.gov/pgdata/etc/medialib/blm/wo/Information_Resources_Management/policy/im_attachments/2009.Par.34083.File.dat/IM2009-043_att1.pdf

Electric Transmission Line Guide for State Fish and Wildlife Agencies
The Association of Fish and Wildlife Agencies' Wind and Transmission Subcommittee created *Electric Transmission Line Guide for State Fish and Wildlife Agencies* (Association of Fish and Wildlife Agencies 2010). The document includes information on how state wildlife agencies can become engaged in the transmission, planning, and citing process and how agency staff can best provide guidance for proposed projects. It also provides specific wildlife recommendations, an overview of the transmission industry, and web links to additional resources.

Bureau of Land Management Reclamation Policy
In 2009, the BLM established a Wyoming Reclamation Policy in coordination with BLM specialists, WO-310, the Wyoming Governor's Office, the University of Wyoming, local governments, and professionals from private industry. The policy provides guidance for the modification, preparation and/or review of all reclamation plans. The policy outlines 10 requirements for reclamation plans which are necessary as part of the permit process for federal actions authorized, conducted, or funded by the BLM that disturb vegetation and/or mineral/soil resources: (http://www.blm.gov/wy/st/en/programs/reclamation.html).

Wyoming Wind Legislation
Recent increases in the amount and rate of wind energy development in Wyoming prompted the Wyoming Legislature in 2010 to enact new legislation. Legislation significant for wildlife conservation includes SEA0038 which expands the jurisdiction of the Industrial Siting Council (ISC) over facilities to include wind energy facilities which consist of 30 or more towers or which are expanded to include 30 or more towers. The legislation also requires the ISC to establish rules for decommissioning, site-reclamation standards, and bonds to ensure these standards are sufficiently met. Also, the potential development impacts to wildlife including Threatened, Endangered, Rare, or other species identified in Wyoming's State Wildlife Action Plan must be disclosed.

HEA0048 places a moratorium on the exercise of eminent domain for the purpose of erecting collector systems associated with wind energy projects. The moratorium is effective until June 30, 2011, or until new legislation establishing additional conditions for the use of condemnation for collector systems associated with wind energy projects is enacted. HEA0064 requires all facilities generating more than 0.5 megawatts of electricity from wind power to obtain a permit from every county in which the facility is located. This legislation also establishes the minimum standards that counties must apply when issuing the required permits. Permitting requirements include the development of waste management, site reclamation, and decommissioning plans, and descriptions of any environmental, social, or economic effects. Lastly, HEA0018 imposes upon the energy company a tax of one dollar per megawatt hour which goes into effect three years after the turbine first produces electricity.

Energy Development Research, Planning, and Conservation Projects

State and Regional GIS Wildlife Decision Support Systems

The WGFD and the University of Wyoming's Wyoming Geographic Information Science Center (WyGISC) are involved with a pilot project to create a Decision Support System (DSS) for housing and disseminating GIS data. The project is focused on two key elements: 1) organizing and centralizing the storage of data from a variety of sources, and 2) establishing an Internet-based mapping system to provide access to this data to partners and the public. Secondary partners may include the Wyoming Department of Transportation, Wyoming Office of State Land and Investments, Wyoming Department of Environmental Quality, Wyoming Natural Diversity Database (WYNDD), BLM, Medicine Bow National Forest, Natural Resources Conservation Service (NRCS), and USFWS. Wyoming's DSS will eliminate the need to contact multiple agencies and individuals for data and will provide data-quality assurances for conservation and development planning and analysis. The system is planned to be functional by 2012.

This effort is linked to the Western Governors' Wildlife Council's effort to establish a Western Regional Wildlife DSS to map crucial habitats across the West. In 2008, the Western Governors Association called for decision support systems to be established in each state that would compile information at scales useful for analyzing proposed energy, land use, and transportation projects, as well as support climate-change adaptation efforts. Presently, the Western Governors' Wildlife Council has developed definitions for crucial wildlife habitats and has presented states with guidelines to facilitate the establishment of regionally compatible systems.

Wyoming Wind Conflict Map

The Governor's Planning Office produced a wind energy development conflict map in 2009. Wind for power generation is ranked from Class 1 (the lowest) to Class 7 (the highest). In general, wind power Classes 4 or higher are considered viable for generating wind power from turbines. The wind power conflict map was produced by evaluating Class 4–7 winds in Wyoming, as modeled by the National Renewable Energy Laboratory (NREL), against areas where statute, regulation, or federal agency resource management plans would likely prohibit development activities[1] as well as where the protection of natural resource values are a high priority that require a very high mitigation standard that would need to be met prior to allowing development[2]. Location of sensitive species' priority habitats, Sage-grouse Core Population Areas, big game crucial winter ranges, national wildlife refuges, and state wildlife management areas were included in the

[1] Included in this category are: state parks, National Park Service lands, National Forest System lands (including National Grasslands), National Wildlife Refuges, Wilderness Study and Visual Resource Management Class I areas, BLM lands with a no-surface occupancy stipulation for sage-grouse, and state wildlife habitat management areas.

[2] Included in this category are: sage-grouse core areas, BLM Visual Resource Management Class II areas, BLM Areas of Critical Environmental Concern, BLM Rawlins Resource Management Plan –Wind Avoidance Areas, and big game crucial winter ranges.

evaluation in the mapping process. http://gf.state.wy.us/downloads/pdf/Class4Map_Final_for_Web_lowres.pdf

Western Governors' Western Renewable Energy Zones Initiative
The Western Renewable Energy Zones Initiative (WREZI) is a collaborative effort between the Western Governors and the U.S. Departments of Energy, Interior, and Agriculture, the Federal Energy Regulatory Commission, Canadian provincial premiers, renewable energy developers, tribal interests, utility planners, environmental groups, and government policymakers. The focus area is the Western Interconnection electricity grid which covers 12 western states including Wyoming as well as portions of Canada and Mexico. In its first phase, a report has been created that identifies areas with low environmental impacts for the development of large-scale renewable resources and associated high-voltage transmission lines. Additional refinements are planned which will identify crucial wildlife habitats. Future work will focus on facilitating the efficient delivery of energy from renewable resource areas to population centers throughout the Western Interconnection. http://www.westgov.org/wga/publicat/WREZ09.pdf

The Nature Conservancy's Development by Design
The Nature Conservancy's (TNC) Development by Design blends landscape-level conservation with the mitigation hierarchy—first avoid, then minimize/restore, and finally offset—to improve mitigation efforts. This is accomplished in a four-step process: 1) develop a landscape conservation plan (or use an existing conservation plan); 2) blend landscape conservation planning with mitigation hierarchy to evaluate conservation and development conflicts; 3) determine the residual impacts associated with development and select an optimal offset portfolio; and 4) estimate the offset contribution to conservation goals.
In Wyoming, TNC's Energy by Design has been used to prioritize project funding for the Jonah Interagency Mitigation and Reclamation Office and will similarly assist for mitigation planning for Continental Divide-Creston, Hiawatha, and Pinedale Anticline oil and gas fields. http://www.nature.org/aboutus/development/

Wyoming Landscape Conservation Initiative
The Wyoming Landscape Conservation Initiative (WLCI) was created in 2007 as a multi-agency and stakeholder initiative designed to maintain and enhance wildlife habitat and other resource values in the face of intensive energy development and other changes. The WLCI has brought together diverse groups to work toward common goals across a 19-million-acre area. Through the WLCI, partners are conducting science-based research and monitoring, completing habitat enhancements and restoration, encouraging effective reclamation and mitigation practices, identifying and prioritizing landscape-scale conservation work, and promoting grazing practices which benefit wildlife, ranchers, and open-space conservation. Projects have included fence modifications and exclosure fencing, prescribed burns, riparian enhancements, invasive species treatments, river restoration, and conservation easements. Initial funding has come through federal appropriations. http://www.wlci.gov/

Offsite Reclamation Funds
The Jonah Interagency Mitigation and Reclamation Office (JIO) was created by the Jonah Project Record of Decision. Its purpose is to provide overall management of on-site monitoring and off-site mitigation activities primarily focusing on pronghorn and greater sage-grouse in the vicinity of natural gas developments near Pinedale, Wyoming. Encana Oil & Gas (USA) and BP America Production Company committed $24.5 million in compensatory (off-site) mitigation. Encana designated $16.5 million of the fund to be used to mitigate wildlife impacts, while the remaining $8 million could be used to mitigate other resource impacts, perform monitoring, or accomplish other activities. Similar mitigation activities are underway for other oil and gas fields, including the Continental Divide-Creston, Hiawatha, and Pinedale Anticline. http://www.wy.blm.gov/jio-papo/

USFWS – Strategic Habitat Conservation – Adaptive Management Framework
Strategic Habitat Conservation (SHC) is an adaptive resource management framework used by the USFWS to determine how and where to apply conservation efforts to achieve desired outcomes. SHC incorporated elements of biological planning, conservation design and delivery, monitoring, and research. In response to a request by the WGFD and industry, the USFWS is applying SHC principles to develop an alternative to standard timing stipulations that would provide additional conservation benefits to raptors, while allowing industry to drill year-round. Along with industry, the USFWS is focusing survey efforts in a small pilot project area (~100 square miles) to record forage availability (i.e., to map white-tailed prairie dog towns, ground squirrel colonies) and raptor nest sites. Data collected in 2010, in conjunction with historic data and habitat models, will be used to convert standard timing stipulations into no-surface occupancy areas—where no activity (e.g., drilling) will be permitted. In exchange for not drilling in the areas designated as most important to raptors, the other areas will be open to year-round drilling with no development activity buffer around active nest sites. Results from 2010 survey and mapping efforts may determine if this alternative is feasible and could be applied to other species and projects.

Assessment of Wildlife Vulnerability to Energy Development Project (AWVED)
The Wyoming Natural Diversity Database and Wyoming Cooperative Research Unit are currently conducting research to evaluate the vulnerability of Wyoming terrestrial SGCN to oil, gas, and wind development. Vulnerability is being determined by evaluating each species' potential exposure and sensitivity to energy development. Exposure is being evaluated through a GIS analysis that overlays distribution maps of SGCN with areas of known and projected energy development. Sensitivity is being determined by examining habitat and behavioral attributes of SGCN as well as reviewing existing impact studies. Research results will not only give an indication of which species and taxonomic groups are potentially vulnerable to development, but also help direct future research to address information gaps. The AWVED project is being funded jointly by the United States Geological Survey, Wyoming Landscape Conservation Initiative, and WGFD.

Interstate Agency-Industry-NGO Research Collaborative on Wind Energy Development Effects on Sage-grouse
State wildlife agencies from Wyoming, Idaho, California, and Oregon have convened the wind industry, academia, and NGOs to develop a focused research initiative. This initiative will work to maximize efficiencies and leverage funding that will focus specific research to better understand the potential impacts of wind development on sage-grouse across their range. This initiative has developed coordinated research questions and protocols and solicited study proposals to replicate studies across the sage-grouse range to foster predictability of impacts from wind development on sage-grouse. For the foreseeable future, the initiative will primarily address research gaps regarding the impacts of wind turbines and associated infrastructure[3]. Additional objectives include: coordinate study results into a comprehensive analysis of impacts across sage-grouse range, ensure peer review of studies is completed and outreach of results is conducted, and provide the science needed to inform wind developers of federal and state agency wind-development stipulations and mitigation strategies while accommodating the need for adaptive management as new science findings occur.

Thunder Basin Grasslands Prairie Ecosystem Association
Among the most notable partnerships between landowners, natural resource agencies, and non-profit organizations is the Thunder Basin Grasslands Prairie Ecosystem Association. The Association was established in 1999 as a landowner-driven effort to develop an ecosystem management plan for species of

[3] Including turbines, meteorological towers, guyed wires, and short-haul transmission within the annual home range of sage-grouse being studied.

concern while balancing these needs with sustainable economic and social activities. Members in the Association include private property owners within a designated 931,192-acre landscape in eastern Wyoming. Areas of interest include management activities related to ranching, coal, coal-bed methane, oil, and gas production, and the conservation of wildlife including black-tailed prairie dogs, burrowing owls, swift fox, ferruginous hawks, and sage-grouse, and the recovery of black-footed ferrets.

Wyoming Game and Fish Department Industry Reclamation and Wildlife Stewardship Awards
The WGFD established the Industry Reclamation and Wildlife Stewardship Awards in 2006. Nominations are evaluated annually, and awards are presented at the Wyoming Hunting and Fishing Expo in Casper every September. The awards recognize companies and agencies whose primary mission is not wildlife-related, yet who have significantly contributed to the maintenance, restoration, or enhancement of wildlife, wildlife habitat, or recreation. Past recipients include Anadarko Petroleum Corporation, Encana Oil & Gas (USA) Inc; Yates Petroleum Corporation; Rio Tinto Energy America; Bridger Coal Company; Lower Valley Energy; PacifiCorp's M&M Ranch; Fidelity Exploration and Production Company; Marathon Oil Company; North Antelope Rochelle Mine, Powder River Coal Company; and Antelope Coal Mine, Rio Tinto Energy America. Two consultants who work with energy companies on wildlife-related issues have also been honored: Jim Orpet, Intermountain Resources, and Gwyn McGee, Jones and Stokes.

Examples of projects that have received recognition include using black-tailed prairie dogs as a tool for reestablishing mountain plover habitat, creative use of water produced as part of gas extraction for wildlife habitat enhancements, providing wildlife recreational opportunities on energy-company-owned land and reservoirs, wildlife monitoring studies, reclamation work, and placing conservation easements on reclaimed mined lands.

Current Challenges for Improving Wildlife Conservation Efforts Associated with Energy Development

Incomplete understanding of the effects of energy development on wildlife species and habitats.
It can be difficult to fully understand the effects of energy development on both species and habitats especially given variations in the type, pace, and intensity of energy development, local site conditions, changes in energy development technologies, and the influence of other factors including weather and natural wildlife population fluctuations. Monitoring protocols have not been established for many wildlife species including SGCN. Immediate monitoring needs, such as responding to potential ESA listings, often drive monitoring efforts, diminishing resources directed toward understanding the larger effects of development on ecological systems and the success of mitigation efforts.

Difficulties in identifying specific goals and performance indicators by which to develop conservation plans and quantify the success of mitigation efforts.
It is difficult to establish performance indicators to evaluate the success of mitigation efforts given the diverse, changing, and incomplete understanding of the effects of energy development. There is also a lack of consensus on the timeframe or benchmarks by which success should be evaluated. Although improvements have been made, there can be a lack of standardization on how various variables are measured. A significant amount of wildlife mitigation and enhancement techniques pertain to riparian areas and wetlands, which tend to be geographically limited and defined. It can be more challenging to establish effective performance indicators in habitat types that occur on a landscape scale, such as sagebrush.

A diverse array of maps identifying important wildlife habitat are currently available to help guide energy development; however, they are

often species-specific or wildlife-group-specific and can vary by organization. Further maps are needed that specify areas of multiple conservation values, including areas needed for sustaining populations of sensitive species, big game crucial winter ranges and migration corridors, and intact portions of representative habitat types.

Lack of understanding and investigation into cumulative impacts.
Currently, Environmental Assessments and Environmental Impact Statements are applied on a project-by-project basis. This results in potentially underestimating the cumulative impacts of multiple concurrent or sequential projects. To be effective, development planning and analysis should include an evaluation of impacts for multiple forms of development as well as successive projects for a single type of energy development.

It is often difficult to keep Bureau of Land Management Resource Management Plans sufficiently updated and specific to meet the needs for effective mitigation and conservation planning.
BLM RMPs are often very general and not always sufficient to evaluate site-specific impacts. Consequently, information provided to decision-makers can be inadequate for them to use in formulating effective mitigation plans, lease stipulations, or conservation areas. Once written, there can be limited flexibility to accommodate new information collected post-RMP development. Additionally, at this stage, energy development rights have often already been issued, typically making modifications difficult and expensive. Rapidly changing technologies and threats can also cause RMPs to quickly become outdated. Recently proposed BLM mineral leasing reform should address many of these issues.

Lack of follow-up and enforcement in meeting monitoring and stipulation requirements.
The BLM often does not have the time or resources to monitor industry actions and compliance. State regulatory agencies also do not have adequate resources for follow-up or enforcement efforts where requirements or standards are not met. Kniola and Gil (2005) documented 84% of coal-bed methane wells and facilities in NE Wyoming that did not comply with reclamation standards and other conditions of approval.

Inadequate bonding system to ensure sufficient funds for the future decommissioning and reclamation of energy-development sites.
Lease development bonding is often tied to the original developer; however, leases may change hands multiple times. The type of company that secondarily acquires a lease usually changes over the lifetime of the lease, including companies that specialize in primary, secondary, and tertiary extraction as well as salvage and scrap operations for energy-development equipment and infrastructure. Some of these companies go out of business or declare bankruptcy prior to the land being fully reclaimed, making accountability for reclamation difficult.

Recommended Conservation Actions

Advance efforts that identify important wildlife habitats and areas of potential energy development to guide development and conservation planning.
Careful, statewide planning will be critical in streamlining development and minimizing its subsequent impacts on Wyoming's wildlife. Currently, multiple regional, statewide, and local habitat mapping efforts are ongoing including the Sage-grouse Core Area Strategy; TNC's Development by Design; WGFD's SWAP SGCN priority areas and Strategic Habitat Plan Crucial Areas, and Wind Conflict Maps, among others. Continued attention should be directed toward involving federal and state agencies, industry, landowners, and conservation organizations on cooperatively refining and consolidating these maps. In addition to habitat identification, vulnerability assessments that

identify areas of current and projected energy development, as well as other habitat stressors such as rural subdivision, invasive species, and climate change, should be incorporated into mapping efforts. These mapping activities will allow development planning to be conducted on a landscape or watershed scale so that wildlife conflicts can be identified early in the process to facilitate avoidance of impacts (high mitigation priority) and develop appropriate on- and off-site mitigation measures for unavoidable impacts.

Efforts should continue to establish state and regional decision support systems to house and disseminate GIS data.
The WyGISC Decision Support System (see Current Initiatives,(page 5) should be further established and associated data made easily accessible to agencies, industry, government officials, and the public for energy development and wildlife conservation planning. A DSS would facilitate the development and updating of maps identifying priority wildlife conservation and energy development areas described above. GIS analysis is also particularly effective for identifying and understanding the cumulative impacts of multiple development projects. Efforts should continue through the Western Governors' Western Regional Wildlife Support System to ensure Wyoming's DSS is compatible with those of the surrounding states to facilitate planning multi-state energy transmission and infrastructure developments. Consideration should be given to the appointment of a Geographic Information Office who would oversee the collection, storage, and dissemination of GIS data for state or federal natural resource projects approved in Wyoming. Increasing resources provided to WyGISC would also help to advance the development and implementation of the DSS in Wyoming.

Monitoring efforts should be both designed to scientific standards, including having treatment and control sites, and formulated to answer specific questions.
The purpose of monitoring should be more clearly defined to evaluate the impacts of energy development and the success of mitigation efforts. The type and level of monitoring needs to be tailored to the specific attributes of the development project and the ecological sensitivity of the site. A framework for establishing this approach is found in the monitoring recommendations within the WGFD's *Recommendations for Development of Oil and Gas Resources within Important Wildlife Habitats* (Wyoming Game and Fish Department 2010a) and *Wildlife Protection Recommendations for Wind Energy Development in Wyoming* (Wyoming Game and Fish Department 2010b). WLCI has also begun compiling information to assist in the establishment of effective energy-development–wildlife-monitoring protocols and plans to serve as a clearing house for this information in the future. Increasing WLCI capacity in this role, or alternatively creating regional or statewide monitoring committees composed of agency personnel, industry, and scientists who have strong backgrounds in monitoring, should be considered. Monitoring plans could be voluntarily submitted to these committees for review. While accounting for the site-specific nature and purposes of monitoring, monitoring definitions should be standardized to the greatest degree possible to allow more accurate comparisons of cumulative impacts on a landscape or watershed scale. It is particularly important to establish baseline data on wildlife and habitat conditions prior to energy development in order to be able to monitor future impacts.

Habitat mitigation and monitoring requirements should be based on desired ecological outcomes.
The desired outcomes for habitat reclamation requirements should be clearly stated, but should not be overly prescriptive as to designate specific steps and techniques. Over-prescription can be contrary to the site-specific nature of mitigation and monitoring efforts and

can stifle innovation while doing little to improve the quality of results. Land and wildlife management agencies should set mitigation requirements and approve monitoring plans while industry should be provided with flexibility to develop techniques to meet specified mitigation benchmarks and accommodate local site conditions.

Establishing a state reclamation policy should be considered. A Governor's task force could be established to create guidelines that all state agencies could tier to in their planning documents.

Additional research and coordination should occur to maximize the benefits of on- and offsite mitigation.
The effectiveness of reclamation and mitigation efforts should be reviewed. Offsite mitigation should be used only in addition to, not as a replacement for, onsite mitigation. Attention needs to be placed on further refining goals for mitigation, as well as associated monitoring, in order to evaluate the effectiveness of habitat mitigation and enhancement programs. Offsite mitigation planning needs to consider landscape-level cumulative impacts. Connectivity both in terms of animals that migrate seasonally as well as corridors between localized population segments should be incorporated into mitigation planning. The Nature Conservancy's Development by Design (see Current Initiatives) has been applied to establish prioritization processes to rank proposed mitigation projects for the Jonah Interagency Office and Pinedale Anticline Project Offices.

Efforts should be made to review and consolidate recommendations both within and between agencies to minimize conflicting or unnecessary regulations.
Research should be conducted on mechanisms to allow federal and non-federal minerals (oil and gas) to co-mingle, while retaining the ability to account for each separately. This would reduce the need for duplicating infrastructure to transport these materials. Currently, BLM regulations do not allow federal and non-federal mineral to co-mingle in order to allow for independent accounting. Additionally, single-point source regulations designed to limit pollution can reduce the amount of directional drilling occurring at one drilling site. This results in the construction of multiple drill sites as well as associated roads and infrastructure to extract the same amount of oil and gas while not reducing overall pollution rates.

There should be greater follow-up and enforcement regarding meeting monitoring and stipulation regulations.
The BLM and Forest Service have responsibility for monitoring development stipulations within their jurisdictions. The Wyoming Oil and Gas Conservation Commission assumes this responsibility on private and state-owned lands. The pace of energy development can overwhelm both agencies and industry with the permitting process, leaving few resources available for monitoring and enforcement. The pace of permitting should be reviewed if development is proceeding so quickly as to preclude adequate monitoring, or if mitigation measures cannot be instituted. Alternatively, industry could contribute financial resources for third-party monitoring if agency resources are inadequate.

Monitoring should be based on RMP development thresholds and stated desired future outcomes in lease agreements or on agency/private landowner goals if on private or state owned land. Protocols should be developed by field investigation to determine critical elements to be monitored. A clearinghouse for monitoring requirements based upon lease/APD language could be developed. Future permitting should be based on past performance.

Review reclamation bonds annually and ensure that when leases are transferred they are sufficient relative to reclamation needs.

Continued efforts should be made to develop and implement technologies and techniques to minimize energy-development impacts on wildlife.

Current technologies that have been used to reduce energy-development–wildlife impacts include using smaller rigs, directional drilling, oak mats, and purpose-built rigs. Whenever possible, supporting infrastructure, including power transmission lines, should be placed in already existing corridors to reduce the cumulative impacts to wildlife.

More training opportunities should be provided for wildlife biologists and natural resource agency personnel to enhance their understanding of energy development techniques and issues. Conversely, energy industry personnel should have more educational opportunities regarding wildlife and biological issues on which agency personnel often base their recommendations.

Evaluating/monitoring Success

Trends in wildlife populations should be monitored to learn more about the impacts of energy development and to ensure specified mitigation goals are met.
Continued effort needs to be made to conduct research to understand the potential impacts of energy development on species and habitats where little information exists. New forms of development will require additional research for these as well as for more well-known species. Results of the AWVED project (see Current Initiatives, page II – 2 – 10) will provide guidance as to which species are likely to be impacted by energy development and where additional research is needed.

The long-term effectiveness of reclamation and mitigation measures should be monitored.
Long-term studies should be established to evaluate and compare the effectiveness of various mitigation techniques. Efforts should be made to continually integrate monitoring data into adaptive management strategies, including making individual and compiled results available to industry and agencies to improve energy-development and mitigation techniques. Opportunities to enable agencies, conservation organizations, and energy companies to collaboratively interact and contribute data should be identified.

The location, rate, and extent of energy development should continue to be tracked on a statewide basis to assist in identifying cumulative impacts, evaluating the integrity of wildlife priority areas, and updating conservation plans.
The establishment of a centralized GIS database for biological and energy development information should assist in achieving this goal.

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* Denotes individuals who participated in focus groups on energy development and wildlife conservation. A focus group with representatives from the energy industry was held on June 24, 2009. A focus group with representatives from natural resource agencies and wildlife conservation groups was held on December 17, 2009.

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Additional Resources

Bureau of Land Management – Wyoming State Office
5353 Yellowstone Road,
Cheyenne WY 82009
PO Box 1828,
Cheyenne, WY 82003-1828
Phone: (307) 775-6256
http://www.blm.gov/wy/st/en.html

Office of State Lands and Investments
Herschler Building, 3rd Floor West
122 West 25th Street
Cheyenne, WY 82001
Phone: (307) 777-7331
http://slf-web.state.wy.us/

Petroleum Association of Wyoming
951 Werner Court, Suite 100
Casper, WY 82601
Phone: (307) 234-5333
http://www.pawyo.org/

The Nature Conservancy in Wyoming
258 Main Street, Suite 200
Lander, WY 82520
Phone: (307) 332-2971
http://www.nature.org/wherewework/northamerica/states/wyoming/

U.S. Fish and Wildlife Service
Wyoming Field Office
5353 Yellowstone Road, Suite 308A
Cheyenne, WY 82009
Phone: (307) 772-2374

U.S. Forest Service R2/R4
Wyoming Capitol City Coordinator
Herschler Building 3 West, Room 3603
122 West 25th Street
Cheyenne, Wyoming 82002-0600
Phone: (307) 777-60870

Wyoming Department of Environmental Quality
Herschler Building
122 West 25th Street
Cheyenne, WY 82002
Phone: (307) 777-7937
http://deq.state.wy.us/

Wyoming Game and Fish Department
Habitat Protection
5400 Bishop Blvd
Cheyenne, WY 82006
Phone: (307) 777-4506
http://gf.state.wy.us/

Wyoming Geographic Information Science Center (WyGISC)
Department 4008,
1000 East University Avenue
University of Wyoming
Laramie, WY 82071
Phone: (307) 766-2523
http://www.uwyo.edu/wygisc/info.asp?p=12694

Wyoming Mining Association
2601 Central Avenue
Cheyenne, WY 82007
P.O. Box 866
Cheyenne, WY 82003
Phone: (307) 635-0331
http://www.wma-minelife.com/

Wyoming Natural Diversity Database
Dept. 3381, 2nd Floor, Wyoming Hall
1000 East University Avenue
Laramie, WY 82071
Phone: (307) 766-3023
http://uwadmnweb.uwyo.edu/wyndd/

Wyoming Oil and Gas Commission
2211 King Boulevard
Casper, WY 82602
P.O. Box 2640
Casper, WY 82602
Phone: (307) 234-7147
http://wogcc.state.wy.us/

Wyoming Power Producers Coalition
P.O. Box 21869
Cheyenne, WY 82003
Phone : (307) 321-0387
http://www.wyopowerproducers.org/

State and Federal Energy Development Regulations

Wyoming Statewide Rules
The Wyoming Oil and Gas Conservation Commission (WOGCC) issues state-wide rules and regulations to govern the development of oil and gas in Wyoming. Current WOGCC rules and regulations can be accessed through the links below or through the *Rules/Statutes* page on the WOGCC's website (http://wogcc.state.wy.us/). These rules and regulations apply to the drilling and mining of private, state, and federally owned minerals. The intent of WOGCC rules and regulations are to prevent waste and to conserve mineral resources, as well as to protect human health and the environment. This is accomplished through designating extraction methods which are designed to avoid soil or water contamination at drilling or producing locations. Compliance with state rules does not relieve the owner or operator of the obligation to comply with applicable federal, local or other state permits or regulatory requirements.

National Environmental Policy Act
National Environmental Policy Act (NEPA) requires federal agencies to integrate environmental values into their decision making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. Under NEPA, there are three steps that can occur regarding energy development projects: 1) scoping, 2) developing an Environmental Assessment (EA), 3) and/or developing an Environmental Impact Statement (EIS). The scoping notice identifies issues and concerns that will need to be analyzed in an EA or EIS. A written EA analyzes how a proposed federal action might affect the environment. If no

significant effects are determined, the agency issues a finding of no significant impact (FONSI). The FONSI may address measures which an agency will take to reduce (mitigate) potentially significant impacts to an insignificant level. In some circumstances, an EA does not need to be done prior to doing an EIS. If the federal agency or the project proponent already suspects that the environmental consequences may be significant, the EA process can be bypassed and the process goes directly to developing an EIS. In these circumstances significant time and money is saved by bypassing the EA step. An EIS is a more detailed evaluation of the proposed action and alternatives that discusses the potentially significant effects and consequences. The public, other federal agencies and outside parties may provide input into the preparation of an EIS and then comment on the draft EIS when it is completed. If a federal agency anticipates that an undertaking may significantly impact the environment, or if a project is environmentally controversial, a federal agency may choose to prepare an EIS without having to first prepare an EA. Additional information on NEPA can be found at: http://www.epa.gov/compliance/nepa/index.html.

National Environmental Policy Act (NEPA) – Categorical Exclusion Reviews

Categorical exclusions are "a category of actions which do not individually or cumulatively have a significant effect on the human environment … and for which, therefore, neither an environmental assessment nor an environmental impact statement is required." The Council on Environmental Quality (CEQ) developed the categorical exclusion process to decrease the paperwork and time associated with NEPA compliance. The categorical exclusions for Mineral Management Services (MMS) activities are listed in the MMS Manual.

The CEQ acknowledges that occasionally exceptions to a categorical exclusion may be needed. As a result, the CEQ requires all agencies to develop procedures to determine whether a normally excluded action may have a significant environmental effect. The Categorical Exclusion Review (CER) determines whether a proposal that is categorically excluded may meet any of the Department's extraordinary circumstances criteria.

Federal Mineral Leasing

The Bureau of Land Management manages the nation's publicly owned mineral estate, including its leasing, and is also the federal agency responsible for conducting NEPA analyses for the mineral leasing activities that the agency approves. The Wyoming BLM State Office and WGFD entered into a memorandum of understanding (MOU) in 1990 to guide the cooperative input and consideration of wildlife resource values on BLM lands. Appendix 5G of that MOU deals specifically with coordination and cooperation related to oil and gas development activities.

Consideration of environmentally sensitive areas and other resources are addressed in two ways within the BLM federal leasing program: "no leasing" and "leasing with restrictive stipulations." "No leasing" is prescribed for specific areas only through a congressional mandate or through the BLM planning process when a determination on a given land-use plan is made not to lease in a specific area.

To limit conflicts with the variety of resources encountered on federal lands, the Wyoming BLM state office has developed Lease Notices and four standard types of stipulations that can be attached to a lease. Notices and stipulations are attached as part of a lease when the environmental and planning record demonstrates a necessity for them. The notices and stipulations are in addition to the terms of the lease as printed on the lease form, and once attached, become an integral part of the lease. The stipulation format includes the categories of: 1) no surface occupancy (NSO), 2) timing or seasonal restrictions, 3) controlled surface use, and 4) special administrative stipulations. In all cases, definitive use of the stipulations will require identification of specific resource values to be protected.

A Controlled Surface Use (CSU) stipulation is applied, on all or portions of a lease, where use

and occupancy is allowed (unless restricted by another stipulation), but identified resource values require special operational constraints that may alter the lease terms. These could include prohibiting certain types of activities and/or occupancy unless suitable mitigation can be determined and agreed upon by the BLM and the operator. The CSU is different from the NSO, which totally prohibits surface occupancy, and from timing stipulations, which limit when operations may occur.

Special administrative stipulations are those stipulations provided by another agency or organization, such as the US Forest Service or Bureau of Reclamation. They are used in situations where standard stipulations do not adequately address a specific concern, surface management plan, or an agency regulation or policy.

"Exceptions" can be applied on a case-by-case basis. Exceptions are one-time exemptions from lease stipulations for a specified portion of a leasehold and for a specified period of time. Existing stipulations continue to apply to all other sites and time periods within the leasehold. Exceptions are approved by the BLM Area Manager in coordination with the WGFD.

"Modifications" fundamentally change the provisions of a lease stipulation, either temporarily or for the period of the lease. A modification may, therefore, include an exemption from, or alteration to, a stipulated requirement. Depending on the specific modification, the stipulation may or may not apply to all other sites within the leasehold. Modifications are approved by the BLM Deputy State Director for Minerals and Lands with consultation from the WGFD.

The Federal Onshore Oil and Gas Leasing Reform Act (FOOGLRA) of 1987 further provides for a 30-day public review opportunity before approving or substantially changing terms of a lease or varying lease stipulations. The level and intensity of public involvement is usually based on specific circumstances.

Federal Land Management Agency Planning Documents

The BLM's umbrella planning document for general resource and land use management direction for an administrative area unit is the Resource Management Plan (RMP). The RMP provides management direction for the BLM's oil and gas leasing, exploration, and development process and specific direction for the application of stipulations to oil and gas leases. The RMP also provides direction for conditions of approval (COAs) that are intended to guide the exploration and development stages of oil and gas activities. Similarly, each National Forest and Grassland is governed by a management plan in accordance with the National Forest Management Act (NFMA) http://www.fs.fed.us/emc/nfma/index.htm. These plans set management, protection, and use goals and guidelines. Monitoring conditions on a forest or grassland ensures projects are done in accordance with plan direction, and determines effects that might require a change in management. The US Forest Service determines where and under what conditions oil and gas leasing can occur on National Forest lands. The BLM then determines whether or not NEPA requirements have been met before the BLM offers the Forest Service oil and gas leases for sale at auction.

Mineral Activity on Wyoming State Lands

The State Board of Land Commissioners through the Mineral Leasing Section of the Office of State Lands and Investments is responsible for establishing rules and regulations for lands owned by the state of Wyoming. The Mineral Leasing Section is also responsible for providing information to the public and private sectors concerning state mineral lease availability and individual lease status.

U.S. Environmental Protection Agency and Wyoming Department of Environmental Quality

The U.S. Environmental Protection Agency (EPA) is a federal agency whose mission is to protect human health and the environment through regulation, research, and outreach related to pollutants in the environment. The Wyoming Department of Environmental Quality (DEQ) is a state agency, not directly affiliated with the EPA, which answers to the Governor and Legislature of the State of Wyoming. DEQ develops and implements regulations and policies in response to federal guidelines and in regards to direction from the Legislature and the Governor. Many DEQ programs have been designed to meet the EPA's requirements, so that DEQ is delegated the authority to enforce many of the EPA's environmental programs. By maintaining delegation, DEQ keeps the management of environmental programs within the state, allowing the development of regulations and policy to better meet the specific needs of Wyoming. The EPA retains oversight of any DEQ programs that implement federal requirements. DEQ is responsible for enforcing state and federal environmental laws, including the Clean Air Act, Clean Water Act, National Pollutant Discharge Elimination System (NPDES), Environmental Quality Act, Resource Conservation and Recovery Act (RCRA), Superfund Amendments and Title III Reauthorization Act (SARA), and Federal Surface Mining Reclamation and Control Act.

Wind Energy Development

Wind projects constructed in Wyoming, which consist of 30 or more towers or which expand to include 30 or more towers, regardless of land ownership, require a permit from the Wyoming Industrial Siting Council (WISC). W.S. 35-12-110 (b) requires WGFD to provide information and recommendations to the WISC regarding the impacts of industrial facilities including wind projects subject to WISC jurisdiction and a specific recommendation as to whether the WISC should issue a permit.

Like oil and gas, NEPA also applies to the development of wind energy and associated infrastructure on federal lands. A POD is a plan of development for individual wind energy development projects. Energy companies seeking to develop a wind power project on BLM-administered lands are required to develop a project-specific POD that incorporates best management practices and other appropriate existing BLM mitigation and guidance conditions developed to minimize or reduce environmental effects to other resources. PODs typically include a site plan showing the locations of turbines, roads, power lines, other infrastructure, and additional areas of short and long-term disturbance. ROW authorization can apply additional mitigation measures to address site- and species-specific issues for individual projects related to but not included in a wind energy development POD. Examples include meteorological test towers, connecting transmission lines, and support and maintenance facilities.

Invasive Species

Clockwise from the top: Russian olive removal project in eastern Wyoming (Dustin Hill); Quagga mussels on boat propeller (Utah Division of Wildlife Resources); Fish infected with whirling disease (The Whirling Disease Initiative); Rusty crayfish (USGS); Canada thistle (Danny Dalton, Wyoming Pest Detection Program); Leafy spurge (Danny Dalton, Wyoming Pest Detection Program); Cheatgrass (Richard Old, www.xidservices.com).

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Background

An invasive species is a species that is "1) non-native to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health" (Executive Order 13112, Appendix 1, 1999). Invasive species can include both terrestrial and aquatic plants and animals, and even pathogens such as West Nile virus. Not all non-native species become invasive; many, including agricultural crops and game animals, support human livelihoods and quality of life. However, some non-native species have the potential to cause significant environmental damage.

Terrestrial invasive plants can reduce forage production for wildlife and livestock; diminish breeding, escape, and thermal cover for wildlife; alter hydrologic cycles; change fire regimes; increase sedimentation and erosion rates; and change nutrient cycles and soil properties (Wyoming State Weed Team 2003). Invasive aquatic species can further affect aesthetics, drainage for agriculture and forestry, commercial and sport fishing, drinking water quality, flood control, human and animal health, hydropower generation, irrigation, recreational boating, swimming, water conservation and transport, and land values (Rockwell 2003). In the U.S. alone, damage and losses from invasive species are estimated at approximately $120 billion annually (Pimentel et al. 2005).

Most invasive species have been introduced into this country from abroad. As a result, they often do not have natural control agents or competitors and thus have the potential to dominate the native habitats they occupy. An increase in international trade and travel has worsened the intentional and unintentional introduction of invasive species. Ships are a common pathway for the unintentional introduction of invasive species, whether they travel by clinging to hulls, wrapping on propellers, or traveling within ballast water, or as cargo. Passengers traveling by ship, airline, train, motor vehicle, or even on foot are also common means of transport. Intentional pathways include pet, aquarium, aquaculture, and horticulture trades. In Wyoming, roads serve as conduits to spread invasive species through the creation of disturbed areas and vehicle traffic. Weeds frequently blow off hay being transported along the interstate, rural, and public lands roads.

Invasive species are a major cause of wildlife extinctions worldwide. For example, globally, invasive species have been identified as at least contributing to 48–62% of fish extinctions (68% of North American fish extinctions), 50% of bird extinctions, and 48% of mammal extinctions (U.S. Environmental Protection Agency 2008). In the United States, as many as 49% of all threatened and endangered species are adversely impacted by invasive species to some degree (Wilcove et al. 1998).

Scope and Challenges of Invasive Species and Wildlife Conservation

Terrestrial

Invasive terrestrial plants including noxious weeds inhabit about 1.3 million acres (~ 2%) in Wyoming (Wyoming State Weed Team 2003). The importance and impact of a particular weed species often vary by watershed. Additionally, the attention given to an individual species can shift with changing conservation issues and priorities as well as with the occurrence of new species.

Invasive terrestrial plant species are typically well suited to quickly colonize bare ground and disturbed sites resulting from both human and natural causes (Sheley et al. 1999). This attribute contributes to invasive species being a principal component of, or compounding, other negative effects associated with habitat impacts such as rural subdivision, energy development, disruption of natural disturbance regimes, overgrazing, and off-road vehicle use.

Increasing levels of outdoor recreation aid the spread of invasive species which are commonly

transported on vehicles, boats, and felt-soled fishing boots. Invasive weeds have been transported to alpine areas in hay for recreational horseback riding, although the required use of certified weed-free forage has reduced this problem in some areas.

Climate change and associated changes in atmospheric carbon dioxide levels, modified precipitation regimes, increased ambient temperatures, and altered nitrogen distribution is expected to intensify problems associated with invasive species. While some species are anticipated to experience range reductions, the ranges of others will expand. Additionally, climate change may result in new habitat types or conditions favorable to nonnative species (U.S. Environmental Protection Agency 2008). Climate change may also increase the frequency and intensity of natural disturbances, including fire and drought which could benefit those invasive species that are tolerant of changing hydrologic conditions and easily regenerate after wildfire (see Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Tamarisk (commonly known as *saltcedar*), Russian olive, and cheatgrass (downy brome) may be the terrestrial invasive plant species with the greatest statewide recognition. Tamarisk was introduced into the U.S. from the Mediterranean region and likely escaped cultivation in the 1870s. It is an aggressive colonizer that often forms monotypic stands, outcompeting willows, cottonwoods, and other native riparian vegetation. It received its common name of *saltcedar* from the ability of the stems and leaves of mature plants to secrete salt. This salt forms a crust above and below ground that inhibits other plant growth (Sudbrock 1993). Tamarisk has a long tap root and is an enormous water consumer, which leads to its propensity to lower ground water levels, drying up springs and marshy areas. Additionally, large stands of tamarisk with extensive roots systems can contribute to flooding by choking stream beds (Rush 1994). Infestations often have a detrimental impact on wildlife; however some recent studies suggest that the effects of tamarisk invasion on wildlife vary depending on the ratio of tamarisk to native vegetation, wildlife taxa, and the quality and type of adjacent habitat (Shafroth et al. 2010). Although it provides some shelter, its foliage and flowers provide little food value for native wildlife species. Tamarisk now occupies 650,000 ha in the West and is estimated to cost $7 to $16 billion in lost ecosystem services, namely the provision of water, flood control, and wildlife benefits, over a 55-year period (Zavaleta 2000).

Problems associated with Russian olive are similar to those associated with tamarisk. Russian olive is a native plant from Eurasia that was introduced to many Great Plains and southwestern states in the early 1900s. The trees were extensively planted to provide windbreaks at first, and then federal conservation programs promoted their use for wildlife habitat among other uses. The Natural Resources Conservation Service (NRCS) continued to subsidize Russian olive seedlings for conservation plantings until the 1990s (Wyoming Game and Fish Department 2010). Currently, Russian olive is present in every western state, and occurs in most drainages across Wyoming except for portions in the far west and at higher elevations. In 2007, Wyoming joined other states (CO, CT, NM, and UT) with its listing of Russian olive as a noxious weed by the Wyoming Department of Agriculture. In addition, United States Congress passed the Saltcedar and Russian Olive Control Demonstration Act in 2006, which directs the Secretary of Interior to assess and develop programs to control these two plant species, and to provide a comprehensive scientific assessment of the distribution, abundance, and impacts of the two plant species (Shafroth et al. 2010).

Russian olives can outcompete native riparian vegetation, interfere with natural plant succession and nutrient cycling, and tax water reserves. The spread and establishment of Russian olives has been accelerated by water development projects. Controlling, minimizing, or eliminating flushing flows and the formation of gravel bars is detrimental to the regeneration

and establishment to native vegetation such as willows and cottonwoods, but has little effect on Russian olive or tamarisk reproduction. Cottonwood declines have been associated with flow alterations on the North Platte (Miller et al. 1995) and Bighorn (Akashi 1988, Bray 1996) Rivers in Wyoming. Although Russian olives can provide food and cover, they typically replace native vegetation favored by many wildlife species. Cottonwoods in particular are important to birds by providing both structural diversity for foraging and nesting as well as suitable dead and dying trees for cavity nesters. Some studies have found that Russian olives harbor fewer bird species than native vegetation (Brown 1990, Knopf and Olson 1984), but more recent research generally finds that some species prefer habitat created by Russian olives and some do not, depending in part on the density of the nonnative trees and the surrounding habitat (Shafroth et al. 2010).

Cheatgrass is an annual brome grass from Eurasia that has the capacity to reduce the productivity of desirable forage plants as well as decrease plant species diversity. Cheatgrass has become a particular problem in large areas within the Great Basin, including western Utah, Nevada, and southern Idaho. High densities of cheatgrass increase fire severity by increasing fine fuel loads and shorten the time period between fires due to rapid regrowth. This altered fire regime can change entire plant communities. In some locations cheatgrass-fueled wildfires have converted native grasses and sagebrush habitats to cheatgrass-dominated landscapes. Of special concern are the loss of crucial sage-grouse habitat and other wildlife habitat along with secondary weed invasions from species such as rush skeletonweed and Medusa-head wild rye (Smith and Enloe 2006). Cheatgrass is adapted to surviving continuous years of drought and may grow vigorously when water becomes available. Its adaptation to fire and drought tolerance may make it well suited to thrive in a climate that is warmer and has more variability in precipitation which is commonly predicted for Wyoming in many climate change models (Bradley et al. 2008).

Aquatic

Aquatic invasive species (AIS), including fish, amphibians, mollusks, crustaceans, plants, and pathogens, are currently present in Wyoming, most notably the New Zealand mudsnail (Benson 2009a) and the parasite that causes whirling disease, and more damaging species are present in neighboring states. While these species cause problems and need to be prevented and controlled, the most significant threat to Wyoming is from zebra and quagga mussels (Wyoming Game and Fish Department 2009).

Zebra and quagga mussels have not been documented in Wyoming's waters, but as of 2008, instances of zebra and quagga mussels have occurred in Colorado, Utah, Nebraska, Kansas, Nevada, Arizona, and California (Benson 2009b, Benson 2009c). Zebra and quagga mussels have high reproductive potentials and spread rapidly. They negatively impact water delivery systems and power generation facilities by clogging pipes, pumps, turbines, and filtration systems. They have harmful impacts on fisheries by removing plankton from the water, reducing the productivity of waters. There are high economic and social costs once these mussels become established, including decreased boating and angling and increased water delivery and electricity costs (Wyoming Game and Fish Department 2009). Both species naturally disperse through water currents, but human transport via recreational watercrafts trailered from infested waters is the primary vector for movement to new aquatic systems (O'Neill 1996). As a headwater state, Wyoming's control activities are important in preventing the spread of these organisms and other invasive species to downstream locations.

Wyoming is expected to experience increased energy development, rural subdivision, and recreational use in the future. Additionally, climate change may alter existing habitats as well as create new ones favorable for invasive species. New species are likely to arrive as world trade and travel becomes more commonplace. All these factors suggest that

threats from invasive species to Wyoming's native wildlife will increase in the future and continue to present new challenges to wildlife and natural resource managers.

Current Initiatives to Control Invasive Species

Federal

Most federal land management agencies have invasive species programs. Invasive species management is addressed in US Forest Service and Bureau of Land Management Forest and Resource Management Plans. Executive Order 13112, issued in 1999, mandated the establishment of the National Invasive Species Council to help ensure a coordinated, cost-efficient, and effective federal response to invasive species. Part of the Council's work included the creation of an Early Detection and Rapid Response (EDRR) strategy to prevent the establishment of invasive species. Wyoming is currently developing a state EDRR team and plan modeled after this federal program.

State and Local

Twenty-three Weed and Pest Control Districts have been established in Wyoming as a result of the Wyoming Weed and Pest Control Act of 1973. Weed and Pest Control Districts provide cost-sharing assistance to landowners to eradicate or slow the spread of invasive species. Districts also have crews who treat weed outbreaks along county, state, and federal roads and in the backcountry. Public and professional training and education on weed identification, treatment, and prevention are important components of their work. Weed and Pest Control Districts are funded by mill levies on property.

Wyoming's Weed and Pest Council is comprised of one representative from each Weed and Pest District. The purpose of the council is to encourage the exchange of information and cooperation between districts and other agencies relative to the control of weeds and pests. The council also plays an educational role for the public and professionals in serving as a clearing house for information on weeds and invasive species. When needed, the Weed and Pest Council sponsors appropriate weed and pest laws. It receives funding from a pesticide registration fee, US Forest Service and state private forestry grants, the Wyoming Department of Transportation, and the Wyoming Office of State Lands and Investments for weed control on state highways and state lands, respectively. The Council has also received a bi-annual legislative grant from special management program funds for leafy spurge control.

Growing problems with invasive species and increasing numbers of private individuals and professionals with interests or responsibilities associated with weed control have led to the formation of the Wyoming Weed Management Association (WWMA) in 2006. The WWMA's purpose is to promote collaboration and education on weed management issues among interested parties.

Wyoming has a list of Designated Noxious Weeds (S. 11-5-102 (a)(xi)) and Prohibited Noxious Weeds W.S. (11-12-104). There are currently 25 species on this list, the composition of which usually determines how resources and money are allocated for weed management at the county and state level. Species are added to the list through a joint resolution by the Weed and Pest Council and the Wyoming Board of Agriculture. The process is initiated at the request of one or more Weed and Pest Control Districts. Public hearings are held at the county level and by the Board of Agriculture. Wyoming counties often have independent ranked lists of weed species which guide the allocation of local resources.

Cooperative efforts comprised of multiple agencies and/or counties are becoming increasingly common for invasive species control. Examples include the North Platte Weed Initiative which covers Carbon, Converse, Goshen, Platte, Natrona, and potentially Fremont County; the Big Horn Exotic Plant Group; Greater Yellowstone Coordinating

Committee Invasive Species Program; and the Wyoming Green River Basin Healthy Lands Initiative. Coordinated Resource Management (CRM) teams have used a collaborative, stakeholder-based model to address land management issues in Wyoming since 1975. Currently, there are approximately 40 CRM teams in Wyoming, most of which have a weed management component. The CRM process works well with the Weed and Pest's Weed Management Area designation. CRMs help to identify the ecological needs of the area, to address monitoring and any needed reclamation to ensure success of the control method being used, and to keep control of future invader through good management practices.

The Wyoming Game and Fish Department (WGFD) has actively participated on a statewide basis with almost all 40 CRMs and additional smaller groups which deal with invasive species within specific watersheds, basins, or sub-basins. WGFD habitat biologists and land managers are well trained on invasive species issues and provide input for coordinated management efforts. The WGFD has also substantially increased invasive species control efforts on department-managed lands during the last five years.

Presently, there is no statewide tracking of the location and spread of terrestrial invasive species beyond county-level presence and absence. Additionally, no annual reporting requirements on statewide weed and pest activities exist. There is GIS mapping of terrestrial invasive plant species by counties, but the quality of mapping varies between locations. There are some data-sharing limitations, particularly for data about invasive species located on private lands, as approval from the landowner is required to share this information. The Bureau of Land Management, National Park Service, and US Forest Service have programs to map and track invasive species on their lands.

The WGFD has taken several actions to prevent the spread of AIS across state borders into Wyoming and within Wyoming's borders. The WGFD has used funds from the Wyoming Legislature to renovate hatcheries to effectively manage and control the spread of whirling disease (Beers1999). Additional efforts include regulations to combat illegal fish introductions, chemical removal of rusty crayfish, Hazard Analysis and Critical Control Point efforts for department activities, and education and outreach (Wyoming Game and Fish Department 2009). The Department has also been involved in regional and national coordination on AIS issues. The best source for current information on AIS in Wyoming and other states is the Nonindigenous Aquatic Species database housed by the USGS (http://nas.er.usgs.gov/).

The Wyoming AIS Management Plan was developed by the WGFD in response to the invasive species threats that are currently impacting Wyoming's waters and the imminent threats that are afflicting the waters of neighboring states. The management plan is meant to help coordinate all levels of efforts to prevent, control, monitor, and, whenever possible, eradicate AIS populations that are threatening Wyoming's waters. The four main goals of the management plan are stated as follows: 1) prevent introduction of new AIS to Wyoming and the dispersal of established AIS populations into unaffected waters in Wyoming, 2) eradicate or control established AIS in an environmentally sound manner to minimize the adverse effects of AIS on Wyoming's natural resources, 3) educate the public about AIS threats and how to reduce their potential impacts, and 4) support research on AIS in Wyoming (Wyoming Game and Fish Department 2010 draft).

In order to achieve the aforementioned goals, the WGFD will undertake extensive efforts to inspect and decontaminate watercrafts that are being launched on Wyoming's waters, as well as monitor those waters for AIS. It will also work to control and contain AIS when possible, carry out public outreach and awareness campaigns including educating boaters on how to perform an AIS self-check on their watercraft, and continue to cooperate with other AIS efforts

and evaluate potential control methods. The management strategies that are included in the AIS Management Plan are proactive and realistic and are intended to be implemented in coordination with federal, state, tribal, and local entities. To date, WGFD outreach efforts have been intensive with the hope that generating public awareness will be the most effective way to prevent additional AIS from becoming established in Wyoming's waters.

The plan ranks AIS into one of four priority classes, which indicate varying levels of urgency regarding addressing these threats. Priority Class 1 and 2 species are the main focus of the management plan, with special focus on the mussels that are currently impacting the waterways of neighboring states and are easily transported on watercrafts to other bodies of water. The AIS Management Plan is designed to be adaptable in order to address future AIS threats and to coordinate with other agency/organization programs that are already established to address this issue.

The Wyoming Aquatic Invasive Species Act was passed in 2010 by the Wyoming Legislature, and appropriated $1.5 million for FY 2011. WGFD and the Wyoming Department of State Parks and Cultural Resources will report to the legislature in 2010 and make an appropriations request for FY 2012. WGFD has a permanent AIS coordinator position to facilitate the development, coordination, and implementation of the AIS program. The legislation was signed by Governor Freudenthal in March 2010. In November 2011, Wyoming AIS plan was approved by the national Aquatic Nuisance Species Task Force, making it eligible for funding through the National Invasive Species Act.

Current Challenges for Effectively Controlling Invasive Species

Need for greater coordination for invasive species control efforts at the regional and state level.

While coordination on invasive species control activities is effective at the county level, greater coordination is needed between state and federal agencies. Areas where coordination can be improved include the sharing of goals and priorities, coordinating educational initiatives, and enhancing understanding of individual agency regulations, policies, and guidelines. Federal land management agencies are required to follow state directives; however, at times there is insufficient coordination with federal land management agencies on invasive species issues to achieve this requirement.

Lack of the necessary consistent, multi-year funding required for establishing and implementing effective invasive species control efforts.

Most invasive species funding in Wyoming is allocated annually which makes it difficult to develop long-term programs needed for the effective treatment and monitoring of invasive species. Additionally, funds are often allocated based upon acres treated and less directed toward efforts preventing the spread of invasive species or by the success of past control efforts. Anticipated federal and state budget cuts, due to weak economies and federal deficits, will likely reduce funding for invasive species control in the near future.

Increasing subdivision.

Soil disturbance from construction, the year-round grazing of horses and other hobby livestock, and the use of nonnative plants as ornamentals can facilitate the establishment of invasive species (Maestas et al. 2002). As the number of property owners increases, it becomes more likely that at least some will not adopt invasive species control efforts. This in turn creates source areas for future infestation making it more difficult for surrounding neighbors to control weeds. One study of 162 ranchers in the Sierra Nevada foothills of California found that 25% of interviewees reported that neighbors with weed sources on their properties reduced their investment in control efforts, because of the cost associated with continual reinvasion (Epanchin-Niell et al. 2010).

Inflexible or inconsistent monitoring and enforcement of existing invasive species regulations.
Monitoring and enforcement of invasive species management regulations and contracts on public and private lands are inconsistently enforced. These regulations often pertain to surface disturbance from sources such as road building.

Inadequate statutory authority or invasive species regulations.
Through the recently passed Aquatic Invasive Species Act, WGFD recently received the statutory authority to inspect and decontaminate boats that are being launched on Wyoming waters. However, there is not adequate control regarding the importation and sale of plants that are not on the list of Designated Noxious Weeds. Stronger education, recognition, and regulatory response to the importation and sale of plants recognized as an invasive species is encouraged

Need to increase public and professional knowledge about invasive species and invasive species management.
Knowledge levels about invasive species control and monitoring techniques vary considerably among land management and wildlife agency employees. The same is true for construction personnel, including those associated within the oil, gas, and wind development industries, who are responsible for preventing the spread of invasive species. Frequent employee turnover can diminish local knowledge, momentum, and follow-through for invasive species management programs.

In addition to educating land management and natural resource professionals, there is a need to increase invasive species knowledge levels among suburban residents and those engaging in outdoor recreation. Increasing awareness about the impacts of invasive species is necessary to encourage activities to limit the spread of invasive species and to build public support for control efforts. It is often difficult to get the public to attend workshops or other types of training. In addition to increasing general awareness, educational efforts should include information on where to get further technical assistance on controlling invasive species.

Difficulties in keeping pace with the increasing numbers of invasive species as well as the intensification of the causes accelerating their spread.
Control efforts are not growing at the rate necessary to meet the challenges posed by the increasing numbers of invasive species, greater development pressures, higher levels of outdoor recreation and international trade, and mounting influences from climate change. Frequently, there is only time and money for treatment, and little attention is directed toward monitoring or subsequent efforts to re-establish native species.

Recommended Conservation Actions

Establish a statewide inter-agency working group to coordinate invasive species control efforts.
A statewide inter-agency invasive species working group should be established to facilitate coordination among invasive species control efforts. Responsibilities of the working group could encompass serving as a clearing house for information about invasive species including current treatment efforts and their level of success, increasing awareness about technical and financial assistance available for invasive species management, identifying common conservation goals among agencies, and coordinating educational efforts. Coordinating activities, especially for educational efforts, can reduce costs for individual organizations. The Wyoming State Weed Team, which created Wyoming's Weed Management Strategic Plan, has expressed interest in assuming some of these responsibilities. All federal and state agencies should consider hiring or appointing a point person responsible for invasive species issues.

Increase consistent, long-term funding for invasive species control efforts.
To effectively control invasive species, funding should be multi-year and consistent. This would enable not only adequate treatments, but also the necessary follow-through including post-treatment monitoring and the re-establishment of desired species. Invasive species funds should be line items in federal and state agency budgets and not subject to annual appropriations. Pesticide registration fees should continue to be directed toward invasive species management. The Wyoming Legislature provided for the use of pesticide registration fees to be used for special projects through a grant process. This enabled the Weed and Pest Districts to utilize a source of funds for targeted invasive species management. Grant-writing training should be provided to weed management coordinators to enhance funding opportunities.

Federal funding available to implement State AIS Plans through the USFWS Aquatic Nuisance Species Task Force should be increased. This funding is currently available through the National Invasive Species Act of 1996, but funds are limited to around $30,000 annually for each state with an approved AIS plan.

Better prioritization systems should be established for the allocation of invasive species funding.
Invasive species funding efforts are not always consistent within or between organizations. Additionally, grants are often not allocated according to need or treatment effectiveness. Invasive species control efforts should be focused on the watershed/basin level, and where appropriate, treatment should begin at the top of the watershed to ensure invasive species are not re-established from upstream sources in treated areas. Efforts should be made to involve multiple landowners in coordinated, watershed-level invasive species management plans.

Increase invasive species educational efforts.
Education material needs to be provided at points of entry including road accesses to public lands; trailheads for off-road vehicles, hiking, and horseback riding; walk-in fishing and hunting areas; boat launches; and visitor information centers for tourists. The number and type of educational opportunities should be increased for developers and contractors who are required to treat invasive species, or who have an impact on their ability to spread. General invasive species awareness should increase among land managers and wildlife personnel, including increasing the number and diversity of employees attending trainings. Educational efforts should be designed for specific audiences with regard to how the group best receives and applies information.

Increase Early Detection and Rapid Response (EDRR) capabilities.
Funding should be provided for the creation of an invasive species EDRR program in Wyoming. Reducing the spread of invasive species is less expensive and more effective than control efforts after the species is established. Projected costs for a Wyoming EDRR program are $3 million and $2 million annually for terrestrial and aquatic species, respectively. EDRR funding should be accompanied by increased coordination between the Weed and Pest Council, WGFD, and all other state and federal agencies for both terrestrial and aquatic species.

Coordinate the development of consistent invasive species monitoring protocols among local, state, and federal agencies.
Different land management and wildlife agencies presently use different methods to monitor the spread of invasive species and the effectiveness of control techniques. This lack of consistency makes quantifying and compiling data from different agencies on a regional or statewide basis difficult or impossible. The incorporation of basic protocols with a limited number of standardized descriptive fields into the monitoring protocols of each agency or organization would facilitate data sharing and enhance future invasive species control efforts. Such standardization of basic nomenclature,

including units and rating, could facilitate data sharing without limiting each organization in pursuing its individual mission and monitoring needs.

Evaluating/monitoring Success

Increased attention should be given to monitoring the effectiveness of control efforts.
The level of invasive species monitoring among agencies and landowners varies according to funding, time availability, and the priority placed upon monitoring. Currently, federal land management agencies have little financial or personnel capacity to establish comprehensive invasive species monitoring programs. Demands to address immediate treatment needs and respond to public requests prevent Weed and Pest Control Districts from putting significant resources into monitoring. However, only through monitoring can the cost effectiveness of treatments be evaluated and treatment techniques improved. The cost of monitoring programs can be reduced through multi-organizational cooperative efforts.

Monitor efforts should be designed to evaluate habitat goals rather than just the success of killing targeted species.
Invasive species should not be monitored in isolation, but as part of overall integrated habitat plans. Current monitoring often examines only the effectiveness of treatments. Which species replace treated invasive species is equally as important as both evaluating the success of eliminating the targeted plant or animal and equating that change to impact on the habitat, positive or negative. The success of efforts to prevent the spread of invasive species should also be monitored and quantified.

Greater attention should be placed on monitoring the long-term effects of invasive species management activities on wildlife.
Many past invasive species monitoring efforts have largely focused on evaluating changes in forage production for livestock. When possible, monitoring efforts should include components to determine benefits to wildlife.

It is important that monitoring plans are tailored to the resources level, expertise, and degree of interest of the intended user.
No monitoring technique is effective if it is not actively applied. Invasive species monitoring techniques should be customized not only for the specific species, but also for the intended monitoring personnel. SamplePoint monitoring, created by USDA Agriculture Research Services, is an easy, quick, and effective monitoring method without the need for extensive expertise or training. Free SamplePoint Software can be downloaded at http://www.ars.usda.gov/services/software/download.htm?softwareid=254. The University of Wyoming Cooperative Extension Service and Society for Range Management make available terrestrial invasive plant species monitoring protocols. The WGFD will be developing AIS monitoring protocols in 2010 as part of its Wyoming AIS Plan.

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Additional Resources

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http://www.blm.gov/wy/st/en.html

Center for Invasive Plant Management
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Nonindigenous Aquatic Species Database
http://nas.er.usgs.gov/

University of Wyoming Cooperative Extension Service
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http://ces.uwyo.edu/AG.asp

U.S. Forest Service R2/R4
Wyoming Capitol City Coordinator
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Cheyenne, WY 82002-0600
Phone: (307) 777-60870

USDA Natural Resource Conservation Service Exotic Plant Database
http://plants.usda.gov/java/noxiousDriver

Wyoming Association of Conservation Districts
517 E. 19th Street
Cheyenne, WY 82001
Phone: (307) 632-5716
http://www.conservewy.com/index.htm

Wyoming Cooperative Agricultural Pest Survey (CAPS) / Pest Detection Program
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Renewable Resources
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1000 E University Avenue
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Wyoming Game and Fish Department
5400 Bishop Boulevard
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http://uwadmnweb.uwyo.edu/wyndd/
Fish Division
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Aquatic Invasive Species hotline: 1-877-WGFD-AIS
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Wyoming Natural Diversity Database
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http://uwadmnweb.uwyo.edu/wyndd/

Wyoming Weed and Pest Control Districts
http://www.wyoweed.org/addresses.html

Wyoming Weed and Pest Coordinator
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Wyoming Weed Council
http://www.wyoweed.org/

Climate Change

Clockwise from the top left: Sudden Aspen Decline (SAD) in an aspen stand (U.S. Forest Service). Mountain pine beetle between Dubois and Grand Teton National Park (National Parks Traveler). Wood River near Meteetsee (WGFD). Greyrocks Reservoir during the height of the recent drought (WGFD).

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Background

Climate is a compilation of many meteorological features occurring over a long period of time. Primary elements include temperature, humidity, atmospheric pressure, air flow, and precipitation. "Weather" refers to short-term variation in these elements (i.e., two weeks or less), while "climate" refers to these dynamics over months, years, decades, centuries, and longer (NOAA 2008). Climate is controlled by many factors. It is influenced by Earth's orbit and tilt, which determine interannual changes such as the seasons. Latitude, elevation, terrain, ground cover, and presence or absence of water bodies also impact climate. These factors may affect atmospheric composition, temperature, precipitation patterns, and the many other elements mentioned previously. Climate is also affected by variables such as dust, aerosols, solar output and absorption, and concentrations of greenhouse gases in the atmosphere, namely water vapor, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Paleoclimatology, the study of ancient climates using proxy climate records (e.g., tree rings, ice cores, sediment cores), demonstrates that climate varies naturally over long periods of time. Climate is subject to natural variability from decade to decade primarily as a result of cyclical phenomena such as El Niño-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and North Atlantic Oscillation (NAO), which highlights the importance of long-term data when considering anthropogenic, or human-influenced, impacts to the climate system (Wiens and Bachelet 2009). The study of climate in the 20th century adds to scientific data pertaining to climate dating back thousands of years, painting a historical picture that shows both the warming and cooling of Earth's surface temperatures, as well as various drought and pluvial periods. Simply stated, historical records indicate that Earth's climate is variable and changes over time. Any scientifically recognizable, long-term variability in the aforementioned climatic elements (e.g., temperature, precipitation) is described as "climate change."

The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 as the leading body for the review and assessment of worldwide scientific, technical, and socio-economic information on climate change. This scientific body *does not* perform research or monitor the earth's climate. The IPCC is charged with reviewing voluntary scientific contributions in the field of climate change and translating and conveying to the public the presently documented and potential future consequences of this global phenomenon.

Scope and Challenges of Climate Change and Wildlife Conservation and Management

Global to Local

While climate change is a global phenomenon with broad-scale ramifications at the global level, the ecological impacts are more readily observed, experienced, and addressed at the local level. The western United States has a more diverse landscape with climate variations that are difficult to model on a fine scale, areas that are remote and inaccessible for climate research and monitoring, and a patchwork of publicly and privately owned land that influences management strategies and policy making (Joyce et al. 2007). Wyoming is a unique mixture of mountain and plains landscapes, causing the state's climate to be varied from east to west and north to south. Wyoming is also faced with several unique challenges relating both directly and indirectly to climate and climate change.

According to paleoclimatic records dating back thousands of years, drought—a period of unusually low precipitation—is a defining feature of Wyoming's climate (Gray and Andersen 2009). Examination of western climates over

centuries, which is established primarily by lake sediments, tree ring cores, and packrat middens (McWethy et al. 2010), demonstrates that severe drought is a natural part of Wyoming's climate (Gray and Andersen 2009). However, the baseline for state climate is established using records of climate variability throughout the past century (Gray and Andersen 2009). Most importantly, climate records over the past 30 years are most often used to establish resource management practices. A longer historical record indicates that the 20th century was an unusually wet time period in Wyoming relative to the past several millennia (Gray and Andersen 2009).

In addition to frequent drought, Wyoming is also challenged by the regional semi-arid climate. In other words, even in non-drought periods Wyoming is a rather dry area. Wyoming is the fifth driest state in the U.S.—over 70% of the state receives less than 16 inches of precipitation annually (Gray and Andersen 2009, Water Resources Data System undated). The state also relies almost exclusively on mountain snowpack as its major water source, with 70–80% of precipitation arriving as snow (Hays 2008). A majority of the snowpack is concentrated in a relatively small area (Gray and Andersen 2009), namely the higher elevations in the northwestern and southeastern mountain ranges. Ninety percent of Wyoming's runoff is snowmelt from these areas (Hays 2008). Wyoming is clearly a headwaters state, as its mountains form the headwaters of many major rivers, including the Snake-Columbia, Green-Colorado, Yellowstone-Missouri, and Platte systems (Gray and Andersen 2009). Consequently, water that originates within the state's political boundaries is allocated to downstream states, which means that Wyoming has important water-management responsibilities and also that water availability in this state has the potential to significantly impact other states.

Warming has shifted the periodicity and intensity of snowfall and subsequent runoff in much of North America (Mote et al. 2005, Regonda et al. 2005, Stewart et al. 2005, Wilcox 2010). April 1st snowpack in western watersheds has decreased between the middle of the 20th century and the end of the century (Joyce et al. 2007). The hydrological impacts of potential warmer surface temperatures and subsequently changing snow regimes in areas of high elevation are vast and may have countless secondary implications over time. Snowpack melt will occur earlier and, consequently spring runoff will come earlier and occur faster (Backlund et al. 2008, Wilcox 2010, Gray and Andersen 2009). As a result, late-season water flows will decrease (Joyce et al. 2007), which could exacerbate drought stress and contribute to increasing water temperatures (Wilcox 2010, The National Academies 2009). Overall warmer temperatures will likely lead to increased water loss due to evaporation and plant water use and decreased water yield to lakes, streams, and wetlands (Hoerling and Eischeid 2007).

Warmer winter temperatures might also cause seasonal precipitation to fall as rain instead of snow, subsequently decreasing annual snowpack and inhibiting the recharge of ground water reservoirs (Field et al. 2007). In the western mountain region of North America, the amount of annual precipitation in the form of rain that would normally fall as snow has been significantly increasing since the middle of the 20th century (Knowles et al. 2006), and spring and summer snow cover has been decreasing (Groisman et al. 2004). The West will become more vulnerable to shifts from snow to rain if winter temperatures continue to increase (Joyce et al. 2007). Warmer surface temperatures also will likely intensify drought events, much like those on historical record (Gray and Andersen 2009). Even a small increase in average temperatures with no decrease in annual precipitation would greatly impact Wyoming's water resources (Gray and Andersen 2009). The increase in water evaporation resulting from warmer temperatures would likely offset any increase in total precipitation (Joyce et al. 2000); it would also exacerbate the drought effects of decreasing amounts of total precipitation (Stonefelt et al. 2000, Pulwarty et al. 2005). In other words, conditions that currently define drought could become more of

the norm in a future climate for Wyoming (Hoerling and Eischeid 2007, Seager et al. 2007).

The Rocky Mountain West is the fastest growing region in the U.S. (Gray and Andersen 2009) (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision). Rapidly expanding urban populations pose another challenge for Wyoming as the state must share water with diverse and growing user groups, many of whom are located in downstream, out-of-state areas (Gray and Andersen 2009). The strain placed on already limited water resources by population growth and economic development could increase regional vulnerability to extended periods of drought as a result of allocating water beyond what is annually available (Pulwarty et al. 2005).

Water and drought are a challenge for Wyoming regardless of climate change. Future projections for the western U.S. depict an increasingly warm and consequently drier climate that would alter regional and local hydrology and further strain limited water resources. Wyoming's resource managers, who are already familiar with drought planning and allocating scarce water resources for multiple uses and users, will continue to deal with these challenges in perpetuity. Good water management and planning are strong policies for the state of Wyoming under any realistic climatic scenario, and current projections of a drier climate emphasize this point.

Potential Impacts of Climate Change on Terrestrial and Aquatic Species

Species have evolved according to certain regional and local climate norms and much of their individual phenology and range is directly influenced by climate (Walther et al. 2002, Parmesan and Yohe 2003, Root et al. 2003, Parmesan and Galbraith 2004). Species respond to environmental change based on habitat needs, competitive ability, and physiological tolerances (Manley 2008). Climate change has the potential to alter species' fundamental interactions with other species, organisms, and the physical environment, which could lead to a cascade of impacts throughout the entire ecosystem (The National Academies 2009). The effects of climate change will impact both Species of Greatest Conservation Need (SGCN) and species that are not classified in this category (non-SGCN), including many invertebrates, plants, fungi, and microbes that are typically not directly addressed by state agencies.

Phenology[1]

Many species operate on seasonal cues that are directly related to climate and so changes in climate may lead to shifts in the phenologic trends of some species, impacting breeding and migration patterns and the timing of germination or flowering of plants (Parmesan 2006, Root et al. 2003). The onset of spring, as measured by the timing of a variety of natural phenomena, has been occurring earlier since the 1960s (Walther et al. 2002), which in turn has been impacting some species' observable climate-sensitive behaviors such as breeding, hibernation, migration, productivity, and range (Joyce et al. 2007). Species movement patterns may change according to the duration of the seasons, food availability, and altered migratory routes (Backlund et al. 2008). Migratory species may begin arriving at seasonal and transitional feeding grounds earlier and leaving later in reaction to climate change, or continue arriving and leaving on time even though climate has altered the seasonal processes of stop-over and breeding grounds (Visser and Both 2005).

Not all species are expected to alter their behavior in response to changing climate factors in the same way or at the same rate (Visser and Both 2005, Visser et al. 2004), and there is no guarantee that species responses will be synchronized to the responses of their forage resources. Such mistiming could have significant impacts on the structure of the ecosystem and the relationships of the species within that system. Changing species relationships will have a more significant impact

[1] Phenology is the study of plant and animal life-cycle events that are influenced by variations in climate on an annual or interannual timescale. See Cayan et al. 2001 and Inouye et al. 2000 in the Literature Cited section for specific examples of studies that have documented phenologic changes in species in the western U.S.

on ecosystem structure and function than changes to any one particular species (Harrington et al. 1999, Visser and Both 2005).

Abundance and Biodiversity

The mistiming of specific species' behaviors and forage resources to climate change and subsequent impacts to species relationships such as competition and pollination could result in complex changes to population sizes and densities. For instance, population size may decline if breeding is mistimed with a seasonal food source that peaks at a different time than historically observed, but may increase if forage is available earlier and lasts longer. More directly, populations and species may be affected by changing climate extremes. Changes in species abundance can lead to shifts in community make-up, changing interactions among species and the environment, and the emergence of new, novel communities and species interactions (Walther et al. 2002). Overall biodiversity may be altered by changing climate conditions as some species manage to adapt, some species move, and some become extirpated or extinct.

Genetic Diversity and Morphology

Climate change may also impact genetic diversity and species' morphology (Root et al. 2003). Genetic diversity fluctuates with population size and connectivity, and for many species the transition to a warmer and drier environment will translate to a rapid fragmentation of suitable habitat. Habitat fragmentation and landscapes that are increasingly being altered by human activities severely hinder species mobility and dispersal capacity (Pitelka and The Plant Migration Working Group 1997). Furthermore, warmer and drier conditions may select for individuals with smaller body sizes or other morphological adaptations, eventually resulting in populations with substantially different physical or physiological characteristics than today (Koopman 2008, Root et al. 2003).

Range

Not all species have the same level of plasticity in the face of environmental change, and many may not evolve quickly enough to adapt to changing climate conditions in situ (Parmesan 2006). Some species may shift their range in order to track the physical and biological conditions to which they are already adapted (Root et al. 2003). Climate change may cause species' ranges to expand, contract, or fragment (Ruggiero et al. 2008, Koopman 2008). Warming temperatures are expected to result in a general movement of species' ranges up in both elevation and latitude as a result of physiological tolerances and/or specific habitat needs. Populations of species currently persisting only at high elevations may fragment, forming small isolated populations on mountaintop islands. For example, some low-elevation pika (Ochotona princeps) populations that have been studied in the Great Basin have reportedly gone extinct since the 1930s, while populations inhabiting higher elevations remain intact (Beever et al. 2003, Parmesan and Galbraith 2004).

Similarly, warming water temperatures may drive cold- and cool-water fish species to new ranges or lead to local extirpation or extinction, while high-elevation fisheries may become more productive as temperatures warm. Ranges of cold-water species may contract, while species that are tolerant of warmer water temperatures may continue to expand their range (Stefan et al. 2001). The range of some plant species may also be affected by climate change, and vegetation redistributions may occur as a result of climate factors such as temperature tolerances, water limitations, pollinator interactions, and seed dispersal ability.

Both native terrestrial and aquatic species may increasingly be impacted by nonnative species that cross political boundaries in an effort to disperse and capitalize on opportunities for range expansion resulting from the decline of native species (Walther et al. 2002). Invasive species may contribute to the loss of biodiversity, changes in the abundance and distribution of native species, and alteration of species community structure, and may even cause local population extinctions (Joyce et al. 2000) (see Wyoming Leading Wildlife

Conservation Challenges – Invasive Species). Some species will be successful in fulfilling habitat needs in more favorable climate and some, which are less mobile or adaptable, will not (Midgley et al. 2002).

Species with specific trophic relationships likely will not respond to climate changes in the same way or at the same rate, which may lead to local extirpations, extinctions, community breakdown, and structural reorganization (Root and Schneider 2002, Schmitz et al. 2003). Research indicates that species have responded to rapid climate change in the past, and some have already begun responding to the warming and other changing climate conditions that have occurred in the 20th century. Natural resource managers need to begin considering how both the direct and indirect effects of climate change may unfold across the landscape (Joyce et al. 2007). However, resource managers must also take into consideration a variety of non-climate drivers that impact species distribution (McWethy et al. 2010).

Other Stressors

Many of the potential effects of climate change on wildlife may occur as a result of the exacerbation of other challenges and stressors that affect species irrespective of climatic conditions. Other stressors include habitat fragmentation, loss, and disturbance; limited and declining quality of water resources; invasive species and disease; and declining species populations; among other things.

In particular, warmer surface temperatures could alter the survival and reproduction rates of some pathogens and vectors, which may currently be constrained by temperature minimums and maximums, potentially affecting the virulence and incidence of wildlife diseases like brucellosis, chronic wasting disease, whirling disease, West Nile virus, and bluetongue disease, as well as important plant pathogens such as white pine blister rust and mountain pine beetle.

Although all species will be affected by changing climate conditions, not all species will experience the same effects—some will benefit, while others will struggle. The species that may be at highest risk for dramatic impacts from climate change are those with limited ability to adapt. Species that are endemic to a particular area may be at greater risk than those that are geographically widespread. Similarly, species with an ability to move and adjust their range with changing conditions may have more success adapting than those that are unable to disperse or are relatively sedentary. Boreo-alpine taxa, which are already restricted to high elevations, will have limited options for population migration/dispersal as the climate warms and becomes more arid. Species that are habitat specialists or rely on specific interactions with other species, organisms, or physical aspects of the environment may be at greater risk of adverse effects of climate change than species that are more generalist in nature. Additionally, climate change has the potential to negatively impact species with low physiological tolerances to changing atmospheric, local weather, or environmental quality conditions. Finally, populations of species that have low genetic diversity or that have experienced recent or ongoing declines in population size may be more vulnerable to the effects of climate change than those species that have populations that are both rich and abundant (Midgley et al. 2002).

Potential Impacts of Climate Change on Habitat

Species survival depends largely on sufficient and healthy habitat; intact critical areas, such as breeding grounds or spawning beds; and connectivity among these areas (Joyce et al. 2000). Here again, non-climate stressors and natural ecological occurrences that are exacerbated by climate change may have the biggest impacts on habitat quantity and quality.

Terrestrial Habitat

The 11 terrestrial habitat types that are described in this SWAP include various types of forested land, shrublands, and grasslands; riparian areas and wetlands; and rocky areas with little vegetation (see Wyoming Habitat Descriptions – Terrestrial Habitat types).

Wyoming's diverse terrestrial habitats are home to SGCN and non-SGCN alike, and all are influenced by regional climate and will be affected in some way by changing climate conditions. The structural components of an ecosystem may be significantly altered by changing interactions among species, which can impact the quality and quantity of habitat. Natural landscape disturbances, which may be compounded by changing climate factors, will likely have profound effects on Wyoming's terrestrial habitat.

Wildfire is increasingly causing stress to mid-elevation forests as both the length of the fire season and the average area burned each year increases in the U.S. The length of the fire season has increased 78 days over the past 3 decades (Westerling et al. 2006), and is expected to grow by an additional 2–3 weeks by 2070 (Barnett et al. 2004). Over the past 20 years, the average area burned in the West has increased six-fold (Westerling et al. 2006). Climate is one factor among many that may influence the frequency and severity of wildfire (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes). Wildfire is a natural occurrence that regularly alters vast expanses of wildlife habitat. Coupled with the effects of climate change—namely warming temperatures, drought, and vegetation changes—wildfire may lead to more major ecosystem changes in the future. Water limitations resulting from the increased intensity of regional drought could hinder forest regeneration, causing meadow and grassland ecosystems to permanently replace current woodlands and forest (Joyce et al. 2007). Frequent fire also discourages the recovery of shrublands, and thus some of Wyoming's sagebrush habitat could be permanently converted to grassland (Bureau of Land Management undated).

Forests are natural water filters and flow regulators. The general loss of forested land predicted under a warmer and drier climate may compound water-quality issues and irregular hydrological flows, which are also being impacted more directly by rising surface temperatures. Overall declines in vegetative cover as a result of increased intensity and severity of wildfire may lead to further habitat alteration by damaging organic soils and causing increased soil erosion (Spigel and Robichaud 2007). Erosion can lead to increased runoff, sedimentation, and debris flow in streams and rivers, which can negatively impact aquatic habitat and associated species (Rieman and Clayton 1997, Dunham et al. 2003).
Periodic outbreaks of insects as a result of favorable climate or ecological conditions are a natural occurrence that may also be exacerbated by climate change. Perhaps the most widespread example of insect proliferation and outbreak is the ongoing pine bark beetle epidemic that is affecting vast tracts of forest throughout western North America (see Wyoming Habitat Descriptions – Montane and Subalpine Forests). Bark beetle outbreaks are a natural part of forest ecology; however, researchers suggest that warmer winters in recent decades coupled with drought have caused forests to become more susceptible to the prolonged and more intense epidemic that is currently occurring (Hicke et al. 2006, Romme et al. 2006). Warmer temperatures may be allowing for enhanced beetle population growth and range expansion to higher-elevation forests (Joyce et al. 2007). Large, contiguous tracts of dead and fallen trees as a result of beetle kill also create a greater risk for vast and frequent wildfire, as well as impacts on local and regional hydrology including changes in annual water yields, peak flows, and low flows. Research also suggests that the loss of large numbers of trees in concentrated areas impacts local weather and atmospheric conditions by causing changes in precipitation, temperature, and air quality, which may further impact wildlife by leading to more vegetative restructuring (ScienceDaily 2008). Wildlife managers may also encounter difficulty with maintaining hunter access to public lands resulting from increasingly hazardous forest conditions.

Climate change has the potential to intensify periodic drought. Prolonged and more severe drought will significantly alter terrestrial habitat, affecting a range of species that rely on these

habitats and associated resources. The combination of drought and increased evaporation from surface water and terrestrial ecosystems as a result of warming surface temperatures may have severe effects on wetlands and riparian areas. These areas could become increasingly sparse and/or less connected, or may dry up completely. Wetlands and riparian habitat are vitally important to aquatic and terrestrial species in Wyoming, providing both shelter and forage. A vast majority of species use these areas either daily or seasonally as part of their lifecycle, and many of Wyoming's bird species are wetland or riparian obligates (Nicholoff et al. 2003, Copeland et al. 2010). These habitats also serve as migration and dispersal corridors. The alteration of wetlands and riparian areas may also compound other hydrological effects of climate change by contributing to a decrease in surface water storage, less flood control, decreased filtration of sedimentation, and uncontrolled stream flow (Copeland et al. 2010), all of which impact the quality of species' habitat.

Long periods of drought may cause a decline in forested area as the land becomes too arid to support forest ecosystems (Joyce et al. 2007, The National Academies 2009), and may further increase the susceptibility of forests to insect epidemics (Logan et al. 2003). Decreasing soil moisture could also kill trees planted for shelterbelts and cottonwood galleries, both of which provide important habitat for numerous terrestrial species. Finally, drought may cause terrestrial habitat such as shrublands, sagebrush, and perennial grasses and forbs to decline due to water limitations (Bureau of Land Management undated). Such habitats may convert to other types or may simply become more barren of vegetation, consequently decreasing the forage value of the land, increasing susceptibility to the invasion of drought-tolerant species and wildfire, and leading to the decline of associated wildlife species.

As ecosystems and landscapes are altered by changing climate conditions and other disturbances, the opportunity for exotic and invasive species to establish populations in Wyoming may increase. Terrestrial habitat may be increasingly affected by invasive flora that can outcompete native flora in a warmer climate and in a landscape that is more frequently being disturbed by wildfire, insect outbreaks, and drought (Bureau of Land Management undated). Increasing amounts of valuable and structurally diverse habitat may be altered by invasive plant species, which in some cases may result in a naturally diverse mosaic of native communities being converted into a more monotypic habitat (see Wyoming Leading Wildlife Conservation Challenges – Invasive Species).

The viability of riparian areas, which are highly productive and provide critical habitat for species (see Wyoming Habitat Descriptions – Riparian Areas), is also being affected by invasive species such as Russian olive and tamarisk (Bureau of Land Management undated, Archer and Predick 2008, Wilcox 2010), and the impacts of these invasive species may be exacerbated by the effects of climate change (see Wyoming Leading Wildlife Conservation Challenges – Invasive Species). As changing climate conditions alter average seasonal temperatures and the hydrology of the West, riparian areas may become increasingly important as corridors for species movement to more suitable habitat, refuge, and also important areas for terrestrial grazers (Western Governors' Association 2008).

Aquatic Habitat

The State Wildlife Action Plan (SWAP) identifies six aquatic basins in Wyoming (see Wyoming Habitat Descriptions – Aquatic Basin types). The potential impacts of climate change on water resources in Wyoming may significantly affect aquatic habitats and, like terrestrial habitats, exacerbate existing stressors to these ecosystems and the species they support.

Climate change may significantly impact hydrology in terms of both water quality and quantity, which could have far reaching impacts on aquatic habitat and the species that rely on

that habitat. Warmer water temperatures resulting from increasing average surface temperatures decrease the oxygen saturation of the water and may negatively affect the viability of the habitat for some native aquatic species (Ficke et al. 2007, Western Governors' Association 2008). Increased air temperature, combined with changing atmospheric composition may also change water chemistry and the primary productivity of aquatic habitat (e.g., algal blooms).

Climate change has been causing mountain snowpack to melt earlier and run off faster in recent decades. Coupled with more severe storms in the future, this could cause more incidents of flooding (Backlund et al. 2008), especially when the previously discussed landscape changes are taken into consideration. Flooding has the potential to alter water quality by modifying aquatic root systems that filter sediments (Manci and Schneller-McDonald 1989), alter geomorphic features of streams and rivers, change riffle and pool distributions, and scour spawning beds (Joyce et al. 2007, Western Governors Association 2008). Decreasing late-season water flows resulting from early runoff and increased evaporation may cause the disappearance of isolated pools, contribute to warming water temperatures, and further lead to aquatic habitat fragmentation and fish mortality (Rahel et al. 1996, Field et al. 2007).

Wyoming's waters are already home to many nonnative species (e.g., walleye), some of which are deliberately promoted by managers, and waters are also threatened by the invasion of undesired species that are afflicting neighboring states (e.g., zebra and quagga mussels) (see Wyoming Wildlife Conservation Challenges – Invasive Species). As aquatic habitat continues to be altered by climate change and non-climate stressors, rivers, streams, lakes, and other bodies of water may become increasingly susceptible to invasive flora and fauna that are more tolerant of and/or adaptable to changes in water quality and quantity.

Climate Change and Uncertainty Regarding Impacts on Species and Species Interactions

The potential impacts of climate change on fish and wildlife and alterations to habitat in Wyoming are uncertain. While a high probability for change exists, the changes may play out in a variety of ways that, at times, will be unpredictable. Examining the ecological and biological impacts of long-term changing climate conditions may be confounded by the natural short-term and interdecadal cycles of changing trophic relationships (Schmitz et al. 2003). Peaks in the populations of some species and declines in others are often a natural part of the ecological narrative in relationships among species. Determining which changes are related to long-term climate trends may prove difficult depending on monitoring protocols and the availability of long-term data.

Modeling can be a useful tool to evaluate regional climate changes and to determine potential future critical habitat locations and species distributions that may result from climate changes. Regional climate modeling may help resource managers identify ecosystems at risk of transformative change. Bioclimatic models, also called envelope models or ecological niche models, may be used for predicting the future range and distribution of native and invasive species (Jeschke and Strayer 2008). Resource managers may be able to use these models to help target management strategies on focal areas where plant or animal species are most likely to survive in the future given climate constraints on the landscape (Bradley 2010). However, these models may also oversimplify estimates of suitable range and habitat by not accounting for non-climate drivers of species distribution, and so while these models may help paint a broad picture of future conditions, management actions should not be based solely on one model and should consider or address change at the appropriate level (e.g., regional or basin level, as opposed to sub-basin level).

Current Initiatives to Understand the Implications of Climate Change[2]

Strategies developed by government agencies and conservation organization to address climate change range from international monitoring and modeling efforts, to federal legislation, to efforts of national and regional conservation organizations, to state and local working groups holding public forums for discussion and completion of on-the-ground projects. The initiatives that follow do not constitute an all-inclusive list of climate change initiatives relevant to Wyoming, but are meant to paint a picture of the various agencies, organizations, and institutions that are providing leadership in the field of climate change science, mitigation, and adaptation.

International

The North American Regional Climate Change Assessment Program (NARCCAP) (http://www.narccap.ucar.edu/) is an international partnership using regional climate models (RCMs), atmosphere-ocean general circulation models (AOGCMs), and special report emissions scenarios (SRES) to generate future climate change scenarios for the purpose of analysis, impact studies, or further downscaling. The climate scenarios that are generated model historical climate trends (1971–2000) and project future climate trends (2041–2070) for the conterminous U.S., northern Mexico, and most of Canada. NARCCAP evaluates and estimates the uncertainty associated with the regional-scale climate change scenarios and aims to produce high-resolution (50 kilometers) climate change scenarios, which will aid resource managers in performing impact assessments on the resources that they are charged with protecting.

NatureServe (http://www.natureserve.org/) is a nonprofit conservation organization established in 1994 with guidance and resources from The Nature Conservancy. The organization is an association of natural heritage programs in the U.S., Canada, Latin America, and the Caribbean. These programs are widely drawn on by resource managers because they are the best source of information on rare and endangered species and sensitive ecosystems. The goal of NatureServe is to provide a clearinghouse for information on biodiversity that is easily accessible to resource managers and policymakers. NatureServe is responsible for the development of the Climate Change Vulnerability Index (CCVI), which is a tool that can be used to rank the level of vulnerability of individual species to climate change. The Wyoming Natural Diversity Database (WYNDD) is the state's natural heritage program, which is located at the University of Wyoming.

National

At the federal level, the U.S. Fish and Wildlife Service (USFWS) is at the forefront of developing strategies and evaluating the potential impacts of climate change on wildlife and habitat. In 2009, the USFWS released a revised draft of its strategic plan for responding to climate change (U.S. Fish and Wildlife Service 2009). The strategy emphasizes the need to move forward with decisive conservation action to address climate impacts despite the uncertainty that surrounds climate change in the future. The document is focused on three main strategies: adaptation, mitigation, and engaging partners. The USFWS also emphasizes landscape-scale approaches as part of the agency's National Fish and Wildlife Climate Adaptation Strategy (http://www.fws.gov/home/climatechange/). Twenty-one Landscape Conservation Cooperatives (LCCs) have formed that encompass all regions of the U.S. and some areas in Canada and Mexico. The purpose of the LCCs is to coordinate regional science and resources to address climate change and provide conservation delivery. Wyoming is divided unevenly by five LCCs, but the majority of the state's land area is covered by two cooperatives,

[2] The majority of the information in this section was obtained from the specific website of each initiative, unless otherwise noted.

the Plains and Prairie Potholes LCC and the Great Northern LCC.

The Department of the Interior (DOI) and the U.S. Fish and Wildlife Service administer funding to states to support the State Wildlife Grant program. States are strongly urged to use some of the funding to address climate change as part of their State Wildlife Action Plan (SWAP) and for projects that are aimed at mitigating the effects of climate change or that aid wildlife populations in adapting to changes.

The U.S. Geological Survey (USGS) established the National Climate Change and Wildlife Science Center (NCCWSC) (http://nccwsc.usgs.gov/) in response to the climate change science gaps that exist that may prohibit the development of sound management strategies for wildlife adaptation. Working with various partners at all levels, including eight regional Climate Science Centers (CSCs) established by the Department of the Interior, the NCCWSC will focus on using scientific data and modeling to make predictions about future species response to climate change and habitat and ecosystem changes that may occur. The CSCs will work in coordination with the Landscape Conservation Cooperatives (LCCs) to gather information and make resources and management tools accessible to resource managers. The USGS also supports research that explores ecosystem responses to climate change, including a project called Exploring Future Flora, Environments, and Climate through Simulations (EFFECTS).

In 1990, the U.S. Congress passed the Global Change Research Act (P.L. 101-606), which established the U.S. Global Change Research Program (USGCRP) (http://www.globalchange.gov/). The USGCRP is comprised of 13 federal departments and agencies and is charged with leading the nation in understanding global changes (e.g., climate, ozone, land cover) and making assessments and predictions to aid decision-making regarding the potential outcomes of these global changes. The USGCRP produces an annual report for Congress, *Our Changing Planet*, documenting its findings and recommending response actions.

The National Wildlife Federation (http://www.nwf.org/) and the National Fish Habitat Action Plan (http://fishhabitat.org/) are examples of wildlife conservation organizations and protection and restoration initiatives that are addressing the issue of climate change through research, mitigation, partnerships, and public education efforts. See Additional Resources within this section for more information on these organizations and relevant publications.

Regional

The Northern Rocky Mountain Science Center (NOROCK) (http://www.nrmsc.usgs.gov/) has stations located in western Montana and Wyoming. The goal of NOROCK scientists and staff is to research and disseminate information specific to species and ecosystems in the northern Rocky Mountain region to aid federal, state, and local resource managers in developing effective management strategies. One of the center's projects focuses on climate change in mountain ecosystems, including research on glaciers, snow and avalanches, and the structure and function of mountain ecosystems.

The Western Governors' Association (WGA) (http://www.westgov.org/) is a coalition of governors from 19 states and 3 U.S.-flag Pacific islands. The WGA focuses on issues that challenge western resources and economies. In addition to a policy resolution on climate change mitigation measures, the WGA has adopted a policy resolution that supports research into adaption measures. The association has developed a number of initiatives and internal working groups to address natural resource issues facing the West including water, forest and rangeland health, wildlife corridors, renewable energy, carbon sequestration, and alternative transportation fuels.

The Wildlife Conservation Society (http://www.wcs.org/), World Wildlife Fund

(http://www.worldwildlife.org/), and the Greater Yellowstone Coalition (http://www.greateryellowstone.org/) are organizations that have regional initiatives that are working to research and understand the impacts of climate change on wildlife, resources, and land management. See Additional Resources within this section for more information on these organizations and relevant publications.

State and Local

The Climate Issues Committee originated as the Governor's Drought Task Force in response to the drought conditions that were impacting Wyoming in 2000. The task force was dissolved and reformed as the Climate Issues Committee in 2008 and set to address broader climate-related issues that impact the state. The committee meets twice a year as appropriate, around April/May to assess the summer outlook and in November/December to recap what happened throughout the year. It is led jointly by the director of the Wyoming Department of Agriculture and the State Forester, and committee members include representatives from several state and federal agencies throughout Wyoming, representatives from the University of Wyoming, and also from the Wyoming Business Council and conservation districts.

In 2009, Governor Freudenthal signed legislation that created a legal framework for ownership and regulation of geologic carbon dioxide (CO2) storage in Wyoming. While the Wyoming Legislature has established that subsurface pore space is owned by the owner of the surface rights, under this legislation the liability and ownership of the stored CO2 belongs to the industry that injected it into the ground. Mineral rights supersede carbon sequestration rights. The pore space rights of multiple landowners are unitized or aggregated for the purpose of carbon sequestration projects, but only if at least 80% of the landowners are in agreement (Pew Center on Global Climate Change undated). The Wyoming Department of Environmental Quality is charged with long-term oversight of underground CO2 storage. This legislation facilitates the continued research and initiation of carbon sequestration projects in Wyoming, which could be a major aspect of future climate change mitigation efforts.

The Wyoming Landscape Conservation Initiative (WLCI) (http://www.wlci.gov/) is a collaborative, landscape-scale effort to conduct research to assess the state of wildlife habitat in southwest Wyoming and complete on-the-ground projects to work to improve habitat and to safeguard wildlife, including 5 species of big game and 151 non-game SGCN. The Green River Basin area is threatened by both energy and residential development, and the area supports not only wildlife and wildlife-migration corridors, but also domestic livestock and family livelihoods. The WLCI funded nearly 40 projects from 2007–2009, and nearly 20 new projects have been proposed for 2010. Projects focus on restoring biological and age-class diversity to terrestrial and aquatic habitats; vegetation monitoring and modeling, including projects to control invasive species; protecting migration corridors and restoring habitat connectivity; and working with landowners to create conservation easement agreements. The WLCI is also supporting projects that evaluate the potential effects of climate change on wildlife and habitat in the region. The majority of the initiative's funding comes from its permanent federal agency partners.

The University of Wyoming houses and supports many different research organizations whose research may directly or indirectly involve climate and the impacts of climate change. The Wyoming Cooperative Fish and Wildlife Research Unit (http://www.uwyo.edu/wycoopunit/) is a partnership between the U.S. Geological Survey, U.S. Fish and Wildlife Service, University of Wyoming, Wyoming Game and Fish Department, and the Wildlife Management Institute. The research unit is located at the University of Wyoming in the Zoology and Physiology Department. Recently, the research

unit has started to examine the past effects and potential future impacts of climate change on ungulates in the Rocky Mountain region.

The Water Resources Data System (WRDS) (http://www.wrds.uwyo.edu/) and the Wyoming State Climate Office (SCO) (http://www.wrds.uwyo.edu/sco/climate_office.html) provide Wyoming citizens, managers, and policymakers with comprehensive hydrological and climatological data from throughout the state. The offices are funded by the Wyoming Water Development Office and are located at the University of Wyoming. The WRDS and SCO compile information on hydrologic and climatic conditions from various resource managers and monitoring sources such as the Bureau of Reclamation and the National Weather Service, and develop the information into usable formats such as maps that depict climate trends over multiple decades. The offices are Wyoming's leading sources on drought information for the state, and the data products they develop help resource managers to identify climate trends and extremes.

Current Challenges for Effectively Managing Climate Change

Climate Change Certainties and Uncertainties

The study of climate over the past century has provided scientists with information about recent climate trends resulting from a combination of natural forces and anthropogenic influences. Studies indicate that Earth's surface temperatures gradually increase and decline over periods of time spanning hundreds of years as a result of solar activity, volcano eruptions, sea surface temperature, and pressure anomalies (McWethy et al. 2010). An examination of temperature records over the past two centuries demonstrates that surface temperatures generally have been increasing worldwide (Intergovernmental Panel on Climate Change 2007). Many uncertainties also exist with regard to the science of modeling and projecting future climate variability and associated ecosystem outcomes. However, uncertainty does not necessarily mean that historical observations and future projections are wrong or inaccurate, but they maybe qualified as inexact due to many uncontrollable variables.

The general scientific consensus on temperature change is that average global temperatures will continue to increase, as will temperatures in North America and the Rocky Mountain West, including Wyoming (Christensen et al. 2007). Temperature records over the past 100 years indicate that the West is already experiencing warming trends, particularly in winter and spring (Joyce et al. 2007). Recent research efforts have put forth a range of projections regarding temperature increases over various spatial (e.g., global, regional, national, statewide) and temporal (e.g., mid-century, late-century) scales, but the rate and magnitude of changes may depend on a suite of factors including global economic growth, adoption of climate change mitigation measures, and interactions between natural variability and the consequences of changing greenhouse gas concentrations.

Consensus on precipitation is more elusive than consensus on temperature. The IPCC projects that overall global precipitation will increase as a result of warmer ocean temperatures (Christensen et al. 2007). However, precipitation is not expected to increase everywhere: currently wet regions are expected to get wetter and dry areas drier. The western United States, including Wyoming, is likely to become drier (Backlund et al. 2008). The past 100 years of precipitation records do not demonstrate any definitive precipitation trends in the West but do indicate a high level of variability (Joyce et al. 2007). Additionally, certain climatic events are expected to intensify. Storms may become more severe with more precipitation in a shorter amount of time, and droughts may extend over longer periods of time much like the megadroughts identified in the historical record (Gray and Andersen 2009).

Climate and Ecosystems

The fact that climate affects biological systems is well established, but how rapid or transformative climate change will impact these systems is less certain. Climate may alter the physical structure of the ecosystem, which includes living organisms (i.e., aquatic and terrestrial wildlife) and non-living, chemical, and physical environmental attributes (Westerling et al. 2006, Rosenzweig et al. 2008). Climate change may also lead to changes in core ecosystem functions such as energy exchange, nutrient cycling, and primary productivity, which form the basis of the ecosystem services (e.g., clean air and water) on which human populations depend.

Large and rapid changes have the potential to place a greater amount of stress on components of the system than long-term gradual changes, which is a concern for many species and ecosystems (Schneider and Root 1998). "Abrupt" climate change is defined as a rapid change in climate over a relatively short period of time, which causes significant disturbance to ecosystems (U.S. Climate Change Science Program undated). Currently, the rate of change is likely a greater threat to ecosystem viability than the actual amount of projected change. Ecosystem change may occur in step-like transitions involving long periods of time with minimal change, followed by a relatively rapid development when conditions are right (Jackson et al. 2009, Gray et al. 2006, Lyford et al. 2003).

Climate may directly or indirectly impact ecosystem structure and function in many ways. Climate impacts average seasonal temperatures and temperature extremes. In turn, temperatures have profound effects on hydrology, including the spatial and temporal patterns of snowpack accumulation and ablation, runoff, water storage and recharge (e.g., glaciers and aquifers), evaporation, and soil moisture (Gray and Andersen 2009, Barnett et al. 2004, Christensen et al. 2007). Climate influences the frequency and intensity of disturbances such as drought, insect and disease outbreaks, storm severity, flash flooding, erosion, and wildfire, and may promote the establishment of invasive and/or exotic species in arid landscapes (Backlund et al. 2008). It may extend or curtail the growing season and impact primary production (Backlund et al. 2008). Climate influences plant and animal migration, distribution, and interaction patterns, and also the survival and proliferation of pathogens and parasites (Backlund et al. 2008, Harvell et al. 2002).

The physical manifestations of climate change have been observed and documented throughout the 20th century and up to present day (e.g., Parmesan 2006). Scientific records show that average global surface temperatures have risen by about 1˚F (0.6˚C), global sea levels by 15–20cm, and global overland precipitation by about 2% since the beginning of the 20th century (Backlund et al. 2008). Most of the continental United States experienced increased precipitation, stream flow, stream temperatures, and glacial retreat (Backlund et al. 2008, Wilcox 2010).

The ecological manifestations of climate change have been similarly documented. Increased vegetation growth, vegetation redistribution, and changes in flora phenologic trends have been observed (Backlund et al. 2008, Cayan et al. 2001). Net primary production (NPP) increased approximately 10% from 1982–1998 (Boisvenue and Running 2006). The advance of the spring season has caused earlier blooming and onset of spring greenness; warming temperatures, which are more pronounced at high elevations and latitudes, may be contributing to the infilling of sub-alpine conifers in alpine tundra; and increasingly limited water resources may be causing drought-tolerant vegetation to shift its range (Myneni et al. 2001, Lucht et al. 2002, Joyce et al. 2007). Changes in the migration and phenologic patterns of some terrestrial species and the displacement of native high-latitude species also have been observed (Walther et al. 2002). Research on the direct and indirect impacts of climate change will likely increase in the future as changes continue to materialize or become more apparent.

Climate change may present human populations and fish and wildlife populations with various tradeoffs. Seasonal changes, such as an earlier spring and a later fall, will increase the length of the growing season resulting in increased agricultural production and extended foraging time for wildlife. However, if warmer temperatures are not coupled with increased precipitation, summer and late-season drought stress will likely adversely impact primary production. Forage quality may be negatively impacted by changing CO2 concentrations (Joyce et al. 2000), and invasive species, which may be more tolerant of changing climate conditions (Joyce et al. 2007). Warmer and milder winters may entail less wildlife winter mortality, but increasingly severe storms, changing temperature extremes, wildfires, and drought may adversely affect reproduction and the survival of young. Climate change is not inherently good or bad, but it is a shift from a previously managed state or structural organization, which will entail tradeoffs, new management goals and strategies, and winners and losers.

As long as global surface temperatures continue to increase and precipitation patterns become more variable, biological systems will be in a constant state of transition. Consequently, using a historic range of variation, formally or informally, to guide future management strategies may be insufficient and even inappropriate for facing the additional challenges that rapid climate change will bring to wildlife and habitat management (Wiens and Bachelet 2009, Joyce et al. 2007). Using 100 years or less of past climate data to inform future management strategies does not capture the variability that long-term proxy data can depict (McWethy et al. 2010) and likely will not accurately account for the ecosystem changes that will occur as a result of recent and future climate change. Goals and conservation strategies may need to be redefined in order to address the needs of wildlife in transitioning systems.

Climate Modeling

Climate change is a global phenomenon driven by large-scale dynamics that affect weather and climate conditions at the regional and local levels (Wiens and Bachelet 2009). At present, General Circulation Models (GCMs) use simplified representations of Earth's oceans, atmosphere, and land surface, and the interactions among these units to help paint a broad picture of general climate patterns and trends and to make projections regarding future possibilities. GCMs can also be run under various assumptions about future greenhouse gas emission levels to output projections about future climate across a variety of social and economic scenarios.

Unlike efforts aimed at short-term weather forecasting, the goal of most GCM-based research is to understand general patterns of climate variability and climate averages. As such, GCMs perform reasonably well in recreating both historical climates seen in instrumental observations and paleoclimates preserved in various proxy archives (e.g., tree rings). This, in turn, generates reasonable confidence in future climate projections, with the major caveat that economic and social variables that relate to greenhouse gas production are highly uncertain (Gray, personal communication, July 9, 2010). However, the usefulness of GCMs in applications related to wildlife management can be greatly limited by their course-scale output and the fact that they do not fully account for topography and ecosystem boundaries that often impact regional and local climate (Barnett et al. 2004).

Based on their ability to reproduce paleo and historical patterns, as well as the underlying chemistry and physics of climate change, scientists have much more confidence in the ability to predict future temperatures than they do for precipitation (Gray, personal communication, July 9, 2010). However, difficulty may still arise when attempting to distinguish between variations associated with climate change and variations driven by forces such as the El Niño-Southern Oscillation (Wiens and Bachelet 2009). Despite the noted

uncertainties and shortcomings of climate modeling, the information produced by these models may be useful for predicting the potential vulnerability of an area to climate change, possible vegetation shifts, and future habitat suitability.

Given the uncertainty associated with global modeling, resource managers should avoid developing management strategies based on a single set of climate projections (Wiens and Bachelet 2009). Managers should instead take action by integrating a wide range of possible climate change scenarios into planning, conservation, and management efforts.

Recommended Conservation Actions

Introduction

Water management and drought are issues that Wyoming has dealt with in the recent past, as well as consistently throughout its history, and they will continue to be paramount as the climate changes, whatever direction the change may take. Although a lot of uncertainty surrounds the issue of climate change, in part because climate in the western U.S. is highly variable and spatially heterogeneous, the science, literature, and experience of resource managers generally confirms that changes are not always gradual and even small changes can have big impacts on the landscape and natural resources. Wildlife will continue to be confronted by a diversity of threats, many of which are influenced by climate and are likely to be exacerbated by rapidly changing climate conditions. While changing climate conditions may favor some highly adaptable and opportunistic species, the projections for this region, namely warmer and drier conditions, may lead to significant loss of abundance and diversity of native fish and terrestrial wildlife as habitat becomes more limited, fragmented, and affected by disturbances.

Currently, wildlife and habitat managers in Wyoming work within the bounds of existing policies and use conservation strategies to maintain healthy and diverse species populations and landscapes to support those species. The future management of individual species, communities, and ecosystems may require increasing flexibility given the uncertainty of future climate conditions and the rate at which conditions are predicted to continue to change. Dynamic and adaptive strategies developed by resource managers may more effectively manage systems in transition than strategies that aim to maintain a historical range of variation or that resist change altogether. Similarly, a proactive approach to anticipated climate variability may yield more successful results than management actions that are reactive responses to wildlife populations and habitat that already have been significantly impacted directly or indirectly by climate change.

Regional climate variables have long been factored into the management of aquatic and terrestrial wildlife populations and habitats. Understanding historic climate variability may help resource managers identify current climate-related changes and develop an idea of how individual species and communities may respond to future changes (McWethy et al. 2010). Incorporating considerations of climate change into WGFD planning does not alter the basic mission of the department or its core principles, nor does it require department wildlife and habitat managers to quantify climate change throughout Wyoming. Climate change consideration may simply require deliberate assessment of the role of climate in current activities and evaluation, and perhaps eventual re-prioritization, of the primary causes of wildlife population decline and fragmentation of Wyoming's native species and how best to maintain or restore healthy wildlife populations and landscapes. Although uncertainty remains with regard to future climate projections, just as there is uncertainty with any management-relevant variable, a growing scientific consensus suggests that the effects of heightened aridity, warmer temperatures, and overall more variable conditions should be considered by the WGFD, as these climate factors are important drivers of

future wildlife populations in Wyoming. Additional resources will be necessary to fully implement the recommendations and monitoring activities that follow, and they should be carried out or completed as resources allow.

Goals and Strategies

In light of the uncertainty regarding future climate conditions and the natural variability of climate in Wyoming, the overall goal of the WGFD is relatively simple and straightforward: continue to develop sound wildlife and habitat management policies and continue to employ sound wildlife and habitat conservation practices while evaluating a range of possibilities of future climate conditions and bringing climate into the planning and management processes as appropriate.

Projections of a warmer and drier climate in the western U.S. warrants the consideration of wildlife and habitat managers. Strategies that are practical across a range of possible future climate conditions will provide wildlife and habitat managers with the flexibility needed to adjust those strategies as appropriate and will not limit or inhibit future management options. Mitigating current threats to aquatic and terrestrial wildlife populations and habitat integrity, monitoring species and ecosystem health, and managing species populations, communities, and landscapes in accordance with what is known about natural disturbance regimes and ecosystem processes are good wildlife and habitat management strategies, as well as good climate change management strategies. Regardless of the accuracy of messages concerning climate change, it is important to maintain realistic and attainable management goals and objectives.

Scenario planning is a strategy that allows resource managers to evaluate current goals and objectives in light of climate change and to identify management actions that will address a range of issues facing aquatic and terrestrial wildlife populations.

Building scenarios involves the consideration of several likely directions and intensities of future climate change without requiring exact temperature and precipitation predictions. This type of planning acknowledges the uncertainty in climate projections and biotic response and provides resource managers a framework in which to better consider how various future climate conditions may impact the ecosystems, system components, and processes that they manage. Further, resource managers can evaluate how current goals may need to change and assess the future efficacy of current management strategies given a variety of climate scenarios. During a workshop on climate change organized by the WGFD in January 2010, participants were challenged to carry out a scenario planning exercise to evaluate the potential impacts of climate change on sagebrush ecosystems and the North Platte riverine ecosystem.

In addition to scenario planning, adaptive management techniques may help wildlife and habitat managers deal with the uncertainty surrounding future climate conditions.

Adaptive management involves the continual reevaluation through monitoring and improvement of management strategies as climate change plays out and causes sometimes predictable and sometimes unpredictable impacts on ecosystems and species communities. Managing for a historic range of variation and favoring the maintenance of native species populations and community structure may become increasingly costly and impractical in future climates. Both short-term and long-range management strategies will be necessary to deal with future climate variability. These strategies have usually guided by past experience and historical records. Given what is known about historical climate variation in the West and the future climate projections for this region, the coming decades may prove to be quite different than recent previous decades. Predictive models, flexibility, and adaptive management will be key to dealing with this

uncertainty, as will a policy-making and management environment that supports creativity and moderate risk-taking. The use of historical records and trends may no longer be sufficient for developing future management strategies.

Wildlife and habitat managers will likely pursue a combination of mitigation and adaptation measures as they employ strategies to maintain the health of aquatic and terrestrial flora and fauna and the integrity of the Wyoming landscapes that support these species.
Mitigation strategies involve actions that lessen the input of greenhouse gases into the atmosphere and are more likely to develop as state-level policy. Adaptation strategies, on the other hand, are not meant to resist inevitable changes or slow their occurrence, but are measures adopted to build the capacity of a species or ecosystem to deal with the impacts of climate change while maintaining stability and ultimately adapting and thriving under new conditions. An adaptation strategy may involve enhancing the quality, quantity, and connectivity of wildlife habitat so that wildlife populations are able to adjust their range according to physiological tolerances to changing climate conditions. Building and maintaining ecosystem health in order to accommodate change as opposed to resisting it is fast becoming the preferred method for wildlife management in the face of climate change.

Recommendations – General

Pursue financial, technical, and human resources to develop and implement a structure to coordinate the incorporation of climate change into WGFD activities at the agency level.
The WGFD will need a coordinated approach in order for climate change considerations to be effectively incorporated into WGFD planning and monitoring, and also to aid the timely development and implementation of projects and strategies addressing the impacts of changing climate conditions. This will require the WGFD to have increased authority, staff, and technical and financial resources.

A point person from within the department would serve as a contact for communication with federal resource management agencies and the public, and would also aid with the intra-agency dissemination of information regarding climate change and the coordination of all other climate change-related efforts.

Evaluate the potential impacts of climate change on Wyoming's key ecosystems, ecosystem components, ecosystem processes, WGFD management goals, strategies, and major challenges as an ongoing strategy.
One of the first steps to integrating climate change into planning, management, and monitoring efforts involves evaluating current goals and objectives and viewing current management challenges through a climate change lens. Understanding how climate change may impact key ecosystem components (i.e., species and habitat features) and processes that are essential to attaining management goals for SGCN, non-SGCN, and associated habitats is an important primary consideration and action that should be given serious attention by wildlife and habitat managers. Given the uncertainty about the exact changes of future temperature and precipitation, but with knowledge about the general trajectory that future climate may follow according to various climate models (i.e., warmer, drier, more variable), this challenge may be aided by the scenario building approach.

In 2010, WGFD organized a workshop to begin to evaluate the potential impacts of climate change on sagebrush and riverine ecosystems using a scenario building approach. Wildlife and habitat managers should expand on this effort and use existing knowledge about key terrestrial and aquatic ecosystems and wildlife to begin an informal scenario building process to gain increasing understanding about the influence of climate on wildlife and habitat management, and also how current goals, strategies, and challenges may be affected by

changing climate. The impacts of several climate scenarios (e.g., current/historical, warmer with more seasonal precipitation, warmer with no change in seasonal precipitation, and warmer with a decrease in seasonal precipitation) on the specific habitat types outlined in the SWAP (e.g., sagebrush, riparian, etc.,), game species, SGCN, and ecosystem processes (e.g., periodic wildfire or grazing regimes) should be evaluated as an ongoing effort.

As wildlife and habitat managers begin to consider the potential impacts of climate change on the species and landscapes that they manage, it will be necessary to periodically evaluate the actual impacts of climate conditions on current management goals and strategies. The efficacy of some management techniques and the practicality/cost of some management goals may change with changing climate conditions. WGFD should take the appropriate steps to consider these impacts.

Identify and prioritize implementation actions that will benefit management targets by addressing a range of stressors given various future climate scenarios as an ongoing strategy.
After the potential impacts of several scenarios have been assessed and current management challenges considered in light of climate change, a range of no regret actions may be identified that address multiple issues and management challenges relating to both species and habitat. The desired outcome of the WGFD 2010 workshop on climate change was to develop a range of possible strategies to address the potential impacts of various climate scenarios on sagebrush and riverine ecosystems. Adaptive management techniques supported by internal policies that encourage creativity and moderate risk-taking may aid wildlife and habitat managers in developing and implementing strategies that safeguard these resources against multiple stressors.

Partner with other agencies and organizations, and support initiatives related to climate change and wildlife and habitat management as an ongoing strategy.
Engaging in a variety of partnerships is an effective means of cost-sharing, compensating for limited human and technical resources, and avoiding the duplication of effort. Statewide and regional interagency collaboration will facilitate information sharing, the assignment of appropriate roles to partner agencies, the request of appropriate data products from partner agencies, and the more efficient allocation of scarce resources for wildlife and landscape conservation. Additionally, partnerships may offer funding opportunities for climate-related research, mitigation, and adaptation projects. Coordinating efforts with federal, state, local, and non-profit partners should be an ongoing priority when dealing with climate issues.

WGFD should continue to participate in regional partnerships such as Landscape Conservation Cooperatives, continue to work with conservation organizations to achieve wildlife and habitat management goals, stay informed about state and local efforts related to climate change and support these efforts with technical or financial assistance when appropriate (e.g., WLCI, see section on Current Efforts), and identify sources of funding for climate-related research and projects.

Offer additional education opportunities for WGFD employees about climate change issues pertaining to wildlife and habitat management in Wyoming as an ongoing strategy.
The development of appropriate goals and the implementation of timely and successful strategies will require that agency employees are well-informed on how to integrate climate change into monitoring, planning, and management within the context of their current jobs. A point person for the dissemination of information may be beneficial for this purpose (see recommendation under Evaluating/Monitoring Success). Fostering an environment of increased awareness about climate and wildlife/landscape-related issues through individual and group education

opportunities is important. WGFD has organized climate change workshops in the past and should continue to organize workshops to discuss future climate projections and to specifically aid employees with the scenario building process, the enhancement of existing data-gathering programs to account for climate factors, and the development of adaptive management techniques.

Disseminate information to the public about climate change issues pertaining to wildlife and habitat management in Wyoming.
Hunters, anglers, and wildlife viewers are important stakeholder groups within the state. The dissemination of information to the public regarding the observed and future potential impacts of climate change on wildlife and habitat in Wyoming will be necessary. The use of existing forms of media provides an opportunity to convey climate-related issues to Wyomingites and to gain public feedback on proposed mitigation and adaptation measures. WGFD should consider using Wyoming Wildlife magazine and existing newsletters as forums for discussing appropriate and timely climate-related issues. Additionally, WGFD should consider developing future climate change workshops for public attendance and participation, and relate the topic of climate change to current and accepted wildlife management issues.

Work with regional organizations to evaluate existing laws and regulations and make recommendations in light of climate change as a long-term consideration.
Existing regulations and policies may need to be reexamined and/or modified to safeguard wildlife and habitat and to support reasonable conservation expectations as changes in climate occur. Dealing with certain laws will be a challenge if species become increasingly threatened by climate change and variability. Much like the development of strategies, policies should be flexible and should be revisited or revised more often to assess the need for changes and to avoid the use of scarce resources on hopeless causes. Timely recommendations on policy adjustments to either mitigate the effects of climate change or aid climate change adaptation should be welcomed and given due consideration. WGFD should work with regional organizations such as the Western Governors' Association and the Association of Fish and Wildlife Agencies to identify and recommend needed statutory and regulatory changes at the state and federal levels.

Recommendations – Species Management

Wildlife managers should continue to focus on good wildlife management techniques, including reducing non-climate stressors and promoting biological and genetic diversity.
Continuing to enhance efforts to minimize the impacts of non-climate stressors and continuing to manage for species and genetic diversity will help safeguard individual species populations and species communities from any current or future threats (e.g., development pressures, natural disturbances, climate change) by increasing species' ability to adapt to environmental changes. WGFD should continue management practices that balance the abundance of wildlife populations with the carrying capacity of the land (e.g., big game management using harvest quotas), while also focusing on biodiversity (e.g., SGCN), and use existing knowledge about non-climate stressors affecting aquatic and terrestrial species to continue to enhance strategies to address these wildlife stressors (e.g., Aquatic Invasive Species program and initiatives to control invasive terrestrial flora).

Wildlife managers should build an understanding of past responses to climate change and climate as a driver of species behavior, range, and distribution.
Climate change and variability impacts species individually and may result in previously unforeseen vulnerabilities on Wyoming's wildlife. Climate change may have significant ecological and economic effects, including impacting hunter and angler recruitment and retention, causing the decline of SGCN, and

leading to the establishment and continued proliferation of populations of nonnative species in the state.

Understanding how species have responded to stresses and disturbances in the past may provide wildlife managers with important insight about how species may respond in the future to climate change and stressors that are expected to be compounded by climate change. The use of existing research, literature, and experience, as well as utilizing historical data sets compiled by the USA National Phenology Network (http://www.usanpn.org/), may aid wildlife managers in building an understanding of climate as a driver of species behavior, range, and distribution. Although uncertainty exists, the use of historical climate data, available through the Wyoming State Climate Office, in conjunction with long-term data sets documenting species behavior or characteristics may contribute to this understanding. Wildlife and habitat managers should identify research and information needs and develop strategies to bridge knowledge gaps regarding the relationship of individual species and climate.

Assess the vulnerability of SGCN to climate change and evaluate the impacts of climate on select species.
Conducting species vulnerability assessments to determine which species are at high, medium, and low risk of being impacted by climate change should be considered before the next revision of the SWAP. A comprehensive climate change vulnerability assessment that is external to the Native Species Status matrix but could be incorporated into it will help wildlife managers evaluate the relative sensitivity, level of exposure, and adaptive capacity of the species that they manage. Managers may also be able to identify species with certain patterns of habitat use (e.g., sagebrush obligate species) and specific taxa that are at highest risk, which may aid future mitigation or adaptation efforts. WGFD should consider using the Climate Change Vulnerability Index (CCVI) developed by NatureServe (see section on Current Efforts) as a means to evaluate the vulnerability of Wyoming's SGCN. Furthermore, WGFD should determine who needs to be involved in the vulnerability assessment process for the results to be accepted as credible. An interim publication may be considered to distribute the results of the CCVI before the next revision of the SWAP.

WGFD should take necessary steps to evaluate the observable and realized effects of climate conditions and climate-related disturbances on wildlife. WGFD should consider SGCN as well as recreational and economically important species. However, the department should begin by using the CCVI to select a few SGCN that are ranked as having high vulnerability to climate change, and evaluate the impacts of climate conditions on these species at regular intervals before the next revision of the SWAP. The evaluation of all other species may be a long-term consideration as resources allow, or taken up on a species-by-species basis in the case of a status change that warrants additional attention. Existing wildlife monitoring programs that may already be tracking changes in species health and behavior should be identified and utilized (e.g., USA National Phenology Network), and WGFD should continue to execute or participate in wildlife surveys to specifically monitor population dynamics.

Evaluate the feasibility of developing approaches to model future species distribution based on multiple drivers, including climate change. Build databases and produce maps depicting future species distribution including climate as a driver as a long-term consideration.
The SWAP includes current distribution maps for SGCN. Consideration should be given to developing maps of the potential future distribution of both SGCN and non-SGCN species based on key drivers of distribution, including climate factors. Evaluating the feasibility of using current species distribution maps to model the future distribution of species is a first step to understanding the potential impacts of climate change on individual species. Additional baseline information may be needed to produce maps that accurately depict future

species distribution contingent upon multiple drivers, and knowledge gaps should be filled through continued research efforts or by obtaining data from the appropriate sources. Wildlife managers should identify the key drivers of SGCN and non-SGCN distribution and assess the feasibility and the quality and completeness of data for mapping the future distribution of SGCN and non-SGCN as a goal before the next revision of the SWAP. Producing maps for species with sufficient data and clear drivers of distribution may be a long-term consideration.

Downscaled climate data and finer-scale climate models may be necessary to make appropriate species management decisions in the future, and the availability of this data should be evaluated.
Modeling future species distributions and developing a clearer understanding about future climate scenarios across Wyoming will require more precise information about temperature and precipitation predictions. Through regional partnerships involving scientist and organization that are working on downscaling climate date to a relevant level for wildlife managers, asses the availability and quality of downscaled climate models for Wyoming and identify information gaps to guide development of finer scale models.

Assess the impacts of climate on disease dynamics. Incorporate this information in ongoing disease monitoring, and enhance disease distribution mapping, both current and projected
WGFD currently tracks and monitors diseases that are specific to certain species or populations, and is updating a wildlife disease manual that describes diseases that affect species in Wyoming. Additional research on the influence of climate factors on disease incidence and/or prevalence would complement existing knowledge and may benefit wildlife managers in the future by allowing them to establish a network of early detection sites where future cases of disease are likely to emerge given climate conditions and other factors. WGFD should continue to support research efforts to establish links between climate factors and the ecology of both aquatic and terrestrial wildlife diseases, including pathogens, vectors, and hosts. WGFD should also work with other agencies to understand the links between climate and mountain pine beetle, as the drastic alteration of Wyoming's conifer forests or precautionary closure of public lands will have significant implications for future wildlife and habitat management. WGFD should enhance wildlife disease monitoring efforts to describe the current distribution of diseases and predict potential future distribution or locations conducive to outbreaks based on known drivers as a long-term consideration.

Recommendations – Habitat Management

Habitat managers should continue to focus on sound conservation, restoration, and management practices as outlined in the WGFD Strategic Habitat Plan, which will help maintain the integrity of ecosystem structure and function in the face of many ecosystem stressors, including climate change.
Continuing to implement good aquatic and terrestrial habitat management practices will help maintain regular hydrological flows by regulating peak flows, increasing terrestrial water storage, and controlling late-season flows. WGFD should utilize existing data systems and tools to identify natural watershed storage features to aid in land management decision-making and continue to develop and execute wetland and riparian restoration projects, which will increase the distribution and function of the quantity of stored water.

Ecosystem restoration, or on a smaller scale habitat restoration, may be considered both a mitigation and adaptation strategy as intact systems store more CO2 and positively feed into species health and biodiversity. Habitat managers may want to consider emphasizing ecosystem function and diversity over the maintenance of specific communities of species as climate change may cause managing for historic conditions to become increasingly

costly, challenging, and impractical. WGFD should continue to work with private landowners, government agencies, and conservation organizations to manage landscapes to meet the needs of wildlife and to address access issues, and continue to support conservation programs, such as NRCS habitat extension programs, that aid landowners with the restoration and long-term protection of natural ecosystems.

Promote connectivity as outlined in the Strategic Habitat Plan as an ongoing strategy, and undertake additional mapping efforts that depict critical areas of wildlife movement, transition, and refuge as an ongoing strategy.
Increasing the overall amount and connectivity of habitat, including migration corridors, transitional areas, and refugia, is a strategy that will build ecosystem health and species resilience to a variety of stressors. Porous landscapes, or those that are easily traversed by fish and terrestrial wildlife, will allow some species to adjust to changing environmental conditions through population movement. Riparian areas may become particularly important as wildlife movement corridors and may require special focus. WGFD should continue to work with private landowners, government agencies, and conservation organizations to restore and maintain habitat connectivity and to connect core conservation areas by encouraging the development of solutions to help wildlife bypass obstructions, such as wildlife-friendly fencing and highway underpasses for terrestrial species and channels for aquatic species to move around waterway obstructions. WGFD should also continue to build the fish passage database to catalogue obstructions on Wyoming waters.

WGFD should use existing knowledge to map and prioritize wildlife corridors, transitional grounds, and refugia as an ongoing strategy to aid future management and land conservation efforts under changing climate conditions

Consideration should be given to conducting habitat vulnerability assessments as an ongoing strategy.
As with species management, the consideration of climate factors in habitat management may require additional research and data gathering to fill knowledge gaps. The identification of terrestrial and aquatic areas that may become priority areas for management in the future will require the evaluation of the potential impacts of climate factors and other stressors on habitat types and focal areas. Conducting vulnerability assessments on habitat may be equally as important as species vulnerability assessments. WGFD should assess and rank the vulnerability of focal areas to threats from energy development (including renewable energy development and carbon sequestration projects), rural subdivision, climate change, invasive species, and the disruption of natural disturbance regimes. Consideration should also be given to evaluating the potential impacts of climate change on what are currently defined as "crucial areas" and "enhancement areas" in the Strategic Habitat Plan.

WGFD should also begin to evaluate the observable and realized impacts of climate and climate-related disturbances on habitat using the 11 terrestrial habitat types and 6 aquatic basins that are described in the SWAP as units to compile and assess this information. Existing monitoring programs that are already tracking climate-driven landscape/hydrologic changes (e.g., USGS Streamgage Program) should be identified and utilized. WGFD should continue current habitat monitoring programs with consideration of the addition of a climate component to begin tracking the impacts of climate-related factors on management targets (e.g., monitoring water temperature changes in trout habitat). WGFD may consider doing a thorough analysis of the impacts of climate conditions on select habitat types as a long-term consideration.

Evaluating/monitoring Success

After wildlife and habitat managers have developed an idea of how climate change may affect the species and landscapes that they manage and have ranked the relative vulnerability of species and/or habitats, incorporating the predicted impacts into species and land management plans will be the next step. Modifying existing protocols or developing new protocols and enhancing existing programs for monitoring the impacts of climate change on wildlife and ecosystems requires wildlife and habitat managers to determine what to monitor and to identify indicators of climate-driven change or early warning signs of climate-related stress.

WGFD should identify species and climate-driven behaviors that may provide an early indication of climate-related environmental change. For instance, species that are particularly susceptible to hydrological changes or species that have observable phenology such as migration and breeding patterns may provide wildlife managers with indicators of ecosystem change resulting from changing climate conditions from which they can begin to anticipate other changes or start to re-evaluate management goals and strategies. Similarly, WGFD should identify and monitor climate-driven landscape changes that may impact the efficacy of current management strategies and provide insight on potential future conditions.

Develop standard monitoring protocols.
In order to effectively monitor the impacts of current and future climate conditions on wildlife and landscapes, the WGFD may need to modify existing protocols or develop new protocols to capture specific climate-related information that will be valuable for the future development of mitigation and/or adaptation strategies for wildlife and habitat. Standardizing these monitoring protocols across the WGFD should be an ongoing effort, and the department may want to consider investigating methods and assessment tools that have been developed and successfully implemented by other states or regular partner agencies/organizations. Factors that should be assessed in terms of climate trends and local impacts include habitat, physiology, phenology, and species interactions.

Establish a reasonable planning timeline as part of a long-term strategy.
It is not practical to carry out all strategies and recommendations at once. WGFD will need to determine which actions are feasible now and which should be done in the future—and at what point in the future. A reasonable planning timeline will be key to the successful evaluation of the impacts of climate on species, ecosystems, and processes, as well as the implementation of timely mitigation and adaptation strategies. WGFD should develop a planning timeline for developing and implementing new climate monitoring protocols and programs for the most sensitive species and the most vulnerable landscapes.

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Additional Resources

Assessments and Publications

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Beyond Seasons' End: A Path Forward for Fish and Wildlife in the Era of Climate Change. A collaboration of Ducks Unlimited, Trout Unlimited, BASS/ESPN Outdoors, Izaak Walton League of America, Association of Fish & Wildlife Agencies, Coastal Conservation Association, American Sportfishing Association, Pheasants Forever, and Boone and Crockett Club. Published by the Bipartisan Policy Center, 2009.

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Voluntary Guidance for States to Incorporate Climate Change into State Wildlife Action Plans & Other Management Plans. A collaboration of the Association of Fish & Wildlife Agencies and Teaming with Wildlife, 2009.

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National Fish Habitat Action Plan
http://fishhabitat.org/

Western Native Trout Initiative
http://westernnativetrout.org/

Desert Fish Habitat Partnership
http://www.nature.nps.gov/water/DFH_partnership.cfm

Great Plains Fish Habitat Partnership
http://www.prairiefish.org/

NatureServe
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World Wildlife Fund
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http://www.worldwildlife.org/what/wherewework/ngp/index.html

Wyoming Game and Fish Department Climate Change Workshop
http://gfi.state.wy.us/ClimateChangeWS/index.asp

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Disruption of Historic Disturbance Regimes

Photos courtesy of WGFD

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Background

A disturbance is any event or series of events that alters ecosystems by affecting functions or processes, habitats, animal populations or their physical environments, by either natural or human causes. Disturbances are natural components of virtually all ecosystems and can include fires, floods, droughts, storms, herbivory, and disease outbreaks. Humans are significant agents of habitat disturbance, and examples of human-induced disturbances range from pre-European settlement fires set by Native Americans to improve game habitat to modern-day mechanized logging and crop cultivation. Some human activities can mimic natural disturbances and are important in maintaining or enhancing wildlife diversity, while others can degrade habitat and may even lead to species extinctions.

A disturbance regime is distinguished from a single disturbance event by describing a pattern, frequency, and intensity of disturbances across the landscape or watershed. For terrestrial ecosystems, variations in these factors, along with changes in soil and topography as well as competitive interactions among plants, typically result in patches of vegetation in various stages of disturbance and recovery. Patches can be distinguished from each other by the height and structure of individual plants as well as the composition of plant species, both of which change over time as regeneration progresses. "Patch dynamics" and "shifting mosaic steady-state" are concepts used to describe this dynamic. The attributes of various disturbance regimes vary with the natural communities in which they occur.

Disturbances can act both singly and in concert with multiple other disturbances to determine plant and animal communities. The number and type of disturbances can change over time. Maintaining wildlife diversity as well as habitat for individual species often depends on the availability of a patchwork of cover and habitat types throughout the landscape. In addition to wildlife habitat and plant regeneration, periodic disturbances are essential to maintaining the productivity of an ecosystem and its capacity to produce clean air and water through facilitating nutrient cycling.

The loss of "historic"[1] disturbances as well as interactions within and between various types of disturbances and associated habitats is a significant cause for the decline and extinction of many wildlife species. Flow alteration is the leading cause for reductions in native plant and animals populations in rivers worldwide (Poff et al. 1999). In the Rocky Mountain West, fire suppression and altered grazing patterns by wild and domestic ungulates have contributed to declines in aspen (Nicholoff 2003). In Wyoming, it is estimated that over half of the recent historic aspen acreage has converted to other community types (Nicholoff 2003). Aspen stands are second only to riparian areas in biodiversity (Kay 1998).

Disturbances such as fire, floods, and insect outbreaks can be detrimental to human health or destructive to human property. There have been efforts to limit natural fluctuations in abundance associated with disturbance cycles in favor of achieving consistent, sustained yields for plants and animals which have high economic or social values such as timber, livestock forage plants, and game animals. Disturbance regimes under which many native habitats and wildlife evolved may be lost, altered, or no longer possible as natural habitats become increasingly fragmented and modified through human development. Additionally, climate change will likely further alter the frequency, type, and intensity of disturbances as well as the local composition of plants and animals responding to these events.

[1] "Historic" disturbance regime refers to environmental disturbances under which native species and habitats evolved. This term has been selected as opposed to "natural" disturbance regime since it is often not possible, or meaningful, to segregate the influence of pre-Columbian human-induced disturbances caused by Native Americans, such as fires intentionally lit to improve game habitat, from those caused by natural sources, such as lightning strikes.

The role of historic disturbances in maintaining native species and habitats has only recently become known and appreciated by habitat managers. In order to conserve native species and habitats, more effort is being placed on retaining historic disturbances where possible or mimicking their effects by active management where not. While Wyoming habitats are influenced by a diversity of historic disturbances, alterations to historic stream flow, fire, and herbivory regimes are considered the most significant and will be the focus of this chapter.

Scope and Challenges of Integrating Historic Disturbance Regimes into Wildlife Conservation

Disruption of Water Flow Regimes

Variation within and between seasons in the timing, duration, frequency, and magnitude of water flows are typical for rivers and streams in Wyoming. Seasonal spring floods move water and sediment through channels and onto floodplains, depositing or exposing alluvial soils necessary for the establishment of cottonwoods, willows, and other riparian plants (Friedman et al. 1997). High water flows move fine sediments and maintain gravel and cobble habitats, which support diverse aquatic insect communities and fish spawning sites. Spring runoff and high water events also bring woody material into stream channels, providing structure and food for aquatic species. Other important habitat features, such as cobble bars and scour-pools, are also formed and maintained by high flushing and channel-forming flows. The timing of high water events is important to the lifecycles of many aquatic and riparian species. For example, the seed release of riparian trees such as willows and cottonwoods is synchronized with the timing of spring flood recession to maximize dispersal efficiency and germination (Natural Resources Conservation Service 2006).

Natural flow regimes in many stream segments around the state have been severely altered by a number of human activities including irrigation diversions, hydroelectricity, waste disposal, and flood control. In the United States, only 2% of rivers remain in their natural, unmodified condition (Graf 1993). In Wyoming, the disruption of flow regimes is often a consequence of broad-scale changes in land use and management such as agriculture, grazing, timber harvest, and housing development. These activities can affect the amount and type of streamside vegetation and the quantity and rate at which precipitation flows over and through the land to streams and lakes, altering both ground water cycles and surface flow regimes.

Such flow regime changes can affect plants and animals by altering water quality (e.g., increasing sediment, organic material, and pollutants, raising water temperatures, and reducing dissolved oxygen) and changing physical stream characteristics. Secondary effects can include altered species interactions (e.g., a shift in competitive advantage for one species), increased disease transmission, and accelerated exotic species invasion. Communities may also be negatively impacted by flow alterations from land-use changes by ground water depletions, declines in water quality and flow availability, and more frequent and intense flooding (Natural Resources Conservation Service 2006).

Wyoming is an arid state, and considerable development of dams and water diversions has occurred to control, store, and deliver water, as well as to produce hydroelectric power. There are approximately 1,530 permitted dams in Wyoming which are subject to regulation under Wyoming Safety of Dams Statutes (W.S. 41-3-307 through 41-3-318)[2] and many smaller dams that are not subject to state or federal Safety of Dams regulations. Most of the dams in the

[2] Section 41-3-307 defines the term dam as any artificial barrier, including appurtenant works, used to impound or divert water and which is or will be greater than twenty (20) feet in height or with an impounding capacity of fifty (50) acre-feet or greater. Dams with less than 15 acre-feet capacity regardless of height, or 6 feet or less in height regardless of capacity, are excluded provided that there are no habitable buildings immediately downstream.

state were constructed to provide water for irrigation, enhance the availability of domestic water supplies, reduce the risk of flooding, and provide new boating and fishing opportunities on manmade reservoirs.

While water development can threaten native species, some coldwater fish species, such as trout, and warmwater species, such as walleye, have benefited from dam construction. The simplification of natural systems by human development tends to favor species with generalized and broad habitat requirements. For example, the walleye fisheries in the North Platte River reservoirs and Boysen Reservoir depend on the consistent deep water and forage production inherent in these man-made water bodies. Stable stream flow releases from dams, with relatively low peak flows and relatively high base flows, perpetuate productive sport fisheries. The famous "Miracle Mile" trout fishery below Kortes Dam and the "Grey Reef" fishery below Alcova Dam are examples.

Alternatively, dams and water diversions typically result in major alterations to natural flow regimes that negatively impact many species (Annear et al. 2004). Most notably, dams reduce peak flows commonly associated with spring runoff and change the quantity, timing, and consistency of base flows. The loss of high spring flushing flows on dammed rivers greatly reduces the natural cycle of sediment transport and deposition. Depending on a variety of factors, releases from dams can accelerate down-cutting of stream channels to the extent that side channels and shallow water habitats are depleted or eliminated. In other situations, releases can lead to the armoring of the stream channel by removing most of the fine materials from the streambed and leaving an almost impervious surface with diminished value for aquatic insects and fish. These and other changes in channel geomorphology also favor the replacement of native cottonwoods and willows, which are dependent upon seasonal flooding for seedling establishment, by Russian olive and tamarisk (commonly referred to as saltcedar), which are exotic invasive species. Reduction in the size and structural complexity of cottonwood stands, through lack of tree regeneration, has been associated with declines in riparian bird species diversity (Slater 2006). In Wyoming, cottonwood declines have been linked to flow alterations on the North Platte (Miller et al. 1995) and Bighorn Rivers (Akashi 1988, Bray 1996).

Dams and water diversions can also significantly limit connectivity in stream habitat and prevent seasonal migrations of aquatic species. Dams are a leading cause in the reduction of range-wide sauger numbers and significantly contributed to their extirpation from the North Platte River drainage in Wyoming (Nelson and Walburg 1977, Hesse 1994, Pegg et al. 1996, 1997, Maceina et al. 1998, McMahon and Gardner 2001). Dams and diversion structures have also isolated several Colorado cutthroat trout populations in headwater tributaries within the Little Snake River watershed (Cook 2009).

Reduction in the number and distribution of beaver is another major contributor to altered stream flows. Similar to man-made dams, beaver ponds accumulate sediment, improve water quality, reduce stream velocities, raise water tables, and increase the size of associated riparian zones. These effects create and maintain both terrestrial and aquatic habitats. Beaver ponds also control the timing and duration of flow in streams by slowing surface-water runoff and storing large amounts of water in the surrounding water table. Much of this stored water releases into streams throughout the year, which helps maintain late-season flow in many small streams with high beaver densities. In some active beaver habitats, bird densities have been shown to be three times that of adjacent riparian habitats (Collins 1993). Studies have also shown that trout size and biomass are greater in streams with beaver ponds (Olson and Hubert 1994). Over the centuries, beaver ponds have trapped tens to hundreds of billions of cubic meters of sediment that would otherwise been carried downstream (Naiman et al. 1988). Today, the physical character and vegetation of many meadowlands is the result of historic beaver activity.

Fur trapping in the 19th century greatly reduced beaver numbers and extirpated them from many areas. By the early 21st century, beavers have reoccupied most of their historic range, but at only approximately 10% of the pre–European-contact densities (Naiman et al. 1988). One study found that beavers had been extirpated from more than 25% of first, second, and third order streams in Wyoming, and concluded their historic ecological influence was absent from a far greater percentage (McKinstry et al. 2001).

Predicted future rises in mean temperature and greater variability in precipitation may lead to less snow accumulation, shorter and earlier spring runoffs, and higher evaporation rates (IPCC 2007). These changes will likely further compound the effects of current disruptions to historic flow regimes. Additionally, as the human population of the region grows, additional dams and diversions will likely be created to ease the growing demand for water resources by various user groups.

Notable Wyoming Species of Greatest Conservation Need (SGCN) negatively impacted by alterations to natural flow regimes in Wyoming include bluehead suckers, flannelmouth suckers, roundtail chubs, western silvery minnow, sauger, cutthroat trout (Bonneville, Yellowstone, Snake River, and Colorado River), Wyoming toad, and northern leopard frog.

Alterations to Fire Regimes

Historically, fires were common in Wyoming wherever sufficient fuel accumulated. Semiarid deserts and plains likely burned infrequently, but fires were a regular occurrence in riparian zones, montane forests, some grasslands and dense shrublands and woodlands (Knight 1994).

Fire frequency and severity vary by climatic conditions, site characteristics, and vegetation types. In turn, these variables influence the plants that re-colonize a site and the wildlife species that inhabit it during the vegetation successional stages that follow. Native Americans often started fires to facilitate hunting, either to attract animals to palatable re-growth or by using fire as a tool to drive game (Knight 1994). A review of historical accounts of fire in the Rocky Mountains concluded that fires set by Native Americans were common in lowlands and may even have occurred annually, though not likely in the same spot in consecutive years (Gruell 1985). In the foothills, prior to European settlement, fire may have occurred every 5 to 25 years (Knight 1994). Fire intervals in sagebrush habitats and forests in Wyoming were more variable and site-specific. In forested areas, fire intervals likely ranged from decades at lower elevations to several hundred years or more in high alpine forests, where fuel levels are low and required climatic conditions rare (Knight 1994). Estimates on historic fire intervals for sagebrush habitats range from every 10 to 400 years or longer depending upon species and site conditions (see Sagebrush Shrublands Habitat Type).

Fire releases nutrients and increases the amount of bare soil. Fire-blackened soils warm quickly, which increases microbial activity, furthering nutrient cycling and encouraging plant growth. In forests, fire can reduce canopy coverage favoring the growth of sun dependent plants. In prairies, fire can remove dead vegetation that hinders new growth, reduce invasive plants[3], and encourage native species. Due to variations in plant species tolerance levels, fire can have a significant influence on plant species composition. Because fires kill many young trees and some shrubs it can often create savannas by reducing tree densities. Ponderosa pine habitats in Wyoming were believed to be more savanna-like prior to European settlement as a result of frequent fires (see Xeric Forests Habitat Type).

Intensity has a strong influence on the ecological effects of fire. Extremely hot fires that burn through the forest canopy can kill

[3] Fire can also promote the spread of cheatgrass and other invasive species under certain circumstance (Paige and Ritter 1999).

most of the trees and significantly alter habitats. In contrast, surface fires often burn forest floor litter, may sterilize the soil, and kill few organisms. Perennial grasses, forbs, and some shrubs and trees have the ability to sprout from surviving roots, leading to recovery in several years (Knight 1994).
Beginning in the 20th century, fire suppression management techniques have been linked to increasing fire severity due to greater fuel load accumulations (Omi and Martinson 2004).

Ponderosa pine, limber pine, and Douglas-fir appear to be increasing in density and expanding their range in part as a result of fire suppression (Knight 1994). Many believe that juniper has expanded its range northward and to lower elevation grasslands and shrublands that previously had higher fire frequencies (Gillihan 2006).[4] Increasing tree densities and greater age uniformity among lodgepole and ponderosa pine stands have led to increased stress resulting from competition for water and soil nutrients, which may be causing trees to become more susceptible to mountain pine beetle infestations (Knight 1994).

Fire suppression and increased grazing by wild and domestic ungulates have led to notable declines in aspen, true mountain-mahogany, serviceberry, and skunkbush sumac. These species provide important food and cover for a diversity of wildlife. Throughout the West, aspen have declined between 50 to 96% (Bartos and Mitchell 2000).

Changes to historic fire regimes, both natural and prescribed, have also altered the interaction of fire with other disturbances, most notably grazing. Grazing animals are attracted to burned areas immediately following fires to feed on nutritious re-growth. In contrast, most current fire management strategies recommend growing season deferment from livestock grazing for one or more years following fires to facilitate native plant growth and reduce the establishment of invasive plant species (Bureau of Land Management 2005). Similarly, prescribed fires are often applied to entire pastures during the dormant growing season, whereas historical fires were likely patchy in distribution and occurred during mid to late summer when there is the highest incidence of lightning strikes. Over the past decade, the Wyoming Game and Fish Department's prescribed fire plans have been increasingly focused on promoting patchiness.

Cheatgrass is an increasing annual invasive from Eurasia. Cheatgrass is highly fire-adapted and fire prone and has the potential to increase fire frequency in areas where it becomes widely established (Whisenant 1990). Altered fire regimes can change an entire plant community by converting native grassland, sagebrush, and other plant communities to cheatgrass-dominated landscapes. Of special concern are the loss of crucial sage-grouse and other wildlife habitats along with secondary weed invasions from species such as rush skeletonweed and Medusa-head wild rye (Smith and Enloe 2006).

Climate change is expected to increase precipitation variability and drought frequency (Christensen et al. 2007). Both factors will likely further alter historic fire regimes in Wyoming. The length of the fire season in the U.S. has increased significantly over the past 30 years and is expected to continue to grow in coming years (Westerling et al. 2006, Barnett et al. 2004). Moreover, the amount of acres burned each year in the West over the past two decades has also increased (National Wildlife Federation 2010). Wildfire coupled with a combination of warming temperatures, drought, and vegetation changes resulting from changing climate factors may lead to drastic ecosystem changes in the future.

Alteration to Grazing Regimes

Herbivory has a long history of influencing habitats and associated plants and animals (Milchunas et al. 1988). Before the arrival of Europeans, bison, elk, deer, antelope, prairie

[4] Some researchers believe that historic climate change may have an equal or greater influence on juniper distribution in the West which has gone through a number of range expansions and contractions (Miller and Wigand 1994.)

dogs, as well as a diversity of other wildlife and insects, grazed and browsed Wyoming vegetation. Today, elk, deer, and antelope remain abundant, while domesticated livestock are the predominant grazers across Wyoming ecosystems.

Grazing is a keystone process in maintaining habitat diversity (Collins 1992, Knapp et al. 1999). Historically, the distribution of grazing ungulates was uneven across the landscape. Prior to European settlement, grazing and fire interacted closely to influence bison behavior. Bison were attracted to recently burned areas to graze on palatable, re-sprouting grasses. This localized high grazing pressure permitted vegetation in other areas to accumulate which in turn made these locations more prone to subsequent fire (Fuhlendorf and Engle 2001, Fuhlendorf et al. 2009). Prairie dogs, often thriving in areas recently grazed by bison, lived in large colonies, digging burrows and cropping vegetation. Burrows and open patches of ground created by bison and prairie dog colonies create habitat for other wildlife species including the black-footed ferret, burrowing owls, long-tailed weasel, mountain plover, and swift fox (Kotliar et al. 1999, Kotliar 2000). The resulting patchwork of variation in plant structure and composition shifted across the landscape.

Bison and prairie dogs have experienced substantial reductions in both numbers and range. Other pre-Columbian herbivores, like the Rocky Mountain locust, which likely had a very significant grazing impact during outbreaks, are believed to be extinct (Lockwood 2004).

Cattle and sheep were introduced in large numbers in Wyoming in the 1880s following the elimination of bison in most areas of the state outside Yellowstone National Park. Uncontrolled livestock grazing at the end of the 19th century and the beginning of the 20th century substantially altered some ecosystems (Belsky and Blumenthal 1997). In 1934, the federal Taylor Grazing Act was passed, which led to the creation of grazing districts in which grazing use was apportioned and regulated on public lands. Since this time, range conditions and grazing practices have improved although some habitats remained modified by this period of overuse through changes in plant composition as well as altered fire frequency (Laycock 1991).

Wildlife species often depend upon habitats produced by one grazing level while others require conditions supported by a diversity of grazing intensities (Derner et al. 2009, Toombs et al. 2010). For example, mountain plover and McCown's longspur prefer habitats that have been intensively grazed while Caspian sparrow thrives in more lightly grazed areas (Knopf 1996). In contrast, many modern rangeland management practices were developed to increase livestock production through evenly distributing livestock and enhancing vegetation use. This strategy emphasized uniform moderate grazing levels thereby eliminating grazing extremes (i.e., none, light, and heavy). Over time, such practices can lead to decreases in plant species and structural diversity (Fuhlendorf and Engle 2001). Although practices such as water placement can create grazing gradients by reducing grazing intensity at distances farther from water sources, such gradients tend to be static if water sources are not moved or altered. In such cases, repeated, heavy, localized grazing can lead to the initial stages of rangeland deterioration (National Research Council 1994).

Riparian areas are often the most diverse and productive habitats in Wyoming. Most riparian habitats evolved with some feeding and trampling from animals; however, repeated intensive use during the same season each year can have negative impacts. Impacts include a change, reduction, or elimination of bank vegetation; increased water temperatures; excessive sedimentation and upland erosion; channel widening and bank sloughing; and heightened coliform bacterial counts (Kauffman and Krueger 1984). Although livestock are often associated with riparian overuse, high concentrations of wild ungulates, particularly elk, have substantial impacts on riparian and

aspen communities (Ripple and Beschta 2004). There has been considerable improvement in conditions for many riparian areas through improvements in livestock management strategies (Smith et al. 1992).

In addition to being a natural component of many Wyoming habitats, grazing is the cornerstone of Wyoming's ranching industry. The continued function of a considerable amount of crucial wildlife habitat located on private land within the state is closely tied to the future sustainability of the state's ranches, which will continue to increase with increasing partnerships between ranchers, conservation organizations, and state and federal land management agencies (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development).

Current Initiatives to Maintain, Restore, or Duplicate Historic Disturbance Regimes

Hydrology

In 2001, several habitat types were identified in the WGFD Strategic Habitat Plan (SHP) that were considered particularly important to maintain or enhance. Among these were riparian and wetland habitats, prairie stream systems, and cutthroat trout streams. Declines in late season water flows, water quality, and loss of water flow and native fish due to water diversions are significant factors contributing to less than optimal prairie stream system habitat and adversely affecting cutthroat trout habitat. Updates to the SHP in 2009 identified specific regional priority areas for conservation work. These areas included crucial areas, necessary for maintaining terrestrial and aquatic wildlife populations and enhancement areas where there is the potential to enhance or improve important wildlife habitats that have been degraded. Combined, these prioritization efforts will help guide conservation and restoration efforts for aquatic habitats.

In 2005, the WGFD held a Fish Passage workshop with representation from state, federal, and private sector specialists. In 2008, fish passage goals were added to the SHP and in July 2009, the WGFD designated fish passage as a department program with an associated budget. Projects completed and continuing around the state include reinstalling or replacing culverts that prevent passage, replacing or modifying diversion dams to provide upstream passage, installing bypass channels around diversion structures, and screening diversion ditches and canals. Fish movement studies continue to be used to evaluate upstream passage at existing diversion structures and fish mortality in various canal systems. The WGFD developed a fish passage database to document fish passage diversions around the state and prioritize projects to address passage issues.

The Bureau of Reclamation, State Engineer's Office, Wyoming Water Development Commission, and the WGFD have worked together to establish formal and informal water management strategies for some reservoirs. These agreements benefit aquatic wildlife, including sport fisheries, while still serving the reservoirs' legislatively authorized purposes. Examples include the Snake River below Jackson Lake Dam, Shoshone River below Buffalo Bill Dam, Green River below Fontenelle Reservoir, Bighorn River below Boysen Reservoir, and the North Platte River below Kortes, Pathfinder, Grey Reef, and Glendo Dams. Maintaining historic flow regimes is typically a secondary consideration compared to traditional focuses on flow releases to benefit agriculture, sport fisheries, and recreation.

Instream flow water rights provide the ability to manage natural flow regimes up to designated base levels for fisheries and, by association, may benefit nearby riparian corridors. The WGFD began evaluating various methods and quantifying instream flow needs for fish in 1979. In 1986, the Wyoming Legislature enacted a statute (41-3-1001 to 41-3-1014) that formally recognizes opportunities to maintain or improve instream flow as a beneficial use. Because water

rights can only be issued for uses that have been officially recognized as "beneficial," this designation is of critical importance. Since the inception of the program, the WGFD has employed biologists to identify priority areas and quantify instream flow regime needs for fish habitat, and the WGFD has submitted applications for over 100 instream flow water rights. Every five years the program is reviewed and a plan devised with explicit goals for upcoming efforts.

Wyoming has also undertaken a comprehensive water planning effort which has influence on the management of flow regimes. In 1999, the Wyoming Legislature approved a planning framework and authorized plans for the Bear and Green River Basins (Wyoming Water Development Office 2010). In the years that followed, the Legislature authorized funding for the five remaining river basins. The Platte River Basin Plan was the last plan completed, in May 2006. Anticipating completion of the individual river basin plans, the 2005 Legislature authorized funding for the Statewide Framework Water Plan. The purpose of this plan is to summarize the results of all seven river basin plans and to provide future water resource planning direction to the state. It includes an inventory of the state's water resources and related lands, a summary of the state's present water uses, a projection of future water needs, and potential options for meeting those needs. In early 2010, initial steps were taken to address the plan's environmental and recreational components, including riparian habitats.

Fire

In Wyoming, the Bureau of Land Management (BLM), US Forest Service (USFS), Wyoming State Forestry Division, and other cooperators utilize the National Fire Plan (NFP) as the overarching plan to guide all fire management activities. NFP primarily focuses on ensuring there is capacity to address wildfire prevention, fire preparedness and suppression, as well as post-fire stabilization and rehabilitation. As one of many objectives, NFP includes elements of both duplicating historic fire regimes and benefitting wildlife habitat.

NFP prioritizes fire suppression responses through District Fire Management Plans and activity level plans. These plans dictate what Fire Management Units receive for fire suppression resources upon the detection of a fire as well as, based on a lightning tracking system, the allocation of resources prior to a fire. Fire Management Units are tied to local USFS Forest Plans, BLM Resource Management Plans (RMP), and Fire Management Plans which incorporate goals of managing for historic fire regimes. The LANDFIRE GIS system and Fire Regime Condition Class methodology are two tools which are used to determine fire fuel loads and departures from historic fire regimes in order to guide management objectives and set priorities for habitat and fuel treatments.

The NFP also establishes an intensive, long-term hazardous fuels reduction program. In many areas fuel loads are unusually high as a result of decades of fire suppression, sustained drought, and increasing infestations by insects, disease, and invasive plants. Hazardous fuels reduction treatments are designed to lower the risks of catastrophic wildfire to people, communities, and natural resources while restoring forest and rangeland ecosystems to closely match their historical structure, function, diversity, and dynamics. Treatments are administered using prescribed fire, mechanical thinning, herbicides, grazing, or combinations of these and other methods. Treatments are being increasingly focused on the expanding wildland/urban interface. Fuels management treatments are developed by teams of natural resource specialists.

When catastrophic fires do occur, stabilization and restoration work begins immediately to restore lands that are unlikely to recover naturally from the effects of wildfires. This work, often implemented over the course of several years following a wildfire, includes reforestation, fence replacement, fish and wildlife habitat restoration, invasive plant

treatments, and replanting and reseeding with native or other desirable vegetation.

As the human population grows, concerns for human safety and property loss will diminish the viability of natural and prescribed fire in habitat management. In many locations in Wyoming, commercial timber harvest is also economically important and will continue to be a leading forest management objective (Wyoming State Forestry Division 2009). Under these circumstances, efforts have been placed on duplicating the effects of fire in forest management activities including commercial timber harvest (North and Keeton 2008). Silviculture practices designed to duplicate the effects of historic disturbance regimes typically include increasing forest structural complexity, plant species diversity, and spatial patterns of timber removal and thinning (North and Keeton 2008). Accomplishing these goals may require lengthening tree harvest rotations and retaining large green trees, snags, and logs in harvested areas (Swanson and Franklin 1992, Franklin et al. 1997). While the effects of fire can be duplicated by mechanical and other means, reproducing its influence on soil turnover, soil carbon dynamics, and nutrient cycling is more difficult (North and Keeton 2008).

Herbivory

Grassland pasture and rangelands cover 587 million acres or 25.9% of the U.S. land base (Ruben et al 2006). Nationwide, grazing occurs on approximately 160 million acres of BLM lands and 95 million acres of USFS lands (Vincent 2005). Collectively, the BLM and USFS administer nearly 27,000 grazing permits on more than 28,800 allotments (Bureau of Land Management 2010, Thomas 2004). The terms and conditions for grazing on federal lands (such as stipulations on utilization levels and season-of-use) are set forth in the permits. Grazing permits issued by the USFS and BLM last 10 years and are renewable if it is determined that the terms and conditions of the expiring permit are being met. To achieve desired conditions, these agencies use rangeland health standards and guidelines. The BLM Code of Federal Regulations establishes intervals and standards for monitoring grazing permits. The results of monitoring help managers determine whether changes are necessary for livestock grazing management. The USFS conducts both implementation monitoring annually to evaluate vegetation use and permit compliance, and effectiveness monitoring every five to six years to assess whether activities and objectives set forth in forest plans, allotment management plans, or other relevant documents are being met.

State-owned lands are typically managed in conjunction with the ownership of surrounding lands including private landowners and federal land management agencies. Every state parcel has a field sheet that describes the land's elevation, topography, annual anticipated precipitation, and soil type. The sheet also contains information about the amount and type of vegetation present which is used to calculate livestock stocking rates. An inspection of each parcel is planned once every 10 years to update the field sheet and address any concerns. Priority is given to known problem areas. The Wyoming Office of State Lands and Investments, which manages state lands, cooperates with the Natural Resources Conservation Services (NRCS) on conservation and wildlife programs as well as with the BLM on allotment plans and local RMPs.

The NRCS, conservation districts, University of Wyoming Cooperative Extension program, and local Coordinated Resource Management teams have numerous programs and initiatives to assist landowners in establishing grazing management plans. Notably, the Environmental Quality Incentives Program (EQIP), administered by the NRCS, offers financial and technical assistance to implement grazing plans and improvements. Many of these programs benefit wildlife and apply disturbance regime management principles; however, duplicating historic disturbance regimes is rarely a predominant management goal in itself.

Current Challenges for Effectively Managing for Historic Disturbance Regimes

Difficulty in quantifying historic disturbance regimes.
The integration of historic disturbance regimes into habitat management decisions is often difficult because of a lack of the scientific data necessary to quantify the frequency and extent of some disturbance regimes. This can be complicated by the large time scales that characterize various disturbance events and long-term changes in climate that can alter the type and frequency of disturbances. Additionally, there is debate as to whether historic management practices of indigenous peoples, such as fire setting, should be factored into efforts to manage for disturbance regimes. Others argue it is arbitrary to select a specific historic time period as the benchmark for modern management strategies.

Insufficient financial incentives to offset reduced economic returns and greater time requirements needed to incorporate disturbance regimes into habitat management.
Current habitat management strategies often emphasize managing for a single species or products such as livestock, game, or timber. It is often perceived that increased variability associated with disturbance regimes may reduce sustained yields. Competitive compensation in terms of direct monetary incentives or demonstrated increases in long-term production needs to be provided before historic disturbance regime strategies are widely adopted.

Human-safety and property-loss concerns often limit the degree to which natural disturbances can be allowed to proceed without intervention or can be actively prescribed in habitat management strategies.
Greater numbers of people and structures in areas where fires have historically been common have limited the ability of agencies to allow wildfires to burn or to incorporate prescribed fires into habitat management strategies. Similar concerns may apply to natural flooding events by rivers and streams. Environmental concerns, including releasing carbon into the atmosphere, may limit future fire activities.

There is often a lack of understanding about the effects of historic disturbance regimes or the landscape implications of individual management actions.
At present, there is often insufficient funding for monitoring. This can limit the ability of agencies to understand the effects of existing management actions or the long-term effects of natural disturbances when they occur. Most disturbance studies monitor the influence of a single factor for a short period of time and are not directed toward evaluating multiple changes to natural systems. There is also a need for more research on how various types of historic disturbances and management actions interact with each other. Consequently, modeling efforts regarding the effects of historic disturbance regimes and their interactions are limited.

Inadequate public and political support for implementing actions that facilitate or duplicate historic disturbance regimes.
The complexity of natural systems and the multiple effects of historic disturbances make educational efforts challenging. The benefits of historic disturbance regime management can be long term and difficult to quantify. Existing knowledge is slow to be incorporated into policy. Additionally, increasing opposition is being raised regarding diminished aesthetic qualities which may follow management treatments such as prescribed fire.

Lack of coordination among natural resource agencies with different and sometimes conflicting mandates.
Natural resource agencies have varying mandates and jurisdictions. Efforts to restore the effects of historic disturbance regimes are often most effectively implemented on a landscape or watershed scale which involves multiple landowners. To better advance the integration of historic disturbance regimes into

habitat management decisions, especially those that would need the support of multiple agencies, more effort needs to be placed on reaching consensus on integrated, ecologically-based conservation goals.

Insufficient budgets to administer management treatments.
Administering habitat treatments such as prescribed burns is expensive. Many natural resource agencies are experiencing budget freezes or reductions and have multiple competing interests. Lack of funding is compounded by a limited ability to use existing funding sources due to difficulty in meeting matching fund requirements. Conflicting fiscal and year-end funding cycles can make establishing cooperative projects difficult. The complexity of obtaining grant funding is also augmented by differences in state and federal requirements.

Regulatory demands, including the National Environmental Protection Act (NEPA) and the Endangered Species Act, can limit the ability to apply habitat management treatments that would duplicate historic disturbance regimes.
The NEPA requirements are lengthy and complex, and federal agencies must seek public comment at many points during the process. These requirements can prevent the application of treatments to duplicate historic disturbance regimes in a timely manner or diminish the cost-effectiveness of management actions due to the time and resources needed to complete the process. Concerns regarding the incidental taking of threatened or endangered species may also limit the ability to administer habitat treatments to duplicate historic disturbance regimes.

Uncertainty surrounding future climate change will compound difficulties for incorporating historic disturbance regimes into habitat management activities.
Climate change will alter the type, frequency, and intensity of historic disturbances as well as the composition of plants and animals responding to these events. All climate change models contain a degree of uncertainty which is compounded by a lack of understanding about how ecological systems will respond (Wiens and Bachelet 2009, Schmitz et al. 2003, McWethy et al. 2010). While down-scaled climate models provide more spatially precise information about future climates, the uncertainties associated with the global models that were used to generate finer-scale models may remain unresolved, unquantified, and even magnified. Further, bioclimatic models that are increasingly being explored to predict the future range of certain species may be oversimplifying a process that is contingent upon factors other than climate. Due to these limitations, it may take decades before climate change models are sufficiently accurate to predict specific species and landscape responses (Keane et al. 2009).

Recommended Conservation Actions

General Recommendations

Incentives should be provided to offset decreased financial returns or increased input costs that may accompany management strategies focused on replicating historic disturbance regimes.
Land and water management strategies are often focused on food, fiber, and energy production. Strategies intended to replicate historic disturbance regimes can result in reductions or delays in access to these resources. Before strategies that emphasize achieving specific ecological outcomes can be widely adopted, incentives need to be developed to compensate for financial losses which do not occur with traditional approaches that are more production-oriented. This is particularly true for privately-owned wildlife habitat. Future financial incentives may arise from programs associated with payments for ecosystem goods and services such as carbon sequestration and viewshed protection.

Efforts should be made to link managing for historic disturbance regimes to natural resource issues of high public importance. Managing for historic disturbance regimes can be expensive. Budget limitations will frequently require historic disturbance regime management strategies to be linked to high profile issues or the support of existing agency priorities. Disturbance regime management activities that reduce conditions favorable for bark beetle epidemics and catastrophic fires are good examples. Educational efforts are particularly important for habitat management treatments such as fire that have safety concerns, are highly visible, and may result in diminished grazing, recreation, or other uses during recovery periods.

Greater research and professional training efforts regarding interactions between historic disturbances should be pursued. Most educational material and training for habitat and wildlife professionals concentrates on managing for individual species or products. There is relatively little information available about managing for multiple species and ecological outcomes, or how various natural processes and disturbances influence one other. Current research gaps need to be identified in order to create effective training programs.

The implications of climate change on historic disturbance regimes should be reviewed and incorporated into habitat management and conservation activities as scientific knowledge improves. Possible climate warming may result in major changes in historic disturbance regimes, plant and animal dynamics, and hydrological responses, and may further result in entirely unfamiliar species communities (Botkin et al. 2007). Existing climate-modeling science needs to be improved and validated to predict alterations to historic disturbance regimes in specific habitats. Research into localized climate change and associated ecological responses should be continually reviewed and considered in habitat conservation planning and wildlife species conservation and management.

Water-flow Regime Recommendations

Maintain U.S. Geological Survey streamflow monitoring gages. The maintenance of streamflow gages is a fundamental first step in assembling information for comparing present-day patterns to historic flow regimes. The U.S. Geological Survey (USGS) maintains a network of 7,292 stream-gaging stations, comprising more than 85% of the nation's total stations[5]. The continuation of gages is always uncertain and subject to federal funding availability. Through the National Streamflow Information Program (NSIP), the USGS can match non-federal investments in the Cooperative Water Program (CWP) on a 50:50 basis. Wyoming is a cooperator in the CWP through the State Engineer's Office, the Department of Environmental Quality, Department of Agriculture, and several other entities. In addition to the economic and infrastructure concerns, streamflow and water-quality data available through these programs are critical for designing stream habitat restorations, designing fish passage approaches, administering water rights, monitoring and protecting water quality, managing wetlands, and for analyzing climate change and identifying response options. To ensure that USGS stream-gaging stations are maintained, steps or a process to provide unified state support of the NSIP and CWP programs should be identified.

Explore statutory solutions and administrative policies that allow private water-rights holders to temporarily change the use of existing water rights to in-channel flows for fish and wildlife and retain ownership of those rights without diminishing their priority or standing.

[5] Stage and flow or discharge are the two key factors measured at most stream-gaging stations. Stage is water depth above some arbitrary datum, commonly measured in feet. Discharge is the total volume of water that flows past a point on the river for some period of time, usually measured in cubic feet per second or gallons per minute.

Although Wyoming law allows some minimum streamflow protections, the opportunities for changing water rights to restore streamflows are limited.

Increase beaver restoration including the creation of a stream-prioritization system for future reintroductions.
Beaver are keystone species in creating and maintaining riparian habitats through dam-building activities. In Wyoming, beaver are entirely absent or present in significantly reduced numbers from much of their historic range. A system should be established to analyze and prioritize streams for reintroductions. Prioritization should take into consideration potential conflicts through unwanted flooding and tree damage.

Enhance fish passage work by fostering coordination among various groups.
A variety of organizations have an interest in the ability of fish and other aquatic organisms to freely access habitats within their range. These organizations include the WGFD, Wyoming Water Development Commission, Trout Unlimited, Conservation Districts, NRCS, U.S. Fish and Wildlife Service, BLM, U.S. Forest Service, Bureau of Reclamation, and irrigation districts. Despite this common interest and independent success, enhanced coordination would increase the resources and scale at which fish passage work could be addressed.

Fire Regime Recommendations

Increase the research and application of mechanical treatments to replicate historic fire regimes.
Safety and property-loss concerns will limit the use of fire as a management tool in areas of increased human development. This trend is likely to continue as Wyoming's population continues to grow. Additionally, some climate models for Wyoming predict a rise in temperature and the frequency and severity of drought, which may lead to more fires (Christensen et al. 2007). Under these circumstances, funding directed for climate-change adaptation should be made available for research and projects to duplicate the ecological effects of fire.

Increase fire-management budgets.
Prescribed burns can be expensive in terms of planning, treatment, and post-fire monitoring and management. Long-term cost reductions through reducing future expenses in fighting catastrophic fires and associated property loss should be factored into budgeting for prescribed fires.

Fire-management activities should take into consideration interactions with other historic disturbances.
Prior to European settlement, fire often worked in concert with other disturbances such as grazing in order to create a matrix of plant communities and habitat conditions. While not appropriate for all sites, increasing the frequency of post-fire grazing treatments should be investigated.

Herbivory Regime Recommendations

Working in cooperation with Wyoming livestock producers and federal and state agencies who issue, authorize, and manage grazing permits will be critical to implementing the following recommendations.

Management often needs to occur at a landscape level in order to replicate historic grazing regimes.
Individual pastures and grazing allotments are often not sufficiently large to replicate the historic mosaic of varying grazing intensities under which many native wildlife species evolved. Where practical, investigations should be conducted about managing multiple public grazing allotments to achieve the needed management scale. With adequate incentives, private lands could also be incorporated into these efforts. It should be noted that grazing strategies cannot be universally applied, but rather should be outcome and habitat specific. Additionally, the establishment of grazing strategies focused on duplicating past disturbance regimes may be limited in sites

where there is in sufficient knowledge of historic regimes and ecological processes, and wildlife species' responses.

Use livestock grazing and associated management as a tool to improve wildlife habitat and maintain native plant communities.
Livestock grazing and livestock grazing management practices can be used as an effective tool for improving wildlife habitat. Some research suggests that livestock grazing can be managed to benefit grassland bird species (Derner et al. 2009, Toombs et al. 2010) and improve forage quality on elk winter range (Clark et al. 2000). The use of livestock grazing to meet habitat objectives should be considered. In addition, it is possible that livestock grazing disturbances before fire may decrease cheatgrass invasions (Davies et al. 2009).

The number of grassbanks should be increased to provide flexibility in applying range management practices.
Grassbanks or forage reserves refer to scenarios where forage is reserved for use and subsequently provided in exchange for management or conservation actions on another property. Such areas can also serve as relief valves or areas for grazing when wild fires remove forage from surrounding areas. Grassbanks have been a component of habitat treatments, such as prescribed fire, where grazing must be reduced or deferred. Both public and private lands[6] have been used for grassbanks. Grassbanks can increase habitat treatment options for both land management agencies and private landowners.

Maintain hunter access to keep game herds within range capacity and evenly distribute grazing pressure.
Hunter harvest is often needed to keep big game herd populations within established herd objectives and within the carrying capacity of the land. Big game animals tend to congregate in areas where there is little hunting pressure or where hunting is prohibited, diminishing overall hunter harvest. Riparian and aspen habitats, two of Wyoming's most ecologically diverse habitats, can be locally impacted by overuse by big game animals, particularly elk. Sagebrush, mountain shrub, and some grassland communities have been degraded by overuse by big game in some areas. Efforts should continue to ensure adequate hunter access is maintained to ensure the health and productivity of these habitats.

Evaluating/monitoring Success

Benchmarks should be developed to evaluate the success of habitat treatments based on desired ecological outcomes.
Currently, the success of management actions is often quantified by the extent of treatments, such as number of acres burned. More appropriately, success should be evaluated by the ability to achieve post-treatment vegetation goals. The development of new benchmarks would require additional monitoring and research to document multiple effects of management actions. Frequently, additional resources will be needed to allow for adequate post-treatment monitoring.

Monitor the landscape changes in vegetation-distribution patterns to help guide habitat management actions to support or replicate the effects of historic disturbance regimes.
Remote sensing analysis is useful in tracking the size and distribution of vegetation communities, which can reflect the frequency and intensity of historic disturbances such as fire and, to a lesser extent, grazing. Evaluation of vegetation patterns can assist in both determining deviations from historic disturbance regimes and directing where habitat management actions should be administered and where natural disturbance should be allowed to proceed. This technique will require the further development of monitoring protocols and the identification of sample sites. Monitoring should be conducted in relation to the possible effects of climate change.

[6] Grassbanks on private land have often been owned by conservation groups such as The Nature Conservancy.

Increase the development and accessibility of the WGFD's fish passage database. The WGFD has established a database to track the location, type, extent, and physical characteristics of fish passage barriers on Wyoming waters. The database can be used to prioritize passage improvement efforts within and across drainages. Efforts should be made to further develop the database and increase its accessibility to interested parties.

The potential effects of climate change should be monitored to determine alterations to historic disturbance regimes and appropriate management responses. Warmer and drier conditions, which have been predicted for Wyoming (Christensen et al. 2007), will fundamentally alter historic disturbance regimes, especially in regards to their frequency and intensity. Greater habitat diversity associated with integrating disturbance regime principles into management practices will increase ecosystem resilience to climate change (Joyce et al. 2000). Research and habitat monitoring data related to climate change should continually be reviewed and adaptive management principles applied to disturbance regime management practices.

Continue to monitor water flows through USGS streamflow monitoring stations.

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Additional Resources

USDA – Agricultural Research Service
High Plains Grasslands Research Station
8408 Hildreth Road
Cheyenne, WY 82009

Bureau of Land Management –
Wyoming State Office
5353 Yellowstone Road
Cheyenne, WY 82009
P.O. Box 1828,
Cheyenne, WY 82003-1828
Phone: (307) 775-6256
http://www.blm.gov/wy/st/en.html

Bureau of Reclamation
Wyoming Area Office
P.O. Box 1630
Casper, WY 82644
Phone: (307) 261-5671
http://www.usbr.gov/gp/wyao/

Natural Resources Conservation Services –
Wyoming State Office
100 East B Street, 3rd Floor
Casper, WY 82602-5011
P.O. Box 33124
Casper, WY 33124
Phone: (307) 233-6750
http://www.wy.nrcs.usda.gov/

The Nature Conservancy in Wyoming
258 Main Street, Suite 200
Lander, WY 82520
Phone: (307) 332-2971
http://www.nature.org/wherewework/northamerica/states/wyoming/
Trout Unlimited –Wyoming
250 North 1st Street
Lander, WY 82520
P.O. Box 64
Lander, WY 82520
Phone: (307) 332-6700
http://www.wyomingtu.org/site/c.deIILOOpGnF/b.3567947/k.93BF/National_TU.htm

University of Wyoming Extension Cooperative Service
Dept 3354
100 East University Avenue
Laramie, WY 82071
Phone: (307) 766-5124
http://ces.uwyo.edu/AG.asp

U.S. Fish and Wildlife Service
Wyoming Field Office
5353 Yellowstone Road, Suite 308A
Cheyenne, WY 82009
Phone: (307) 772-2374

U.S. Forest Service R2/R4
Wyoming Capitol City Coordinator
Herschler Building 3 West, Room 3603
122 West 25th St.
Cheyenne, WY 82002-0600
Phone: (307) 777-60870

United States Geological Survey
2617 East Lincolnway, Suite B
Cheyenne, WY 82001
Phone: (307) 778-2931
http://www.usgs.gov/

Wyoming Association of Conservation Districts
517 East 19th Street
Cheyenne, WY 82001
Phone: (307) 632-5716
http://www.conservewy.com/index.htm

Wyoming Department of Agriculture
2219 Carey Ave
Cheyenne, WY 82002
Phone: (307) 777-7321
http://wyagric.state.wy.us/

Wyoming Game and Fish Department
5400 Bishop Boulevard
Cheyenne, WY 82006
http://gf.state.wy.us/NetTest/frmHomepage.aspx
Fish Division
Phone: (307) 777-4559
Terrestrial Habitat Division
Phone: (307) 777-4565

Wyoming State Engineer's Office
4th Floor East
122 West 25th Street
Cheyenne, WY 82002
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http://seo.state.wy.us/index.aspx

Office of State Lands and Investments
Herschler Building, 3rd Floor West
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Cheyenne, WY 82001
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http://slf-web.state.wy.us/

Wyoming State Forestry Division
1100 West 22nd Street
Cheyenne, WY 82002
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http://slf-web.state.wy.us/forestry.aspx

Wyoming Water Development Commission
6920 Yellowtail Road
Cheyenne, WY 82002
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Wyoming State Wildlife Action Plan
Terrestrial Habitat Types and Aquatic Basins

Introduction

Habitat is a general term which means the environment – physical and biological – that provides the necessary food, water, shelter, space and other items in proximity to meet the seasonal and year around needs of a particular organism or group of organisms. Wyoming contains a diversity of both terrestrial and aquatic habitats. Habitats are typically classified by plant and/or animal assemblages, geographic features, ecological attributes, or a combination of these features. While the goal of classification systems is to make each unit distinct for cataloging information, addressing issues and threats, and proposing conservation strategies, there is considerable overlap between units. Some habitat groupings tend to be geographically well-defined while others are widely distributed wherever suitable conditions exist.

Threats and potential conservation actions can vary considerably between habitat types. A habitat classification system with the following attributes was determined to best meet the purposes of Wyoming's State Wildlife Action Plan (SWAP):

1. Identifies habitats with similar flora, fauna, and conservation concerns;
2. Uses a scale consistent with those frequently used in wildlife management;
3. Describes habitats that are easily recognized by the public and policy makers; and
4. Results in a manageable number of habitats for planning purposes.

Features 2 and 3 were considered important for encouraging support for the SWAP and facilitating coordination with existing local, state, and regional wildlife conservation efforts.

Habitat Classification Systems

Terrestrial Habitat Types

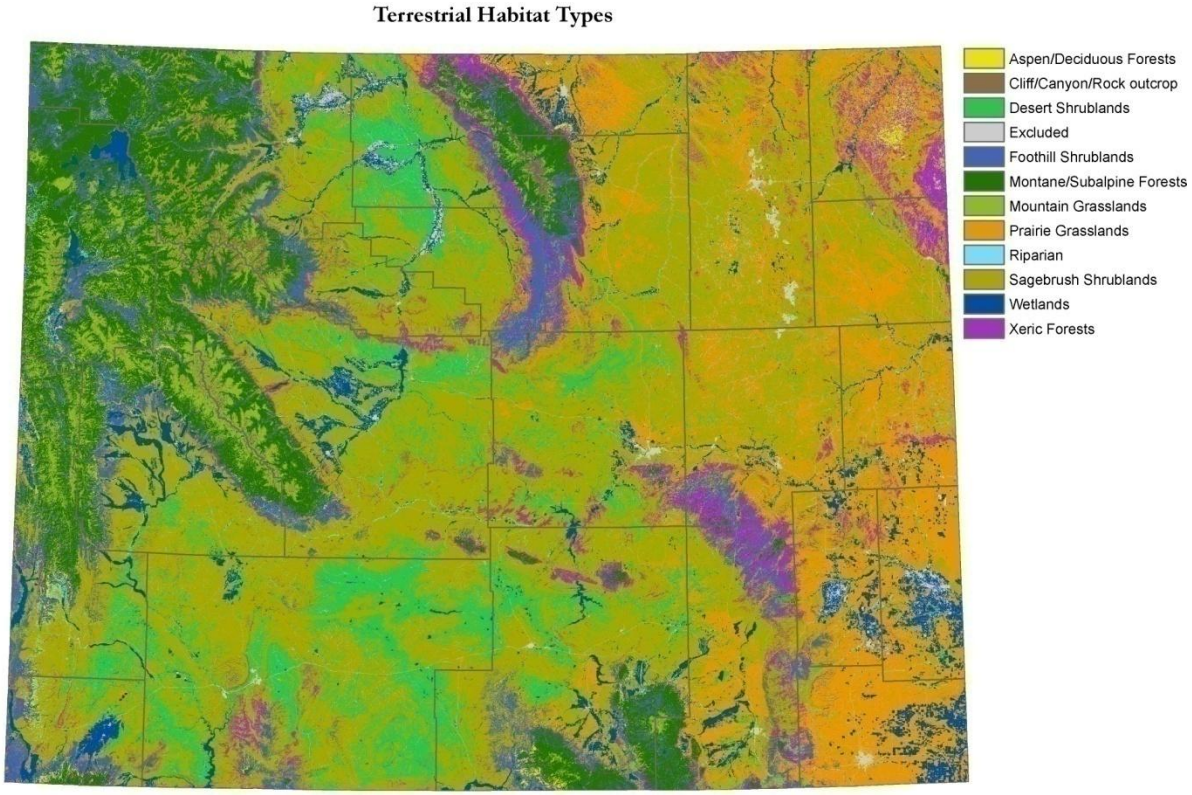
Eleven terrestrial habitat types were included in Wyoming's SWAP based on the attributes described above (Table 1). The habitat types selected closely resemble major types described by Knight (1994) and NatureServe (2010) (http://www.natureserve.org/explorer).

NatureServe Ecological Systems were then assigned to 1 each of the 11 terrestrial habitat types based on shared characteristics by a group of habitat biologists and ecologists from the WGFD and Wyoming Natural Diversity Database (Appendix A). NatureServe Ecological Systems were selected because they provide a classification unit that can be readily mapped and that can be easily identified by natural resource managers in the field (Comer et al. 2003). They are defined by biogeographic region, landscape scale, dominant land cover type, and disturbance regimes. Ecological systems are tied to, but not part of, the U.S. National Vegetation Classification (USNVC) (Federal Geographic Data Committee 2008) and can be cross-walked with other classification systems including the WGFD Wildlife Observation System types. Ninety-six NatureServe Ecological Systems are found in Wyoming and because the systems have been identified for surrounding states, regional and national assessments and analysis can be applied to conserve wildlife. NatureServe Ecological Systems that are composed primarily of developed lands, were exceedingly small, or do not contain any Species of Greatest Conservation Need (SGCN) were excluded. Information about individual ecological systems discussed in the SWAP can be found at: http://www.natureserve.org/explorer.

TABLE 1. Wyoming SWAP Terrestrial Habitat Types

1.	Aspen/Deciduous Forests
2.	Cliff/Canyon/Cave/Rock Outcrops
3.	Desert Shrublands
4.	Foothills Shrublands
5.	Montane/Subalpine Forests
6.	Mountain Grasslands and Alpine Tundra
7.	Prairie Grasslands
8.	Riparian Areas
9.	Sagebrush Shrublands
10.	Wetlands
11.	Xeric and Lower Montane Forests

FIGURE 1. SWAP Terrestrial Habitat Types



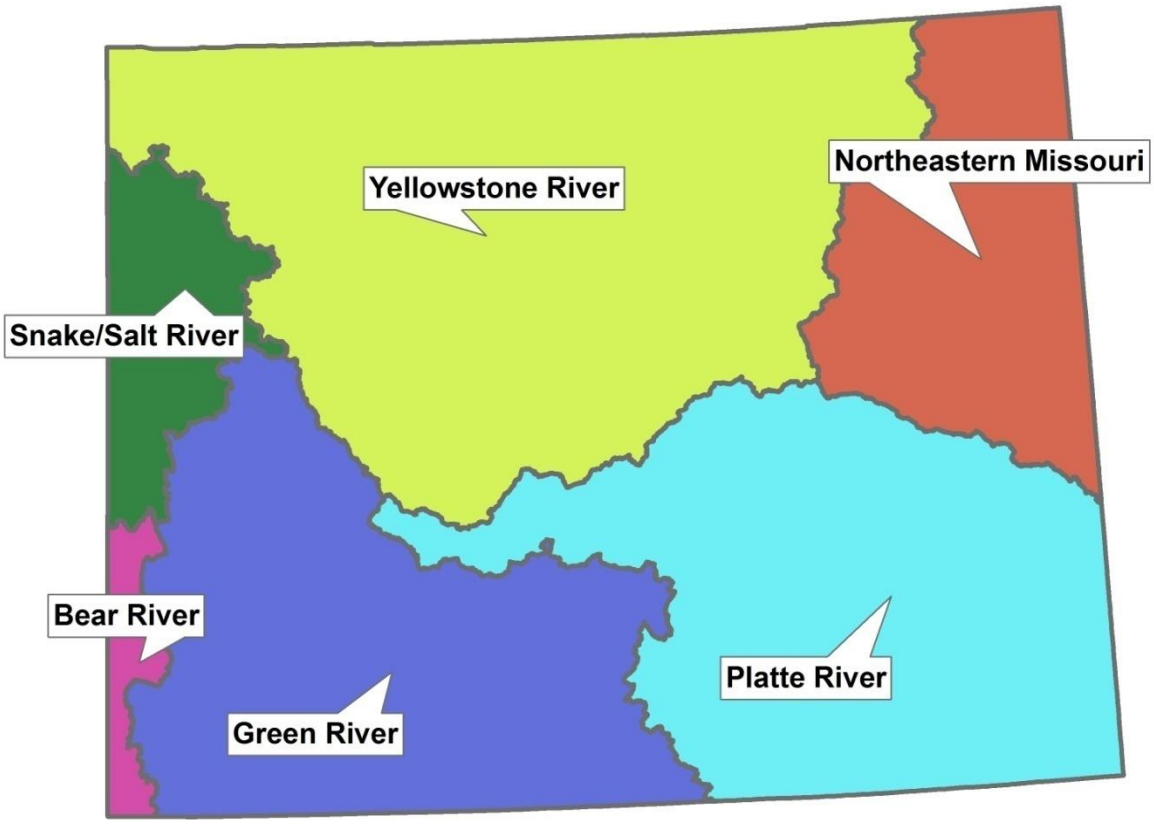
Aquatic Basins

Three of the nation's major river systems have their headwaters in Wyoming: the Missouri, Colorado, and Columbia rivers. Additionally, the Bear River, originating in Wyoming, is major tributary to the inland Great Basin. Based on hydrographic boundaries, fish assemblages, and management considerations, these watersheds provide a natural basis for delineating the six major watersheds used for conservation planning purposes in Wyoming's SWAP (Table 2). The areas are consistent with the aquatic ecosystems identified for freshwater biodiversity conservation worldwide by Abell et al. (2008). The watershed areas are also synonymous with "aquatic zoogeographical units" and "ecological drainage units" identified under The Nature Conservancy's hierarchical classification framework (Higgins et al. 2005). The watersheds each include one to four "sub-regions" (4-digit hydrologic unit code [HUC] watersheds). This approach allows the nesting of multiple spatial and temporal scales for planning and prioritizing conservation actions.

TABLE 2. Wyoming SWAP Aquatic Basins

1. Bear River
2. Green River
3. Northeastern Missouri
4. Platte River
5. Snake/Salt River
6. Yellowstone River

FIGURE 2. SWAP Aquatic Basins



Information Collection

Terrestrial Habitat Types

Information on leading habitat threats, current conservation initiatives, as well as recommended conservation actions and future monitoring was sought for each terrestrial habitat type from habitat experts within the WGFD and also from experts working outside of the WGFD. Individuals were contacted in agencies and organizations that have significant jurisdictional authority, financial resources, and/or technical expertise regarding each habitat type. This approach was considered to be time-efficient for gathering information, as well as encouraging involvement of entities whose participation is important for implementing the SWAP. Collecting information in this way also fulfills Element 7 of federal SWAP guidelines, which requires "Coordination with federal, state, and local agencies and Indian tribes in developing and implementing the wildlife action plan."

The input of several habitat experts was compiled and then further supported by independent research. Existing state wildlife conservation plans used by the WGFD were consulted.[1] Drafts of each terrestrial habitat type were submitted to habitat experts for review and later to the WGFD Assistant Habitat Program Manager and Staff Biologist, Steve Tessman. The reviewed habitat types were electronically posted for review by the WGFD Nongame Section, Habitat Technical Advisory Group, State Wildlife Action Plan Interagency Advisory Team, and representatives from each agency and organization that had contributed information to at least one of the habitat sections. Near the end of each section is a list of individuals who reviewed the document and provided feedback. Before completion, additional edits were incorporated based on feedback from the WGFD Administration, the Wyoming Game and Fish Commission, and the public.

The thoroughness of information and specificity of recommended conservation actions in the sections for each habitat type and aquatic basin vary based upon existing knowledge, the availability of information, and the input provided by section contributors. Individuals providing input were instructed to list only the threats and conservation actions that they believed would have the greatest impact on the habitat type or aquatic basin. As a result, not all issues that may apply to a particular habitat type or aquatic basin are identified, but rather each section provides an overview of the most important issues

Aquatic Basins

Information on watershed characteristics, description of aquatic wildlife, identification of conservation areas, current conservation initiatives, and recommended conservation actions and future monitoring for each aquatic basin were developed originally by four WGFD biologists: the Fish Management Coordinator, Assistant Fish Management Coordinator, Aquatic Habitat Program Manager and the Assistant Aquatic Habitat Program Manager. Information was gathered by consulting department records and sources as well as other pertinent scientific and government agency sources. The WGFD Strategic Habitat Plan was consulted in some cases for development of conservation areas. Drafts of each basin were electronically posted for review by WGFD Fish Division biologists and the public.

Terrestrial Habitat Type and Aquatic Basin Format

Each SWAP habitat type and aquatic basin section is designed to function as a standalone document. This format was adopted because it is anticipated that Wyoming's SWAP will most

[1] Plans included the WGFD's Strategic Habitat Plan (Wyoming Game and Fish Department 2009), Nongame Bird and Mammal Plan (Wyoming Game and Fish Department 1996), A plan for Bird and Mammal Species of Greatest Conservation Need in Eastern Wyoming Grasslands (Wyoming Game and Fish Department 2006), Wyoming Partners In Flight Wyoming Bird Conservation Plan (Nicholoff 2003), Wyoming Wetlands Conservation Strategy (Wyoming Joint Ventures Steering Committee 2010), and A Conservation Plan for Bats in Wyoming (Hester and Grenier 2005).

frequently be accessed through the internet for information on specific subjects, as opposed to being accessed for the document in its entirety. Additionally, it is likely that individual sections of the SWAP will be duplicated and distributed. This approach resulted in some repeated information between habitat sections since many threats, conservation initiatives, conservation actions, and monitoring activities apply to more than one habitat type or aquatic basin. General descriptions of threats, conservation initiatives, and recommendations are provided along with information specific to the habitat type or aquatic basin. Various sections are frequently cross-referenced throughout the SWAP to provide the reader with additional information on a given topic.

The following subject headings are addressed within each terrestrial habitat type and aquatic basin:

Background
This topic heading provides a brief description of the geology, precipitation, vegetation, disturbances, and land uses of each habitat type and aquatic basin.

Maps depicting location and conservation priority areas
The maps identify the location of the habitat type or aquatic basin within Wyoming. Terrestrial maps for the 11 habitat sections were created by displaying the locations of all NatureServe Ecological Systems that comprised a particular habitat type. SWAP Species of Greatest Conservation Need (SGCN) priority areas were superimposed over these habitat maps. Maps depicting the aquatic basins were developed in GIS following Habitat Unit Code boundaries. Separate maps were developed to portray conservation priority areas. **Note the table and figure numbering begins at one (1) in the Introduction, Terrestrial Habitat, and Aquatic Basins sections.*

Associated SGCN
This topic heading lists Wyoming SGCN dependent upon the habitat type or aquatic basin. SGCN may be listed under more than one terrestrial habitat type or aquatic basin. Within the aquatic basin sections, the number of native and introduced aquatic species, number of SGCN, number of extirpated species, and examples of non-SGCN native species are provided. The lists and discussion include fish, aquatic reptiles, mollusks, clams, and gastropods.

Wildlife
This topic heading includes information on: wildlife numbers and species diversity within the habitat or aquatic basin; how the habitat's structure, function, and ecological processes relate to the wildlife it supports; habitat attributes that are critical to supporting associated SGCN; and non-SGCN wildlife species of high social, ecological, or economic value, including keystone species and game species that are associated with the habitat or aquatic basin.

Threats
This topic heading contains primary threats to habitat types or aquatic basins. The threats listed are not intended to be exhaustive, but represent the most significant threats in Wyoming. A description of the general impacts of the threats is provided. Threats were ranked as high, medium, or low in severity based on the input provided by habitat and wildlife experts.

Current conservation initiatives
This topic heading lists local, regional, or national efforts to conserve, manage and/or enhance the habitat type or aquatic basin relevant to Wyoming. Efforts that are listed include those that are particularly large in size and scope, address conservation goals or threats identified within the particular habitat type or aquatic basin or within Wyoming's 2005 Comprehensive Wildlife Conservation Strategy, use specific SWAP-related funds[2], or are established specifically in support of the SWAP.

Recommended conservation actions
This topic heading identifies conservation actions that may have the most significant impact for the long-term conservation of the

[2] State Wildlife Grants, Wyoming Governor's Endangered Species Account, or Wyoming Legislative Sensitive Species Funding.

wildlife value of each specific habitat type or aquatic basin. Conservation actions are listed in general order of priority.

Monitoring activities
This topic heading lists activities that are most achievable and effective in determining the quantity and condition of the habitat type or conditions or species within the aquatic basins, or the success of the recommended conservation actions.

Priority Area Identification

Terrestrial Habitat Types
Areas of the state important for terrestrial SGCN were identified using Marxan, a software tool for systematic conservation planning and reserve selection (Ball et al. 2009, Game and Grantham 2008). The basic steps in using Marxan involve defining planning units, selecting conservation features, setting targets for each feature, and creating a cost layer. The software identifies combinations of planning units that meet defined conservation targets for the lowest cost (Ball and Possingham 2000). The decision to use Marxan for identifying SGCN priority areas was based on the desire for a transparent, objective, and repeatable process that used the best available data on SGCN distributions and habitat condition. The application of Marxan was performed by WGFD geographic information systems **(**GIS) personnel with assistance from its Nongame Section. Training and consultation on the use of Marxan were received from the Wyoming chapter of the Nature Conservancy.

Planning Units
A statewide grid of 1 mi.^{2} hexagons was created, with each of the 98,435 hexagons considered an individual planning unit. Planning units of this size were considered small enough to take advantage of the higher resolution (30 X 30 meter) datasets for SGCN distribution, habitat location, and habitat condition.

Conservation Features
Conservation features included terrestrial SGCN and the eleven habitat types. The location of SGCN across the state was based on the distribution models developed by WYNDD (Keinath 2010). The location of the eleven habitats was based on the Northwest ReGAP dataset for the state of Wyoming (Gap Analysis Program 2010). The area of each SGCN and habitat type inside of each hexagon planning unit was calculated and used to attribute the planning unit for Marxan analysis.

Conservation Feature Targets
Establishing meaningful and realistic conservation targets is challenging. There is no scientific consensus as to the number or size of populations for individual species that should be conserved to ensure their long-term viability (Groves et al. 2002). For the SWAP, conservation targets were established for all 127 terrestrial SGCN based upon each species' distribution and conservation status. Targets were percentages of each species' modeled Wyoming distribution and ranged from 15% to 50% with a mean of approximately 26%. The selection of this range was based upon recommendation from other conservation planning efforts (Groves and The Nature Conservancy 2003, Neely 2006).

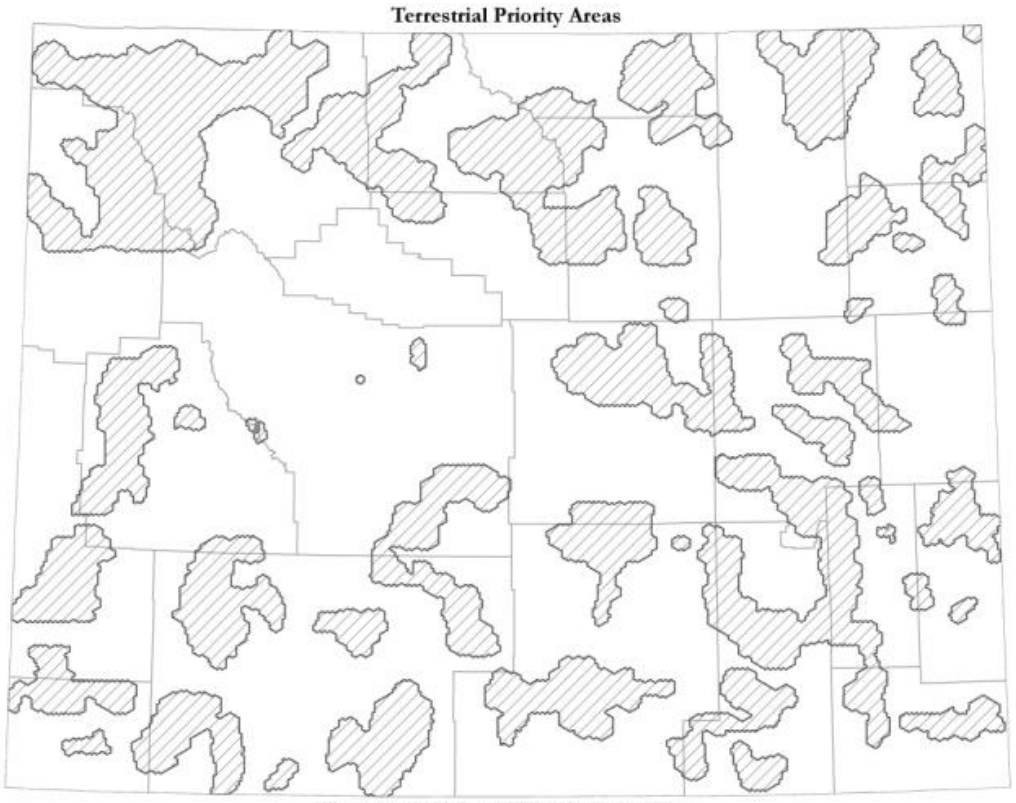
The target for each SGCN was calculated based on its NSS rank (NSS1-NSS4, NSSU) and its range (endemic, limited, disjunct, widespread, or peripheral), with NSS rank contributing up to 35% toward the target and range contributing up to 15%. Most SGCN had targets in the middle of that target range (i.e., 20-30%). Only one species (Wyoming toad) had a target of 50%, and only four species had targets of 15%. All eleven habitat types were given targets of 30%.

Cost Layer
Following the methods outlined in Copeland et al. (2007), the cost layer for Marxan analyses was created to reflect current anthropogenic surface disturbance based on eight criteria: cultivated and hay lands, oil and gas pipelines, oil and gas wells, powerlines, residential development, roads, surface mines, and wind

turbines. Disturbance was calculated for each dataset at a 30-meter resolution and then combined to give a score from zero (low human disturbance) to 100 (high human disturbance). For Marxan analyses, the average disturbance level was calculated for each planning unit and then reclassified to a 4-point scale where 1 indicates low human disturbance and 4 indicates high human disturbance.

Based on the results of Marxan, 44 priority areas were identified (Figure 3). Individual areas range in size from 7 to approximately 4,550 square miles with a mean size of 665 square miles, and cover slightly less than 30% of the state (29,225 square miles). Larger priority areas are comprised of a mix of habitats, and capture the distributions of many terrestrial SGCN. For example, the largest priority area, located in and around Yellowstone National Park, is dominated by Montane/Subalpine Forest, Mountain Grasslands, and Foothill Shrubland habitats, but includes all 11 habitats. It also captures some of the distributions of 81 SGCN, meets the full conservation targets of 11 SGCN, and meets more than half of the conservation targets for 33 SGCN. In contrast, some of the smaller priority areas consist almost entirely of a single habitat type and, in part because of their smaller size, capture the distributions of relatively few SGCN. Priority areas identified with Marxan should be considered as a network that meets conservation targets at the minimum cost, and can not necessarily be interpreted meaningfully as standalone areas. The priority area network has a complementary value that results in the sum exceeding the value of the individual areas (Ball et al. 2009).

Figure 3



The priority areas developed for SWAP meet or exceed the representation targets for 104 of the 138 conservation features. Of the 34 features represented in the priority areas at less than their target, most were very close to the target. Only two SGCN (least weasel, 89%; yellowpine chipmunk, 93%) and one habitat type (Mountain Grasslands, 94%) are represented at less than 95% of their targets. Some SGCN are markedly overrepresented. For example, more than three times the target distributions of northern myotis, pinyon mouse, fisher, and Hayden's shrew are captured by the priority areas. SGCN which are the most overrepresented tend to be located in only a few of the priority areas.

Three of the habitat types (Mountain Grasslands, Montane Subalpine Forests, Aspen/Deciduous Forests) are found in less than half of the priority areas. The other eight types are found in at least 24 of the 44 areas, often, however, as only minor habitat components. Four of the habitat types (Riparian, Wetlands, Sagebrush Shrublands, Desert Shrublands) are found in more than 40 of the areas. Eight of the priority areas, including the four largest, capture portions of all eleven habitat types. The smallest priority area (7 mi.^{2}) contains only three habitat types. Breakdowns of conservation targets achieved by each SWAP SGCN priority areas are available upon request from the WGFD.

The basic conservation goal addressed by this analysis was to efficiently capture the target distributions of all terrestrial SGCN and habitat types. For conservation planning purposes, SWAP SGCN priority areas maps are best used in conjunction with other maps identifying high value wildlife areas. This can be accomplished through multi-layer GIS analysis. The relative priority of locations based on SWAP goals can be compared with prioritization based on different goals. SGCN priority areas overlap three existing priority area datasets previously developed by Game and Fish: sage-grouse core areas, SHP crucial areas, and key nongame wildlife areas. The largest area of overlap (17,726 sq miles) is with crucial areas developed for the Strategic Habitat Plan. Although SGCN were considered when delineating the SHP crucial areas, other criteria (sage-grouse core areas, WGFD-managed properties, big game ranges, aquatic resources, etc.) were equally important. Area of overlap is smaller between SGCN priority areas and both sage-grouse core areas (8,480 mi.^{2}) and key nongame wildlife areas (5920 mi.^{2}). However these two sets of priority areas cover less of the state than the SHP crucial areas.

SGCN priority areas developed for this report used a measure of existing anthropogenic disturbance as a cost. The effect of this was to steer the selection of planning units, and thus priority areas, away from developed and disturbed areas. Approximately 25,000 square miles (85%) of the priority areas are in cost class 1, with only 135 square miles (< 1%) in cost class 4, the most disturbed class.

SWAP SGCN priority areas will be updated in subsequent revisions of the SWAP as new data becomes available and as threats and SGCN change. Planned analyses include using spatial data on locations where threats, such as energy development, invasive species, climate change, and rural subdivision, are expected to intensify so as to rank priority areas accordingly to their vulnerability. In future Marxan analyses, these threats will be used as a second or alternate cost surfaces. Additionally, identifying and maintaining habitat linkages between SWAP SGCN priority areas, to facilitate wildlife movement, will be an important goal for the 2015 SWAP. Very little wildlife data from the Wind River Indian Reservation was included in the MARXAN analysis which identified SWAP SGCN priority areas. Efforts are planned to increase data sharing with the Wind River Tribes before the 2015 revision. The WGFD will make shape files of SWAP SGCN priority areas available on the Web or through other means.

Aquatic Priority Conservation Areas

Some native fish species have been lost from the major river basins in Wyoming. For

example, shovelnose sturgeon, sauger, goldeye, sturgeon chub, and plains minnow are no longer found in the North Platte River basin due primarily to the construction of large reservoirs and habitat alteration. However, these and the majority of other Wyoming fishes can still be found in some waters in the state. Biologists recognize that they cannot conserve these species in each location they were currently identified in,, so they strive to identify the best places throughout the state so that they can actively work to preserve native fish, amphibians, turtles, and mollusks. These areas are referred to as priority conservation areas. The most valuable areas that remaining for Wyoming's warmwater species are generally found on private ranch lands and lands owned and managed by the Bureau of Land Management. Priority coldwater habitats are generally found on lands owned and managed by the U.S. Forest Service or National Park Service.

In many cases, the priority conservation areas identified in the SWAP had already been identified during the development of the WGFD's Strategic Habitat Plan (SHP). In the SHP, drainages or portions of drainages that needed to be protected or managed in order to maintain Wyoming's aquatic SGCN were called "crucial" aquatic habitat areas. Many of these crucial areas were included as priority conservation areas for aquatic wildlife in the SWAP.

In many Wyoming basins non-traditional funding sources have enabled WGFD biologists to complete extensive surveys of fishes and aquatic habitats in recent years. The department has a wealth of new information in some basins, which aids in the identification of places for conservation of Wyoming's native fishes. For example, the WGFD recently completed an exhaustive survey of fishes throughout the Green River basin, surveying 377 sites in 13 different streams in the basin (Gelwicks et al. 2009). The project enabled the WGFD to accurately assess the populations and distributions of native fishes. Subsequently, this information was used to identify a handful of priority aquatic habitats in the Green River basin for the conservation of SGCN. A second example is the Platte River basin. In the 1990s, a researcher from the University of Wyoming surveyed 68 sites on streams in the North Platte drainage and 8 sites on tributaries to the South Platte River (Patton 1997). The WGFD later conducted extensive surveys throughout these drainages in 2004 and 2005, sampling 54 sites and handling over 30,000 fish (Bear and Barrineau 2007). In 2008 and 2009, another project was conducted that surveyed 37 sites in the North Platte drainage and 7 sites in the South Platte drainage (Moan et al. 2010). The data collected during these projects were then used to identify the most important streams in the Platte River basin for the conservation of native fishes (Patton 2001, Bear 2006). In some cases, crucial areas in the SHP are the same as the priority areas that were identified by these surveys. In other cases, these surveys were not completed in time to be incorporated into the SHP.

The priority conservation areas in the SWAP were identified using the best available fish and habitat survey information. These areas generally represent only a fraction of the streams in each basin, but the management of fishes and habitats in these streams is critical to WGFD efforts to conserve Wyoming's rarest native fishes. Unfortunately, this detailed survey information is still lacking for mollusks, and crustaceans. The list of priority conservation areas will likely be revised as the department gains more information about where these species are found and what habitats they require.

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Appendix A

Wyoming State Wildlife Action Plan Terrestrial Habitat Type	NatureServe Ecological System
Mountain Grassland	1. Northern Rocky Mountain Subalpine-Upper Montane Grassland 2. Rocky Mountain Alpine Turf 3. Rocky Mountain Alpine Dwarf-Shrubland 4. Rocky Mountain Subalpine-Montane Mesic Meadow 5. Southern Rocky Mountain Montane-Subalpine Grassland 6. Harvested forest-grass regeneration
Prairie Grasslands	1. Inter-Mountain Basins Semi-Desert Grassland 2. Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland 3. Northwestern Great Plains Mixedgrass Prairie 4. Western Great Plains Foothill and Piedmont Grassland 5. Western Great Plains Sand Prairie 6. Western Great Plains Shortgrass Prairie 7. Introduced Upland Vegetation – Forbland 8. Introduced Upland Vegetation - Annual Grassland 9. Introduced Upland Vegetation - Perennial Grassland 10. Recently burned grassland
Sagebrush Shrublands	1. Great Basin Xeric Mixed Sagebrush Shrubland 2. Inter-Mountain Basins Big Sagebrush Shrubland 3. Columbia Plateau Low Sagebrush Steppe 4. Inter-Mountain Basins Big Sagebrush Steppe 5. Inter-Mountain Basins Active and Stabilized Dune 6. Wyoming Basins Dwarf Sagebrush Shrubland and Steppe
Desert Shrublands	1. Western Great Plains Badland 2. Inter-Mountain Basins Shale Badland 3. Northwestern Great Plains Shrubland 4. Inter-Mountain Basins Semi-Desert Shrub-Steppe 5. Introduced Upland Vegetation - Shrub 6. Inter-Mountain Basins Mat Saltbush Shrubland 7. Inter-Mountain Basins Mixed Salt Desert Scrub 8. Inter-Mountain Basins Greasewood Flat

Foothills Shrublands	1. Harvested forest-shrub regeneration 2. Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland 3. Northern Rocky Mountain Montane-Foothill Deciduous Shrubland 4. Northern Rocky Mountain Subalpine Deciduous Shrubland 5. Rocky Mountain Lower Montane-Foothill Shrubland 6. Western Great Plains Wooded Draw and Ravine 7. Inter-Mountain Basins Montane Sagebrush Steppe
Montane/Subalpine Forests	1. Northern Rocky Mountain Subalpine Woodland and Parkland 2. Northern Rocky Mountain Mesic Montane Mixed Conifer Forest 3. Rocky Mountain Lodgepole Pine Forest 4. Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland 5. Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland 6. Middle Rocky Mountain Montane Douglas-fir Forest and Woodland 7. Rocky Mountain Poor-Site Lodgepole Pine Forest 8. Recently burned forest 9. Harvested forest-tree regeneration 10. Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland
Aspen/Deciduous Forests	1. Rocky Mountain Aspen Forest and Woodland 2. Western Great Plains Dry Bur Oak Forest and Woodland 3. Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland 4. Rocky Mountain Bigtooth Maple Ravine Woodland

Xeric Forests	1. Rocky Mountain Foothill Limber Pine-Juniper Woodland 2. Northern Rocky Mountain Ponderosa Pine Woodland and Savanna 3. Southern Rocky Mountain Ponderosa Pine Woodland 4. Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland 5. Inter-Mountain Basins Juniper Savanna 6. Northern Rocky Mountain Foothill Conifer Wooded Steppe 7. Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna 8. Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland
Riparian Areas	1. Western Great Plains Floodplain 2. Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland 3. Rocky Mountain Lower Montane Riparian Woodland and Shrubland 4. Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland 5. Rocky Mountain Subalpine-Montane Riparian Woodland 6. Rocky Mountain Subalpine-Montane Riparian Shrubland 7. Northwestern Great Plains Riparian 8. Western Great Plains Riparian Woodland and Shrubland
Wetlands	1. Open Water 2. Pasture/Hay 3. Inter-Mountain Basins Playa 4. Introduced Riparian and Wetland Vegetation 5. Great Plains Prairie Pothole 6. Rocky Mountain Alpine-Montane Wet Meadow 7. Western Great Plains Open Freshwater Depression Wetland 8. North American Arid West Emergent Marsh 9. Columbia Plateau Vernal Pool 10. Rocky Mountain Subalpine-Montane Fen 11. Western Great Plains Closed Depression Wetland 12. Western Great Plains Saline Depression Wetland 13. Inter-Mountain Basins Alkaline Closed Depression 14. Inter-Mountain Basins Interdunal Swale Wetland

Cliff/Canyon/Rock Outcrop	1. Rocky Mountain Cliff, Canyon and Massive Bedrock 2. North American Alpine Ice Field 3. Rocky Mountain Alpine Bedrock and Scree 4. Western Great Plains Cliff and Outcrop 5. Inter-Mountain Basins Cliff and Canyon 6. Rocky Mountain Alpine Fell-Field
Excluded	1. Developed, Open Space 2. Developed, Low Intensity 3. Developed, Medium Intensity 4. Developed, High Intensity 5. Quarries, Mines and Gravel Pits 6. Cultivated Cropland 7. Introduced Upland Vegetation - Treed 8. Geysers and Hot Springs

Aspen/Deciduous Forest

Photos courtesy of WGFD

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Habitat Description

Deciduous trees and shrubs occur in a number of Wyoming's State Wildlife Action Plan (SWAP) habitat types in varying proportions. For the purposes of this plan, the Aspen/ Deciduous habitat type is defined as the four NatureServe Ecological Systems where aspen, bur oak, Gambel oak, or bigtooth maple are dominant (Table 1). It spans a range of sites from pure upland to almost completely riparian in nature. A review of the NatureServe land cover classification (NatureServe 2010) reveals several other ecological systems that support deciduous vegetation in Wyoming. Common dominant species in these systems include narrowleaf and plains cottonwood, green ash, box elder, elm, choke cherry, Rocky Mountain maple, alder, and peachleaf willow. Importantly, these cover types are almost exclusively riparian in nature and are thus covered in the SWAP's Riparian Area habitat type description (page III-8-1).

Quaking aspen provides important wildlife habitat in Wyoming. It is the most widely distributed deciduous tree in North America (Little 1971), and about 467,000 acres (190,000 ha) of it occur throughout Wyoming (Nicholoff 2003). The largest concentrations are found on the Sierra Madre, Wyoming, Wind River, and Gros Ventre ranges with sizable stands also occurring in the Medicine Bow and Laramie Mountains of southeastern Wyoming. Relatively little contiguous aspen occurs in the Black Hills and Bear Lodge Mountains, Bighorn Mountains, Absaroka Range, Teton Range, or the Yellowstone Plateau (Nicholoff 2003). Aspen tends to be found in smaller and more isolated stands in Wyoming than elsewhere in the West. An exception would be the west slope of the Sierra Madre Mountains.

Very small and isolated aspen stands occur in Wyoming's intermountain basins as well, typically where large and persistent snowdrifts collect through the winter and provide abundant moisture into the growing season. These small stands often support unique forest wildlife species that otherwise would not occur in these dry, sagebrush-dominated landscapes (Jones 2009).

Aspen occurs where annual precipitation exceeds evapotranspiration. Typically, these sites have at least 15 inches of annual precipitation, but more than 20 inches is common (Jones and DeByle 1985). At these sites winters are often cold with deep snowpack, but the growing season is reasonably long (Jones and DeByle 1985). Aspen communities commonly occur in riparian or spring/seep situations where there is permanent or semi-permanent surface water. The restriction of aspen to moist areas is probably more related to the intolerance of aspen seedlings to drought, as opposed to conditions needed by mature trees (Knight 1994).

Aspen is one of the few plants that can be found in all mountain vegetation zones from alpine tundra to the basal plains (Daubenmire 1943). Elevation limits of aspen in the western United States range from 5,200 to 10,500 ft (Mueggler 1988). At low elevations, aspen growth is often restricted by the availability of moisture, while at higher elevations the length of the growing season is the limiting factor. As a result, at lower elevations, aspen frequently occurs as stringers or small islands on the fringe of the semi-arid sagebrush-grass steppes (Jones 2009). At intermediate elevations, aspen commonly occur on northerly and easterly exposures or in swales or draws which collect moisture (Mueggler 1988). At the higher elevations, persistent stands of aspen are frequently restricted to southern exposures.

Successful regeneration of aspen is associated with natural and human-caused disturbances and gaps in the vegetation canopy. This is due to the inability of aspen to compete in low light environments (Manier and Laven 2001). Natural disturbances include blowdowns, landslides, flooding, and disease, but fire is probably the most important (Nicholoff 2003). Over time, aspens are often replaced by Engelmann spruce, subalpine fir, Douglas fir, blue spruce, lodgepole pine, and ponderosa pine. The conversion back to conifer-

dominated species can occur in less than 100 years or take as long as 400 years depending upon disturbance factors, proximity to conifer seed sources, site conditions, and rate of conifer seedling growth (Nicholoff 2003). At higher elevations, aspens can persist as a subdominant species within lodgepole pine and spruce-fir communities. At intermediate elevations and on deep soils, aspen can occur as scattered stands of successionally-stable, climax woodlands within coniferous forests (Nicholoff 2003).

The location of aspen groves is highly related to microsites that provide favorable moisture and soil site conditions. The tendency of aspen to grow in stands is also influenced by the ability of new trees to be formed by genetically identical sprouts or suckers (Knight 1994). Although individual trees or shoots die after about a hundred years, the clonal root system can survive for thousands of years (Barnes 1975). Single clones can be as large as 200 acres (Kemperman and Barnes 1976). The fact that aspen stands are typically composed of genetically identical trees explains why nearby stands of aspen often turn color at different times in the fall.

Aspen suckers sprout most vigorously following disturbance, with more than thirty thousand sprouts per hectare especially following hot fires; however, many do not survive (Brown and DeByle 1989, Bartos and Mueggler 1991). Aspen sprouts have access to relatively large amounts of stored carbohydrates, allowing them to grow quickly and providing them with a competitive advantage over trees that reproduce by seeds (Knight 1994). The majority of aspen sprouting occurs during the first three to six years after a disturbance which contributes to the formation of even-aged stands. Multiple age classes can occur when older stands begin to die and the canopy opens, stimulating the production of new suckers (Nicholoff 2003). The sexual reproduction of aspen in the Rocky Mountain West is extremely rare. Some speculate that proper conditions for seedling establishment may exist at intervals of 200–400 years (Jelinski and Cheliak 1992). Therefore, when aspen is lost from the landscape it may not reestablish from seed over a management-relevant time scale (Dale 2001).

A broad range of plant species can be found in association with aspen because of the diverse elevation and topography at which it occurs. A characteristic element among nearly all aspen communities is the lush understory of plants when compared to nearby coniferous forests. The abundance and diversity of plants found in the aspen understory results in very high forage availability for both wildlife and livestock. This understory produces insect biomass as well.

Aspen can be considered a keystone species because of the relatively high diversity of plant and animals that depend on them (Dale 2001). Aspen have declined from 50–96% throughout the West (Bartos and Mitchell 2000). It has been estimated that aspen loss in Wyoming since European settlement is as high as 53% (Stam et al. 2008), but there is some debate by researchers over such high estimates. A recent study estimated an average of only 10% loss in the Greater Yellowstone Ecosystem (Brown et al. 2006). Current extensive mortality of conifers from bark beetle infestations may benefit aspen regeneration and expansion in much of Wyoming.

Due to their productivity and species diversity, aspen communities are one of the most valued western habitat types. Besides wildlife habitat and livestock forage production, aspen contribute to maintaining water quality and quantity, provide valued recreational sites, and are appreciated for their aesthetic beauty.

Other deciduous woody species commonly found in association with aspen in Wyoming foothills escarpments are bur oak (in northeastern Wyoming only), Gambel oak (in south central Wyoming only), choke cherry, box elder, and wild plum. Paper birch co-occurs with aspen in the upper elevations of the Wyoming Black Hills. Like aspen, these species occur on wetter sites with deeper soils. The wetter nature of these sites is most commonly due to greater snow accumulation, more

summer precipitation, or runoff from adjacent slopes.

Oak-dominated woodlands are found only in small areas of the northern and eastern slopes of the Black Hills (bur oak) and on the east side of the Sierra Madre (Gambel oak) (Knight 1994). Spring frost and summer drought have limited the spread of Gambel oak northward (Neilson and Wullstein 1983). Both bur oak and Gambel oak woodlands are fire prone, but the species re-sprout vigorously and may increase in density after fire (Harper et al. 1985). Fire suppression has enabled these species to locally expand into less fire-adapted communities, including Rocky Mountain juniper and ponderosa pine. Such mixed communities often present a multi-tiered canopy, with oak species forming a prominent deciduous mid-layer between the understory and conifer canopy. This physical habitat arrangement is rather rare in Wyoming and is perhaps more reminiscent of eastern North American woodlands. Its value to wildlife communities in the West is not well understood and may be a valuable topic for future research.

Portions of northeastern Wyoming support moist ravines and draws dominated by bigtooth maple and a suite of associated deciduous shrubs. These rather productive communities are most common in the foothill zones of the eastern Bighorn Mountains and Black Hills, and are more typical in the northern Great Plains to the north and east of Wyoming.

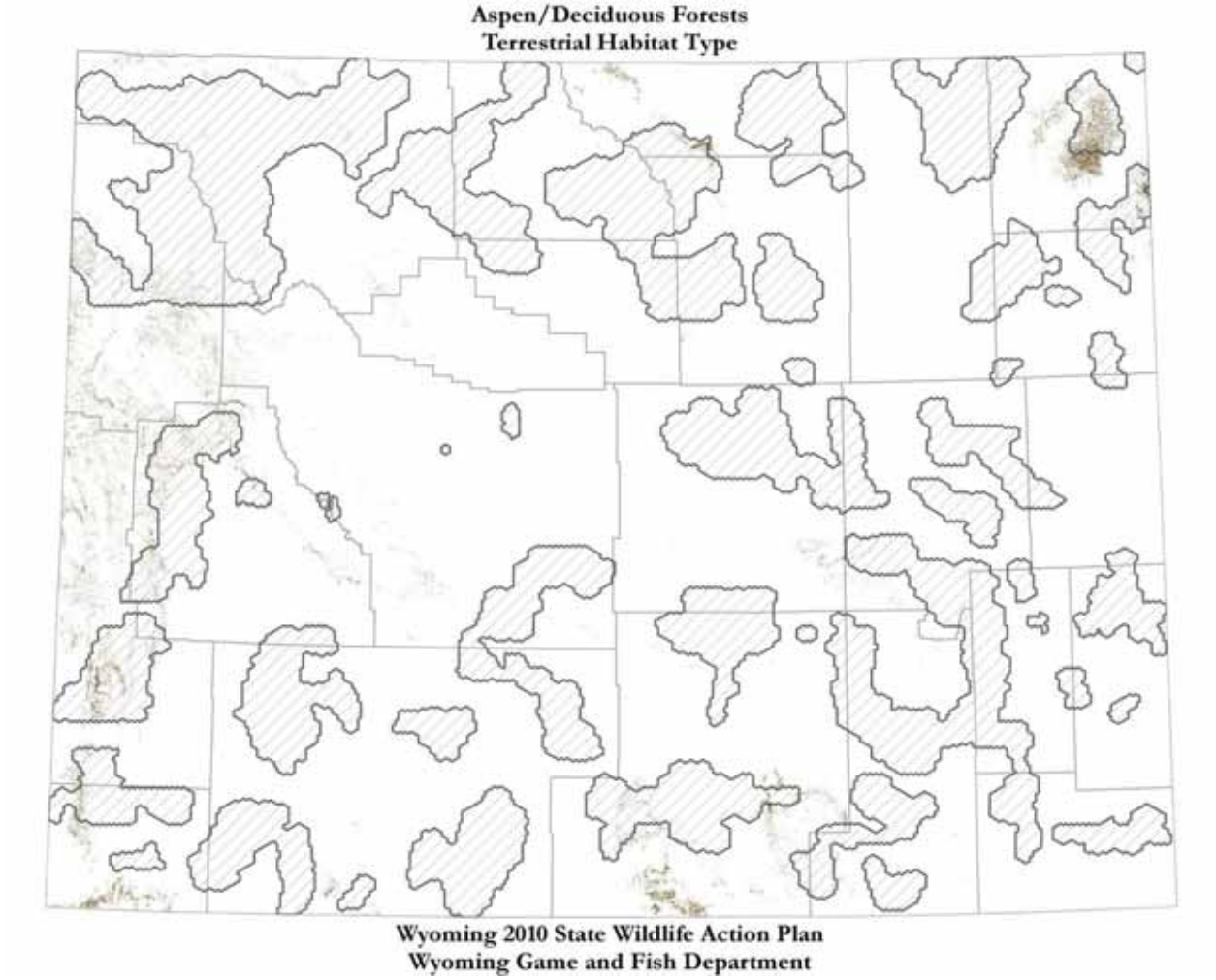

FIGURE 1. Wyoming Aspen/Deciduous Forests and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 1. Wyoming Aspen/Deciduous Forest NatureServe Ecological Systems[1]

1. Rocky Mountain Aspen Forest and Woodland
2. Western Great Plains Dry Bur Oak Forest and Woodland
3. Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
4. Rocky Mountain Bigtooth Maple Ravine Woodland

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://www.natureserve.org/explorer.

TABLE 2. Wyoming Aspen/Deciduous Forest Species of Greatest Conservation Need

Mammals
Big Brown Bat
Dwarf Shrew
Eastern Red Bat
Fringed Myotis
Little brown Myotis
Long-eared Myotis
Long-legged Myotis
Moose
Northern Myotis
Pallid Bat
Pygmy Shrew
Spotted Bat
Western small-footed Myotis
Townsend's Big-eared Bat
Vagrant Shrew

Birds
American Three-toed Woodpecker
Black-backed Woodpecker
Boreal Owl
Columbian Sharp-tailed Grouse
Great Grey Owl
Lewis's Woodpecker
Northern Goshawk
Pygmy Nuthatch

Reptiles
Black Hills Red-bellied Snake
Plains Gartersnake
Red-sided Gartersnake
Smooth Greensnake
Valley Gartersnake

Amphibians
Boreal Toad
Columbian Spotted Frog
Wood Frog

Aspen/Deciduous Forest Wildlife

Aspen communities are valued for high water yield and high biomass productivity, and are ranked second only to riparian areas in wildlife diversity (Kay 1997). These attributes result in aspen having the second highest priority for habitat improvement projects in the Wyoming Game and Fish Department (WGFD) Strategic Habitat Plan (SHP).

Aspen stands typically support high grass and forb production in their understories, providing important foraging sites for large and small herbivores such as mule deer, elk, moose, black bear, blue grouse, chipmunks, and snowshoe hares. High productivity conditions usually also produce large numbers of invertebrates, which make aspen forests important foraging sites for insectivores such as shrews, bats, and many bird species.

About 88 species of birds potentially use aspen habitats in Wyoming (Nicholoff 2003). Bird communities within aspen stands include species which spend the majority of their time within the aspen community itself, as well as species that visit aspen stands periodically for foraging or other specific purposes while also using surrounding habitats. Breeding bird density in aspen stands is related to surface water and ground moisture levels, the number and size of insects in the aspen understory, and the structure and species diversity of plants found on the border of adjoining habitat types (Nicholoff 2003). Bird diversity has been positively correlated to the size (Johns 1993) and maturity of aspen stands (McGraw-Bergstrom 1986), and mature stands of aspen have greater bird diversity than younger stands and those being invaded by conifers. Mature aspen stands are particularly important to cavity nesting birds, as the trees have soft wood and are prone to infection and decay. The trunks of deciduous trees are often excavated by primary cavity excavators, such as woodpeckers, which are then followed by secondary cavity nesters including bluebirds, swallows, and wrens.

Deciduous and aspen forests are especially important to bats. Generally, activity increases as the proportion of deciduous vegetation bordering streams and moth abundance increase. Bat diversity is greater in deciduous habitats than in coniferous habitats. Proximity to open water may provide a critical element for many bats that use deciduous forests. The greatest resources that aspen woodlands provide for bats are cavities for roosting. Aspen trees greater than 40 years of age almost always

harbor heart rot while they are alive and provide excellent conditions for primary cavity excavators (such as woodpeckers) and natural-cavity formation. These live trees are potentially more important to bats in this habitat type than snags (Hester and Grenier 2005).

The northern pocket gopher and beaver serve as keystone species in aspen communities by increasing local productivity and site diversity. Northern pocket gophers accomplish this through constant soil disturbance and root herbivory, which facilitates nutrient cycling, air and water penetration into the soil, and creates a fine-grained patchwork of understory plant communities in various stages of vegetational succession. In riparian and spring/seep situations, beavers create wetlands through damming, which can drown some aspen stems but can also increase adjacent soil moisture, which favors aspen growth. Beavers also affect aspen successional dynamics by browsing aspen heavily. Over time, older beaver ponds fail and drain, leaving moist soils and meadows that can be reclaimed by aspen.

In addition to cover, the acorns of bur oak and Gambel oak provide energy-rich food for wildlife including deer, elk, turkey, bear, and squirrels. Old stands of Gambel oak contain large amounts of dead crown wood and hollow boles and limbs that provide nesting sites for small mammals and birds (Nicholoff 2003). Co-occurring plant species such as choke cherry, box elder, black hawthorn, and wild plum are also important food and cover sources for wildlife. These same species commonly co-occur in bigtooth maple ravines as well. As previously discussed, mixed communities in which oak forms a prominent mid-story between a herbaceous layer and conifer canopy are rather rare in Wyoming and may play an important role in providing a unique habitat for some wildlife.

One of the largest remaining populations of Columbian sharp-tailed grouse in western North America spans the Colorado-Wyoming border in the vicinity of Baggs, Wyoming, and extends as far north as I-80. These birds depend heavily on aspen/deciduous forest habitat in this area, including sites dominated by Gambel oak and other associated species like choke cherry and serviceberry. The habitat in this area also supports smooth green snakes and, occasionally, band-tailed pigeons—both species are rather rare in Wyoming. White-tailed deer throughout Wyoming are often found in, or in close proximity to, aspen/deciduous forest habitat.

Aspen/Deciduous Forest Habitat Threats

Lack of aspen stand regeneration due to disruption of historic disturbance regimes – High

Aspen stands require periodic disturbance to become established and regenerate. Extensive fire episodes during the late 1800s and early 1900s resulted in many aspen stands being from 80 to +130 years old (Gruell 1980). Since this time, fire suppression and reduction of intentionally set human fires has reduced fire frequency in aspen communities. Many aspen stands are now reaching maturity and are increasingly vulnerable to disease or senescence. Colorado, Utah, and Wyoming have recently experienced major episodes of aspen death suspected to be related to both age and climate stress (U.S. Forest Service 2008). Recent increases in conifer mortality in Wyoming may create more opportunities for aspen regeneration.

Overbrowsing and trampling by wild and domestic ungulates can also have a negative impact on aspen regeneration, particularly in riparian areas and in areas with limited aspen groves. Both cattle and sheep browse on aspen leaves and twigs, but sheep typically eat four times as many aspen sprouts as cattle (Stubbendieck et al. 1986, U.S. Department of Agriculture, Forest Service 1937). Deer and moose can impact aspen regeneration, but elk are usually the most damaging because elk typically winter in or near mid-elevation zones where aspen forests are most common. Additionally, elk populations in Wyoming have increased dramatically over the last century.

Moose, which can spend the entire winter within a single aspen patch, can also cause significant, localized damage.

The WGFD sets big game herd unit population objectives based on a variety of factors including habitat condition within the herd unit, hunter demand, landowner input, and biological potential. These considerations result in mixed opinions as to what the objective should be. All objectives are taken to the public for review and approved by the Wyoming Game and Fish Commission. Although the WGFD collects habitat data across the state, seldom is it specific enough to tie the habitat condition directly back to a specific number of animals. Such data is useful; however, in understanding whether big game populations are within the limits of what the habitat can support. The WGFD strives to have populations that are in balance with the majority of the habitats within the herd unit.

Fire suppression works in concert with overbrowsing to reduce aspen regeneration. As aspen stands mature and sprouts become less common, browsing pressure intensifies on sprouts that remain. Furthermore, the removal of fine fuels by browsing and grazing can reduce fire frequency.

Fire suppression and overbrowsing, along with other factors such as disease, drought, and natural succession, often lead to the replacement of aspen by conifers. A decrease in plant diversity and water yield is common as conifers begin to dominate aspen stands (Dale 2001). Water loss can be as much as 5% (Harper et al 1981; Gifford et al. 1984). This results in less water being available for undergrowth and groundwater recharge. Over time this water loss reduces overall site productivity. Although conifer mortality from the current bark beetle epidemic may encourage aspen growth at some sites, the heavy fuel loads created by beetle kill may increase wildfire risk and intensity. Intense fires may overcome the natural fire resilience of aspen stands, resulting in significant above-ground stand mortality and possible below-ground mortality of parent rootstock, although aspen regeneration is often closely linked to the level of ungulate herbivory in the area (Bartos and Mueggler 1981).

Although browsing may not be of such concern in oak and bigtooth maple communities, successional dynamics related to fire are just as critical. Oak, in particular, regenerates vigorously after fire. Depending on site conditions, conifers and other vegetation can replace oak under scenarios of fire suppression; in other situations, fire may be used to reduce oak invasion of other vegetation types.

Drought and climate change – High

Drought has been known to cause the loss of seral aspen stands and contribute to a decline in aspen regeneration. In recent years, there have been dramatic die-offs of aspen in a number of locations in the West including Wyoming, Colorado, and Utah. The phenomenon has been termed Sudden Aspen Decline (SAD). SAD has been differentiated from known past aspen die-offs as it occurs on a landscape scale as opposed to within individual stands, displaying rapid mortality, and involving pathogens and insects which previously have not been a significant threat to aspen.

The onset of SAD has been linked to drought. Aspen stands located at low elevation, on south to west aspects, or with open canopies, are the most vulnerable to SAD, possibly due to higher localized temperatures (U.S. Forest Service 2009). During drought, aspen close off openings in their leaves as a survival measure to reduce water loss. This closure also slows the uptake of carbon dioxide which reduces the rate of photosynthesis. It is speculated that this may cause trees to absorb stored energy from their roots, eventually killing the roots and preventing the growth of new aspen sprouts (Worrall et al. 2008). Simultaneously, drought-weakened trees are more susceptible to attack from disease and insects, which would not be fatal for healthy trees.

In 2008 and 2009, U.S. Forest Service Aerial Detection Survey concluded that approximately 48,300 acres were affected by SAD in Wyoming within USDA Forest Service Region 2. Of this,

63% was in Carbon County, 12% in Converse County, and 9% in Albany County. SAD is a relatively new phenomenon and its causes are not fully understood. The phenomenon is particularly unusual because it appears to weaken even moderately vigorous root systems. A drier, warmer climate, which some climate models project for Wyoming (Christensen et al. 2007), may further impact the health of aspen communities in the state.

Aspen woodlands in riparian situations may be suffering drought-like effects from the historic reductions in beaver numbers and distribution. Fur trapping in the 19th century greatly reduced beaver numbers, extirpating them from many areas in Wyoming. By the late 20th century beavers re-occupied most of their historic range, but only at roughly 10% of pre-European-contact densities (Naiman et al. 1988). Among other important effects, beaver ponds raise water tables and increase the size of the riparian zones near surface water, which increases habitat quality for aspen. Ponds and adjacent banks also store snowmelt for release later in the year, increasing flows, riparian quality, and aspen habitat quality downstream. Although beaver browsing and ponding can reduce aspen numbers at times, over the long term a healthy beaver population forms a dynamic mosaic of patches of varying aspen seral stages along a stream network.

Small and isolated stands of aspen in Wyoming's intermountain basins are likely completely dependent on soil moisture from locally-formed snowdrifts, and thus are predictably threatened by drought (Jones 2009). Other deciduous tree communities in the West that rely on soil moisture may also be threatened by changing climate conditions, including warming temperatures and extended drought.

Lack of industry infrastructure – Moderate
The wood products industry has been a valuable contributor to aspen habitat improvement projects through removing encroaching conifers as part of aspen regeneration projects, lopping and scattering slash to augment fuel in aspen stands for broadcast burning, and using equipment to create control breaks for broadcast burning. Proceeds from timber sales on both U.S. Forest Service and Bureau of Land Management (BLM) lands have also been used to fund aspen habitat treatments.
Poor market conditions due to a depressed economy has resulted in the closure of timber mills and delayed harvest of timber sales under contract. Travel distances for sawmills that remain open can make timber harvest uneconomical. In many areas of Wyoming there is currently a lack of access to biomass, wood pellet, engineered wood products, or pulp industries to offset the loss of timber saw mills. The influence of beetle kill on the quality and amount of pine sawtimber will further alter the future of the wood products industry in Wyoming by having less usable sawtimber, but large amounts of dead biomass available.

Rural subdivision and development – Moderate
Rural subdivision and development can reduce, degrade, and fragment aspen and deciduous forest habitats (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). Houses, outbuildings, and lawns directly replace native wildlife habitat. Soil disturbance from construction, year-round grazing of horses and other hobby livestock, and the use of non-native plants as ornamentals can facilitate the establishment of invasive species that compete with native vegetation on site and, eventually, throughout a given region (Maestas et al. 2002).

Wildlife commonly abandons or alters use of habitats with greater human, vehicle, and pet activity. Increased energy expenditures in avoiding people or greater use of lower quality habitats can decrease animal health and reproductive capacity. Greater road densities and traffic volume can increase wildlife–vehicle collisions. Predation on wildlife can intensify with greater numbers of domestic dogs and cats, as well as increases in generalist predatory species such as ravens and human-commensal species like raccoons (U.S. Department of Agriculture 2007).

Rural subdivisions make accessing deciduous habitats for habitat treatments difficult. The number of private landowners from whom permission must be obtained to gain access to some public lands increases. Some new landowners are absentee landowners who reside in other states or countries, are often unaware of the need for habitat treatment, and tend to be initially opposed to cutting conifers.

Additionally, gaining the involvement of a sufficient number of private landowners to make the size of treatments ecologically and economically feasible can be difficult. This is often true of projects that involve portions of both public and private lands. This problem is particularly relevant for the BLM, which manages hundreds of isolated parcels that are landlocked by private properties and which have no legal access easements. The number, size, and condition of many deciduous stands in these areas are unknown.

Clearly, fire management options are greatly restricted in the vicinity of rural subdivisions, and, as previously discussed, fire is a large factor in determining the presence and persistence of aspen, oak, and other deciduous types. Fire managers have little choice but to suppress wildfires and avoid prescribed fires near subdivisions.

Current Aspen/Deciduous Forest Conservation Initiatives

A number of both public and private organizations have worked independently and cooperatively on aspen regeneration and habitat improvement projects. They include the Wyoming Game and Fish Department (WGFD), U.S. Forest Service, BLM, Wyoming State Forestry Division, Native American Tribes, the wood products industries, local conservation districts, and nonprofit wildlife conservation organizations such as the Rocky Mountain Elk Foundation. Coordination among these organizations is increasing as habitat improvement projects are more often implemented across administrative boundaries including public and private lands.

Considerable research has been conducted on aspen regeneration treatments over the last 30 years. The most common methods include prescribed fire, wildfire management, and mechanical techniques.

Fire can be more cost-effective for larger projects than mechanical treatments. An exception is when the conifer removal portion of some aspen regeneration projects generates commercially valuable timber, which can offset the cost of mechanical treatment.

Mechanical treatments through conifer removal are often coordinated with activities of the wood products industries. The BLM has been able to establish such projects with the cooperation of multiple private landowners in order to increase timber volumes to levels that are economically feasible. The establishment of the wood products biomass energy industry may provide new opportunities for aspen regeneration projects, both as a mechanism to administer treatments and as a funding source. To support the development of the biomass industry in Wyoming, several studies have researched forest products transportation costs, generating woody biomass energy at facilities associated with local sawmills, and building wood pellet manufacturing plants in the Bighorn Basin.

Funding and technical assistance for aspen regeneration projects in areas that are not commercially viable has come from timber sale proceeds, hazardous fuels reduction programs, the Wyoming Wildlife and Natural Resource Trust, Wyoming Game and Fish Trust Fund, Rocky Mountain Elk Foundation, and the Wyoming Conservation Corps. These treatments are often conducted using service contracts or seasonal BLM and U.S. Forest Service labor.

Several watershed and habitat restoration projects have been developed and implemented to improve the health and condition of aspen

communities throughout Wyoming. The Bates Creek Watershed Restoration Project was initiated on private lands in 2004 in Natrona County, with the Wyoming State Lands Division, BLM, and U.S. Forest Service working as partners with landowners. The project employed mechanical, fire, and harvesting techniques to help curb the encroachment of conifers into aspen stands.

The U.S. Forest Service has been re-evaluating all grazing allotments for the last 10 years and is close to completing this effort. Where degraded habitat conditions have been caused by livestock overgrazing, grazing management strategies have been enacted. Local conservation districts and the Natural Resources Conservation Service (NRCS) have provided technical and financial support for activities such as water development or fence construction to support the implementation of grazing plans. Inventory and monitoring of the condition of allotment, including aspen, is conducted by U.S. Forest Service range staff during annual inspections and during the 10-year allotment reviews. Many aspen stands proposed for regeneration are identified by these inspections.

Recently, the BLM High Desert District used prescribed burns to treat over 2,000 acres of aspen stands that have been encroached upon by conifers in the Red Canyon Allotment north of Big Piney and west of Pinedale. This effort is part of the larger Wyoming Front Aspen Regeneration project in which the BLM and the Rocky Mountain Elk Foundation are working together to improve the health of aspen communities along the Wyoming Range Front.

The WGFD has instituted liberal elk hunting seasons for the last decade in some hunt areas, in part, to reduce the impact of overbrowsing by elk on aspen communities. Additionally, aspen/deciduous forest habitat was identified in the WGFD Strategic Habitat Plan (SHP) as one of eight priority habitats to enhance or maintain. The WGFD began the North Laramie Habitat Restoration Project in the Deer Creek watershed in 2007 to create aspen stands with more age-class diversity using mechanical techniques and prescribed burns.
Relatively few conservation initiatives have been aimed directly at oak and bigtooth maple communities, likely because these communities cover significantly less area and show fewer signs of decline than do aspen communities.

Recommended Aspen/Deciduous Forest Conservation Actions

Conduct a statewide inventory of aspen stands to identify priority sites for aspen regeneration projects.
Stand-specific information is essential in identifying and prioritizing aspen stands for regeneration treatments. Flights or aerial photos during the fall, when the colorful leaves of aspen causes them to stand out, can be a cost-effective way to conduct initial surveys to determine status of overstory trees (mortality, defoliation, etc.). On-the-ground stand assessments are necessary to determine a community's seral stage, evaluate the extent of conifer encroachment, and assess the amount and species composition of the understory.

The presence of SAD and levels of regeneration and conifer encroachment should be used to prioritize aspen habitat treatments. Highest priority should go to stands where conditions will allow for successful establishment of mature aspen stands based on topographic and environmental conditions in order to prevent rapid conifer succession from overwhelming regenerating aspen shoots. The chance of success at regenerating stands with high levels of mortality can be low, but the possibility of limited success must be balanced against the possibility of permanent loss of aspen regeneration once an aspen clone dies.

Increase the number of treatments to regenerate aspen stands and create a mosaic of tree age classes.
Prescribed fire can be applied to closely resemble historic disturbance patterns and is often the most biologically and economically

effective method to treat large aspen stands. It is important that fire not only occurs within the stands, but also around the stands to reduce seed cast from adjacent conifer. Conifer-encroached stands, with commercial-size conifers, can be effectively treated in a two-stage process in which a mechanical treatment or commercial harvest is used to put slash on the ground, which is then followed by broadcast burning. Slash can facilitate the spread of fire through more open aspen stands. Mechanical treatment may be the only option in stands where fire is not feasible due to safety, invasive species, or other concerns.

Whenever possible, treatments should be conducted after landscape level assessments have been completed. To reduce impacts on wildlife species dependent upon large contiguous forests, adequate planning is needed to determine spacing and timing of aspen treatments . This will often involve cooperation among multiple landowners and agencies. The Wyden Amendment can be used to support these efforts. This law allows U.S. Forest Service and BLM money to be spent on non-federal lands as long as the project benefits fish, wildlife, and other resources on National Forest or BLM lands within an affected watershed (Public Law 105-277, Section 323 Public Law 104-208, Section 124, and Public Law 105-277, Section 136). Additional funding can be obtained through partnering with non-profit conservation organizations such as the Rocky Mountain Elk Foundation. Public education about the value and purpose of aspen regeneration treatments should occur to ensure ongoing support for aspen habitat improvement projects. Fire treatment can be used as a management tool for oak stands as well, with many of the above concerns applicable.

Encourage careful management of ungulates grazing in aspen habitats to facilitate regeneration.
Successful aspen recruitment in the presence of high ungulate use has been documented, but aspen sprouts can be destroyed by three successive years of browsing (Kilpatrick and Abendroth 2001, Keigley et al. 2002, Tew 1981). Several techniques are effective at managing ungulate browsing levels. Regenerating large amounts of aspen simultaneously and in close proximity to each other can disperse browsing pressure. Temporary solar-powered electric fences can be erected for several years after habitat treatments if browsing exceeds sucker growth. Timber slash placement can often mimic natural disturbances such as snags falling down following fire or bark beetle infestation and can be used as a fencing tool to inhibit ungulate access to the aspen regeneration sites. Within this context, resource managers should carefully consider stocking rates and other allotment specifications regarding livestock use of aspen-occupied areas, especially if such areas are undergoing or scheduled to undergo aspen treatments.

In cooperation with land management agencies and private landowners, reintroduce beavers into stream systems where they have been extirpated or occur at low densities and where appropriate food, security, and dam-building vegetation exists.

- Reintroduce beaver. Beaver dam-building activities can increase the size and quality of riparian habitats for a range of terrestrial and aquatic species (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Natural Disturbance Regimes), and create a shifting mosaic of riparian aspen stands in different seral stages.
- Use enhanced GIS mapping of riparian areas or other means to identify suitable reintroduction locations. Careful consultation should occur with landowners on or adjacent to reintroduction sites prior to reintroductions to minimize unintended economic losses.
- Restore watersheds and develop aspen and willow vegetation (another preferred beaver forage) to levels that will support beaver in targeted areas.

Land management agencies should require reciprocal access easements for the purpose of habitat treatments where access to new subdivisions crosses agency lands.

To reduce habitat loss and fragmentation, land trusts should be encouraged to negotiate conservation easements or other land agreements on private lands within and adjacent to U.S. Forest Service, BLM, and state trust lands.

Efforts should be made to support the continued role of the wood products industry in aspen regeneration projects by providing grants, such as those that were available through the U.S. Forest Service Economic Action Program, for market feasibility studies and new business ventures.

Additional research should be conducted to gain a better understanding of the causes of SAD and the potential impacts of climate change on aspen communities.

Aspen/Deciduous Forest Monitoring Activities

Monitor the landscape distribution and habitat intactness of aspen/deciduous forests through remote sensing and work to improve accuracy of these methods.
Remote sensing is useful in tracking the size and distribution of this habitat type in Wyoming. Information gathered would be helpful in determining the regeneration rate of aspen stands and the impact of SAD. Special attention should be given to monitoring the level and location of aspen death and regeneration in relation to SWAP SGCN priority areas that have a high proportion of the aspen/deciduous forest habitat type (Figure 1). This technique will require the further development of monitoring protocols and the identification of sample sites. Monitoring should be conducted in relation to the possible effects of climate change.

Inventory and monitor aspen stands in federal grazing allotments as part of annual inspections and during the 10-year allotment reviews.
Monitoring should include evaluation of aspen regeneration, community age and structure, conifer encroachment, plant understory composition, and whether or not SAD is present. Completed aspen treatments should be monitored to determine effectiveness of treatments, or whether the regeneration needs additional protection from excessive browsing for it to become established.

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Cliffs, Canyons, Caves, and Rock Outcrops

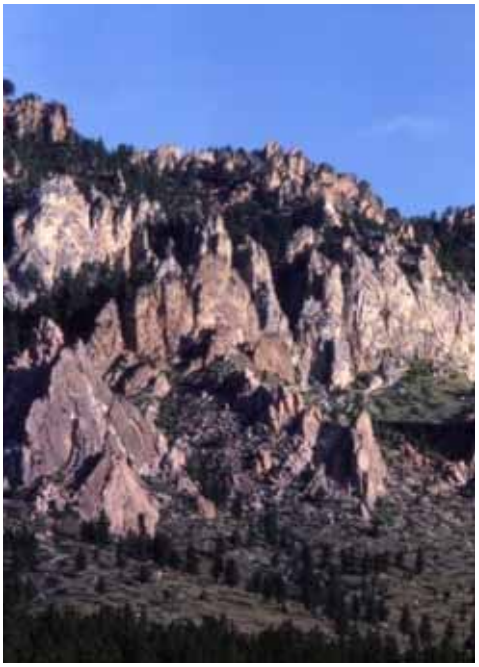

Photo courtesy of WGFD

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Much of the information for this section pertaining to caves and bats was derived from A Conservation Plan for Bats in Wyoming *(Hester and Grenier 2005). Those desiring additional information on bat conservation not covered in this section should consult that document.*

Habitat Description

Cliffs, canyons, and rock outcrops are common features of the mountainous West. Formation of the Rocky Mountains by uplift and volcanism, followed by erosion by glacial and other forces, led to the development of a landscape with high topographic relief (Hester and Grenier 2005). This habitat type is found across a wide elevational range—from high, wet, cold alpine landscapes all the way down to dry desert and warm plains environments. Cliffs, canyons, caves, and rock outcrops are unique habitats that can provide topographic diversity in otherwise homogeneous landscapes.

Cliffs are steep rocky outcrops with greater than 65° in slope and 4 ft in height (New Hampshire Fish and Game Department 2005). Cliffs are exposed to the elements, do not accumulate significant amounts of snow pack, and may be protected from runoff by overhangs. Vegetation of cliffs and outcrops is typically sparse, and often restricted to shelves, cracks, and crevices in the rock, or other areas where soil accumulation allows growth (Colorado Natural Heritage Programs 2010). Larson et al. (2000) describe three basic parts of a cliff habitat: 1) the relatively level plateau at the top, 2) the vertical or near-vertical cliff face, and 3) the pediment or talus at the bottom of the face. These three elements share some physical characteristics, are linked by similar ecological processes, and often support similar plants and animals (Larson et al. 2000). Within larger cliffs, a mosaic of microhabitats can occur including steep slopes, small terraced ledges, overhangs, and cracks and crevices, which contribute to the biodiversity that cliffs can support (Graham and Knight 2004). On the faces of cliffs, there is less hydraulic pressure retaining water than within the rock, so liquid water is more consistently found here than in surrounding habitats (Larson et al. 2000). Erosion by wind, water, and the force of gravity are the primary natural disturbances in cliff habitats. The lack of vegetation on many sites protects them from fire.

Caves and/or rock shelters are associated with cliffs, canyons, and rock outcrops. A cave is any naturally-occurring cavity, recess, or system of interconnected passageways beneath the surface of the earth or within a cliff or ledge that is large enough to be traversed by humans (Kerbo 2002). In Wyoming, caves are found in widely scattered locations, from 4,000 to 11,000 ft. in elevation. Although at least 23 different types of caves exist, including lava tubes, tectonic fractures, sea caves, and ice caves (Kerbo 2002), caves in Wyoming have primarily karst and pseudokarst features. Karst caves are formed by dissolution of rock rather than mechanical erosion, and they occur most frequently in limestone and dolomite. Caves similar to karst, but occurring in nonsoluble rocks are classified as pseudokarst caves which are formed by the process of piping. Cavities form by the action of certain clays that swell and contract with the presence or absence of water (Hester and Grenier 2005). Although most caves in Wyoming have karst features, pseudokarst features are common in Wyoming's basins (Hill et al. 1976).

Caves generally provide an overall climate that is less variable than at the surface, with stable temperatures, high humidity levels, low evaporation rates, and an absence of light (Washington Department of Wildlife 1994). Most have temperatures between 30–50 °F (Hill et al. 1976). Although relatively constant, not all cave temperatures are similar, and may be influenced by a number of factors, including the number, size, and position of portals; the size, slope, and contour of passages; the cave's overall volume; the seasonality and dynamics of airflow; and water intrusion (Washington Department of Wildlife 1994). Cave habitats may be simple or complex, and often include many smaller tubes, cracks, and fissures

(Washington Department of Wildlife 1994; Altenbach et al. 2002).

Caves are irreplaceable natural resources, taking centuries to form, having limited distributions, and containing unique biological communities. Additionally, about 25% of the groundwater in the U.S. is located in cave and karst regions, further increasing their value for society (Kerbo 2002).

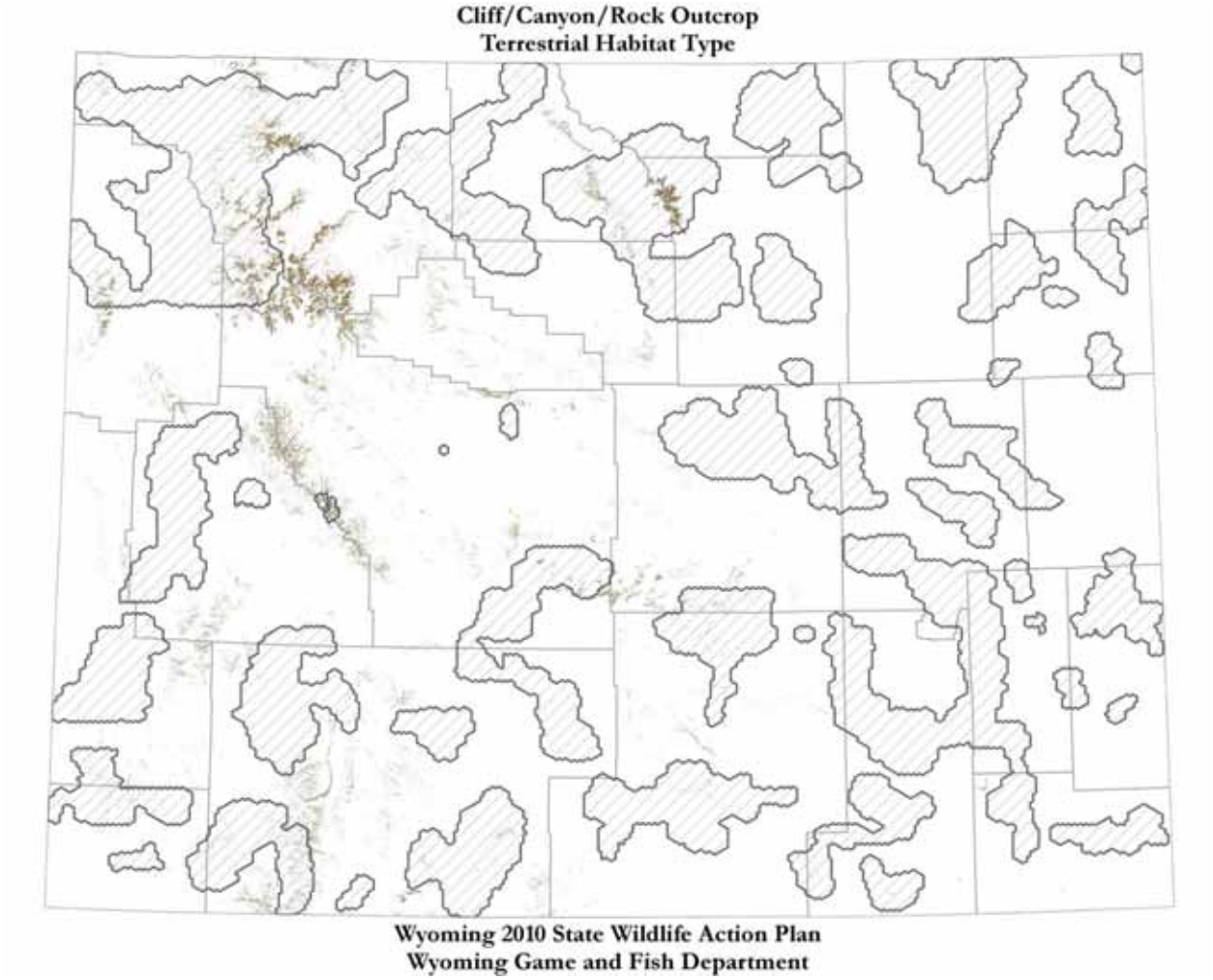

FIGURE 2. Wyoming Cliffs, Canyons, and Rock Outcrops and SWAP SGCN Priority Areas (cross-hatched areas) (*Note: This map does not depict the location of any caves which were not represented as a NatureServe Ecological System*)

TABLE 3. Wyoming Cliffs, Canyons, and Rock Outcrops NatureServe Ecological Systems[1]

1. Rocky Mountain Cliff, Canyon, and Massive Bedrock
2. North American Alpine Ice Field
3. Rocky Mountain Alpine Bedrock and Scree
4. Western Great Plains Cliff and Outcrop
5. Inter-Mountain Basins Cliff and Canyon
6. Rocky Mountain Alpine Fell-Field

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://www.natureserve.org/explorer.

TABLE 4. Wyoming Cliffs, Canyons, Caves, and Rock Outcrops Species of Greatest Conservation Need

Mammals
American Pika
Big Brown Bat
Bighorn Sheep
Canyon Mouse
Cliff Chipmunk
Dwarf Shrew
Fringed Myotis
Little Brown Myotis
Long-eared Myotis
Long-legged Myotis
Northern Myotis
Pallid Bat
Piñon Mouse
Plains Harvest Mouse
Spotted Bat
Townsend's Big-eared Bat
Western Small-footed Myotis
Wolverine

Birds
Black Rosy-finch
Brown-capped Rosy-finch
Peregrine Falcon

Reptiles
Great Basin Gophersnake
Great Basin Skink
Midget Faded Rattlesnake
Northern Tree Lizard
Plains Black-headed Snake
Prairie Lizard

Cliffs, Canyons, Caves, and Rock Outcrops Wildlife

Cliffs, canyons, caves, and rock outcrops occupy a small percentage of the land base, but they are disproportionately important as wildlife habitat and thus transcend all other habitat types. The uniqueness of this habitat often results in entirely different communities during the breeding season compared with adjacent habitats, increasing overall species richness and diversity (Hester and Grenier 2005). Cliffs, canyons, caves, and rock outcrops benefit birds and mammals directly by providing shelter and breeding sites, and indirectly by providing diverse vegetation structure. For example, some shrub species, such as skunkbush sumac, choke cherry, currant, and juniper, are primarily associated with rock outcrops.

The wildlife that use these habitats are highly specialized and are often dependent upon cliffs, rock outcrops, or canyons for reproduction, foraging, or predator avoidance. The stability and persistence of cliff, rock, and canyon formations encourage the repeated use of specific areas as breeding habitat. Well-known cliff-nesting raptors include the peregrine falcon, prairie falcon, golden eagle, and turkey vulture. Big game species such as bighorn sheep and mountain goat feed on the vegetation found on cliffs, canyons, and rock outcrops and also use these habitats to escape predators such as mountain lions. Pika, dwarf shrew, canyon mouse, cliff chipmunk, and bushy-tailed woodrat are examples of smaller mammals found in this habitat type. Permanent snow and ice in proximity to exposed rock are important features of breeding habitat for black rosy finches and brown-capped rosy finches, as well as wolverine, the latter using snow drifts to cache food. Rock shelters also provide very important roosts for several species of bats (Hester and Grenier 2005). In southern Sweetwater County in proximity to juniper habitats, rock outcrops are particularly valuable to several SGCN mammals. The distribution of the cliff chipmunk, canyon mouse, and piñon mouse is restricted to this portion of the state. Important habitat components include high diversity of invertebrates, as well as vegetative seeds and berries.

The preservation of bat roosts in caves is one of the most important issues in bat conservation (Sheffield et al. 1992). At least 21 of the 45 bat species in North America use caves regularly, and many of the remaining species use them at least occasionally (Racey and Entwhistle 2003. Eighteen species of bats are found in Wyoming and occupy all areas of the state, constituting 15% of all Wyoming's mammal species (Hester and Grenier 2005). Bats use caves as winter hibernacula, summer maternity roosts, day roosts, and even night roosts (Sheffield et al.

1992, Hinman and Snow 2003). Caves may serve as refugia for bats in the event of loss or degradation of other roosts in the surrounding landscape, and in some areas, the availability of suitable caves plays a major role in determining the size and distribution of bat populations (Christy and West 1993). Important roosts are often traditional and are used by successive generations of bats over many years (Hester and Grenier 2005). There have been 161 caves documented in Wyoming that could provide bat habitat (Luce 1998).

Even though they are manmade features, many abandoned mines share characteristics with caves that make them some of the most important roosting sites for bats (Hinman and Snow 2003). At this time, approximately 1,000 abandoned mines that have not undergone reclamation are known to exist across Wyoming. The Wyoming Game and Fish Department (WGFD) has located and surveyed only about 300 of these mines. Nearly 100 have been confirmed to be occupied by bats, although WGFD personnel have identified numerous others as having significant habitat potential for bats (Hester and Grenier 2005).

Cliffs, canyons, caves, and rock outcrops are also immensely important to a variety of reptile species. These habitats provide thermally favorable refuges, cover, and hibernacula. These habitats do not need to be expansive to harbor reptile populations, and the presence of only a few exposed rocks could attract snakes and lizards. Snakes are particularly dependent on rock outcroppings for winter dens. Rocky outcrops often provide crevices or other geologic features that allow snakes to travel below the frost line to escape freezing temperatures during winter. Often snakes are intimately tied to their hibernacula, returning to the same den their whole lives. The destruction of a den site often results in the reduction or elimination of local snake populations.

Cliffs, Canyons, Caves, and Rock Outcrops Habitat Threats

Recreation and human disturbance – Locally High

Recreational activities such as rock climbing, hiking, camping, bouldering, bicycling, horseback riding, and spelunking are common in cliffs, canyons, caves, and rock outcrop habitats. Disturbance to birds can be caused by the presence of humans and associated noise or erosion. Rock climbing, in particular, has become more popular during the last few decades and may have reduced the nesting success of some cliff and rock outcrop nesting birds (Nicholoff 2003). Such disturbance may gradually reduce the total number of suitable nesting sites available for birds dependent upon this habitat.

Recreation in caves and abandoned mines impacts roosting bats by the disruption of hibernacula and maternity colonies. Excessive disturbance may result in the loss of subpopulations and can present a significant threat to bats and bat habitat (Hester and Grenier 2005). Interest in recreational caving is increasing in the U.S. The National Speleological Society currently has more than 12,000 members (National Speleological Society 2010). Disturbance during hibernation may cause bats to arouse prematurely and burn stored energy reserves that usually cannot be spared (Sheffield et al. 1992). Even disturbances that may seem trivial, such as light or body heat emitted from humans, as well as noises from movements or whispering that produce high-frequency sounds, can disturb bats (Hester and Grenier 2005). Because bats can require up to an hour or more to arouse from hibernation, they may appear to be undisturbed, but become fully awakened only after humans have left the cave. Furthermore, repeated disturbances may force bats to abandon optimal hibernacula and move to alternative, less-suitable locations where survival rates are lower (Hester and Grenier 2005).

Recreational searching for reptiles may also affect this habitat type. Rock flipping is a

common method to search for snakes and lizards, and numerous rocks can be moved during the course of one afternoon. If disturbed rocks are not placed back into their original positions, microclimates necessary to reptiles can be destroyed. If enthusiasts disturb a large area of rocky habitat, reptile populations could be directly impacted.

Mining – Moderate
Mine reclamation projects have provided habitat for a diversity of wildlife species including cliff-nesting birds, bighorn sheep, mule deer, and others. Where ledges and crevices occur in open-pit mine walls, bats and some species of cliff-nesting birds utilize these sites for nesting or roosting.

However, mining and construction can have negative impacts when they occur at the base or the top of cliffs, rock outcrops, or canyons. Gravel quarries may actually remove buttes and cliffs and disturb or destroy the cracks and crevices where bats roost (Hester and Grenier 2005). The potential for oil shale development in southwestern Wyoming threatens rock outcrop habitats occupied by SGCN including the midget faded rattlesnake, cliff tree lizard, cliff chipmunk, canyon mouse, pallid bat, spotted bat, and Townsend's big-eared bat.

Bat roosting habitat has been lost in Wyoming and continues to be threatened by abandoned mine reclamation or the resumption of mining operations. New mining techniques usually produce open pits, which are unsuitable as bat habitat, and often destroy existing mine entrances and shafts (Brown 1995, Pierson 1998). Some gates or other closures on caves and abandoned mines do not allow access for bats (Oakleaf et al. 1996).

Inappropriate wind-energy development siting and design – Moderate
Wind has become the world's fastest growing power source, increasing about 30% annually since 1996 (Kunz 2004) (see Wyoming Leading Conservation Challenges – Energy Development). Suitable sites for wind development are often found on or near cliff, canyon, and rock outcrops.

Raptor collisions with wind turbines are more common when wind turbines are sited on steep slopes and hillsides, in canyons and draws, on ridge crests and peaks within canyons, and when rock piles that attract prey species are located near turbines (Hoover and Morrison 2005, Kingsley and Whittam 2003, Smallwood and Thelander 2004). Excessive or continuous noise from wind turbines can interfere with the vocal communication of birds, particularly during the breeding season (March through July for most raptors and April through July for most passerines) (Wyoming Game and Fish Department 2010).

Of the 18 bat species found in Wyoming, almost half have been identified in turbine-related mortality assessments conducted throughout the U.S. (Johnson 2005, Arnett et al. 2008). The average bat fatality rate for U.S. wind projects is 3.4 fatalities per turbine per year (Johnson 2004). Nearly 90% of bat fatalities occur in late summer and early fall, during the peak of fall migration (Keeley et al. 2001, Erickson et al. 2002, Johnson 2004). Migrating and commuting bats often follow linear landscape features, and may be drawn to ridges where wind energy facilities are located (Erickson et al. 2002, Kunz 2004). The physical characteristics of wind turbines might also attract bats. It has been hypothesized that light, heat, or high-pitched sounds emitted by wind turbines, or their tall, vertical structures, may attract bats or the insects upon which they feed (Hester and Grenier 2005). Wind turbines may also attract bats as potential roost sites.

Housing development and construction – Low
Development or construction activity that significantly increases human activity levels may decrease habitat use by wildlife. Additionally, development that removes vegetation above caves can alter internal cave climate and light levels, reducing insect populations, and eliminating visual barriers to the entrance of caves, which may increase human visitation

(Washington Department of Wildlife 1994). As housing development and construction occur in an area, humans may be motivated to destroy snake hibernacula. This is often a common practice in regards to venomous species. Rattlesnake dens are located and destroyed to ensure the safety of others. The destruction of these dens often results in the modification of rocky habitats.

Current Cliffs, Canyons, Caves, and Rock Outcrops Conservation Initiatives

Caves on federal lands are protected through the Federal Cave Resources Protection Act of 1988, which requires federal agencies to inventory and list significant caves on federal lands and to protect such caves from harm, either to the cave or its biota (Hester and Grenier 2005).

Before 1994, bats were not legally protected in Wyoming. In 1994, the Wyoming Game and Fish Commission approved nongame wildlife regulations protecting several wildlife species, including bats. In 1998, the Western Bat Working Group was formed as an outgrowth of a range-wide effort to protect the Townsend's big-eared bat. Subsequently, each participating state, including Wyoming, has established its own working group. The Wyoming Bat Working Group (WYBWG), comprised of multiple agencies, meets annually to prioritize and discuss bat conservation efforts in Wyoming.

In 2003, the WGFD and the WYBWG initiated the development of *A Conservation Plan for Bats in Wyoming* which was completed in 2005 (Hester and Grenier 2005). The overall goal of the plan was to consolidate current knowledge about bats in Wyoming and to provide a cooperative framework to identify and coordinate actions to facilitate bat conservation in Wyoming. The plan includes management recommendations for cliff, rock outcrop, and cave habitats. Since the 1990s, the WGFD Nongame Program, U.S. Fish and Wildlife Service, Bureau of Land Management (BLM), U.S. Forest Service, Wyoming Department of Environmental Quality (DEQ), and private landowners have actively taken steps to conserve caves and abandoned mines in Wyoming that are important to bats.

Recommended Cliffs, Canyons, Caves, and Rock Outcrops Conservation Actions

Inform land managers about potential negative effects and mitigation measures for recreational activities on or near cliff, canyon, cave, and rock outcrop habitats.

- Outlets such as the WYBWG, Wyoming Wildlife magazine, recreational clubs, schools, and public education programs can be used to inform the public and agency personnel about potential negative impacts on wildlife caused by recreation and discuss associated mitigation techniques. In addition to distributing educational materials, recreational clubs, such as climbing and spelunking organizations, can be useful sources for collecting information on wildlife observations.
- In cooperation with land management agencies, wildlife agencies, recreational clubs, and private landowners, review current human use levels for cliffs, canyons, caves, and rock outcrops that serve as crucial wildlife habitat. Potential impacts should be evaluated and management scenarios developed where necessary. Where recreational cavers may come into conflict with key maternity or hibernation sites, close hibernation sites to visitation from November 1 to April 1 and maternity sites from April 1 to October 1 (Hester and Grenier 2005). The critical time periods of hibernation and maternity activity may vary regionally and may allow some site-specific flexibility in seasonal closures. At some caves where human disturbance is affecting bat populations, it may be necessary to install bat-friendly closures to allow passage by bats while restricting human access.

- Keep the locations of caves, bat roosts, and cliff-dwelling bird nests confidential. Avoid including them on maps, road or trail signs, brochures, or press releases.
- Use signs and other interpretive media to help people appreciate bats and understand the fragility of roosting bats, and enlist professional outfitter/guides and climbing organizations as allies.

Work with the appropriate federal and state agencies to protect and maintain cliffs, caves, and abandoned mines that provide valuable habitat for bats and other wildlife.

- Where possible, avoid renewed mining activities above, inside, or near abandoned mines inhabited by bats.
- Maintain the microclimate of cliffs and rock outcrops used by bats as roosts by protecting and managing the vegetation up to 790 feet from the roost area (Ormsbee 1996).
- After construction or mining has been completed, reclaim lands with consideration for the unique foraging and roosting needs of bats. All components of bat habitat must be in close proximity (within several miles) for bats to use them efficiently (Keinath 2004). Maintain all vegetation above caves inhabited by bats and near cave portals to avoid altering the internal cave climate and light levels and reducing insect populations, and to avoid removing visual screening barriers that may discourage human use (Hester and Grenier 2005). Avoid timber harvest activities and prescribed burning within a quarter-mile radius of caves inhabited by bats (Stringer et al 1991; Keinath 2004). Time construction and mining activities to avoid disturbing known maternity colonies between April 1 and October 1 (Hester and Grenier 2005).
- Avoid building roads within 300 feet of caves inhabited by bats. Where caves will be visible from roads, or where roads will cause erosion into caves or alter the climate or flow of water in or around caves, institute a quarter-mile buffer (Washington Department of Wildlife 1994). Close roads or apply seasonal restrictions on roads that increase public access to vulnerable bat cave habitat (Oakleaf et al. 1996).

Work with state and federal agencies, as well as private landowners, to reduce potential negative impacts to wildlife from mining and abandoned mine reclamation projects.

- Enhance habitat for birds and other wildlife by placing suitable rocks on reclaimed mined land. Rock should be placed in piles of varying sizes up to 6 feet in height. Rocks and rock piles should be grouped—as opposed to evenly scattered—over large areas with approximately four rock piles taller than 3 feet per acre. The minimum area to include in outcrop habitats should be about 2.5 acres (1 ha), and shrub species should be planted in and around piles to encourage establishment of unique plant communities (Nicholoff 2003).
- Utilize the WYBWG to enhance current cooperative efforts and communication between land management agencies, the Abandoned Mine Lands Division (AML) of the DEQ, WGFD, and private landowners to reduce impacts from the reclamation of abandoned mines that provide bat habitat. Integrate ongoing Office of Surface Mining and AML abandoned-mine safety campaigns with bat habitat education programs and actively discourage recreation in abandoned mines. Identify abandoned mines that have gates or other closures that exclude bats and appear to have significant bat habitat potential.
- Prior to mine closure or renewed mining, evaluate all abandoned mines as bat habitat. Multiple surveys within and across seasons are essential to determine the significance of mine structures to bats for hibernation and maternity, as well as day, night, and lek roost activities (Hester and Grenier 2005).
- Where possible, avoid hard closure of mines that include activities such as bulldozing, backfilling, blasting, sealing with concrete, and foaming that make mines inaccessible to bats

and other wildlife. If the destruction of bat-occupied abandoned mines or caves is unavoidable, safely exclude or remove bats during a non-critical season to avoid mortality (Altenbach et al. 2002). Identify and protect replacement roosting or considering reopening already closed mines in nearby habitat within five miles (Hester and Grenier 2005).

Consult the WGFD *Wildlife Protection Recommendations for Wind Energy Development in Wyoming* (2010) when planning and constructing wind energy development projects.
Recommendations most relevant to the cliff, canyon, cave, rock and outcrop habitats include:

- In coordination with WGFD and U.S. Fish and Wildlife Service, determine appropriate set-backs from ridges, bluffs, or other features to avoid or minimize impacts to bats, neotropical birds, migratory birds, raptors, and reptile hibernacula. Determinations should be made on a project-specific basis based upon site-specific data and information.
- Construction around raptor nests on cliffs, canyons, and rock outcrops should be suspended within specified buffers and seasonal dates to be found in Appendix B of *Wildlife Protection Recommendations for Wind Energy Development in Wyoming* (Wyoming Game and Fish Department 2010).
- Adopt appropriate turbine design and siting standards to minimize bird and bat collisions (see U.S. Fish and Wildlife Service 2003 and Department of the Interior Wind Turbine Guideline Advisory Committee Recommendations 2010).

Cliffs, Canyons, Caves, and Rock Outcrops Monitoring Activities

Continue monitoring SGCN in cliff, canyon, cave, and rock outcrop habitats in order to detect population trends or changes in distribution that may reflect habitat problems.
Implement cliff, canyon, cave, and rock outcrop monitoring programs to establish baseline data and identify changes in habitat quality, both positive and negative, over time. This information should be used to guide future monitoring and research, as well as habitat conservation needs. Monitoring should include documentations of caves and abandon mines that receive significant bat use.

Monitor recreational use in cliff, canyon, cave, and rock outcrop habitats.
Increase educational efforts and develop management plans for sites where the level, timing, or type of recreational activity may negatively impact wildlife.

Continue to monitor the distribution and condition of cliff, canyon, cave, and rock outcrop habitats through remote sensing and ground surveys.
Remote sensing is useful in tracking the size and distribution of this habitat in Wyoming. Information gathered would be helpful in determining the cumulative impacts of activities such as mining. Special attention should be given to monitoring cliff, canyon, cave, and rock outcrop habitats in SWAP SGCN priority areas (Figure 2).

The following individuals reviewed or contributed information to the Cliffs, Canyons, Caves, and Rock Outcrops habitat type:

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Desert Shrublands

Photo courtesy of WGFD

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Habitat Description

Desert shrublands typically occur in basins at elevations between 4,980 and 7,220 feet (Colorado Natural Heritage Programs website) where less than 10 inches of precipitation falls annually (Knight 1994). Soils are often poorly developed and are characterized by being fine-textured, moderately deep, with lower infiltration rates, and a tendency to alkalinity or salinity. With the exception of soil salinity, desert shrublands share many features with sagebrush habitats including a predominance of shrubs, moisture, and nutrient limitations to plant growth and sensitivity to various forms of herbivory (Knight 1994).

Desert shrub communities vary from almost pure stands of single species to fairly complex mixtures. Common Wyoming desert shrubs include greasewood, shadscale, fourwing saltbush, Gardner's saltbush, winter-fat, spiny hop-sage, and kochia which are all characteristic of the Great Basin Deserts to the west (Knight 1994). Cushion-plant vegetation is a community of forbs that commonly provide ground cover under similar location and climate conditions as desert shrubs, but are a distinct form of habitat on windblown rims and rock outcrops in south-central Wyoming (Jones 2005). The composition and distribution of plant species is most heavily influenced by complex relations among physical, chemical, moisture, and topographic gradients (Blaisdell and Holmgren 1984). Greasewood desert shrubland and saltgrass meadows are characteristic of playas (small basins that periodically fill with water) and other comparatively wet depressions (Knight 1994). Bud sagebrush, early sagebrush, and bird's-foot sagebrush are also common short-statured shrubs found in these habitats (Winward 2004). Basin big sagebrush is often found along intermittent drainages (NatureServe 2010). Uplands are composed of mixed desert shrublands, salt desert shrublands, and desert grasslands. Wyoming big sagebrush-dominated shrublands are often found intermingled with desert shrublands, where soils are less saline and better drained, and on the lee side of slopes where snowdrifts form. Expanses of sagebrush steppe often border desert shrublands at slightly higher elevations or where annual precipitation is greater (Knight 1994). Cool-season grasses associated with desert shrublands include Indian ricegrass, squirrel-tail, wild ryes, western wheatgrass and Sandberg bluegrass. Important warm-season grasses are galleta, alkali sacaton, sand dropseed, and blue grama (Blaisdell and Holmgren 1984). A number of annual species may also grow in association with this habitat type, although they are usually rare and confined to areas of recent disturbances (Blaisdell and Holmgren 1984). Perennial forb cover is generally sparse, although in some areas woody aster, Hooker's sandwort, Hood's phlox and globemallow are common (NatureServe 2010).

Desert shrublands have low primary productivity due to dry conditions, cold temperatures, high soil salinity, and a short growing season. Bare ground is common. Sparse plant cover, along with fine-grained saline soils, makes this habitat type vulnerable to water and wind erosion. Many areas within this habitat resemble badlands. Desert pavement and coppice dunes often form in mixed-desert shrublands. Wind can erode silt and sand, leaving a surface of pebbles adjacent to small dunes, where finer particles accumulate around shrubs (Knight 1994). Some desert shrubland soils and plants have high levels of selenium, a naturally occurring chemical element that can be toxic at high levels. High erosion rates in desert shrublands raise concern about both salt and selenium water contamination.

The space between plants is frequently covered by a biotic soil crust (West 1982). This crust is important to long-term soil formation and stability, and its blue-green algal component is a major fixer of nitrogen.

Drought and herbivory are the most common disturbances in desert shrubland communities (Knight 1994). Fires occur infrequently, but can occur in stands of greasewood or mixed-desert shrublands where adequate fuel levels accumulate as a result of light grazing or the invasion of cheatgrass (Knight 1994). Unlike

most species of sagebrush, many desert shrubs have the ability to sprout following disturbance.

Land uses that occur in desert shrublands habitats include livestock production, energy production and mining, wildlife habitat, and a variety of outdoor recreational activities.

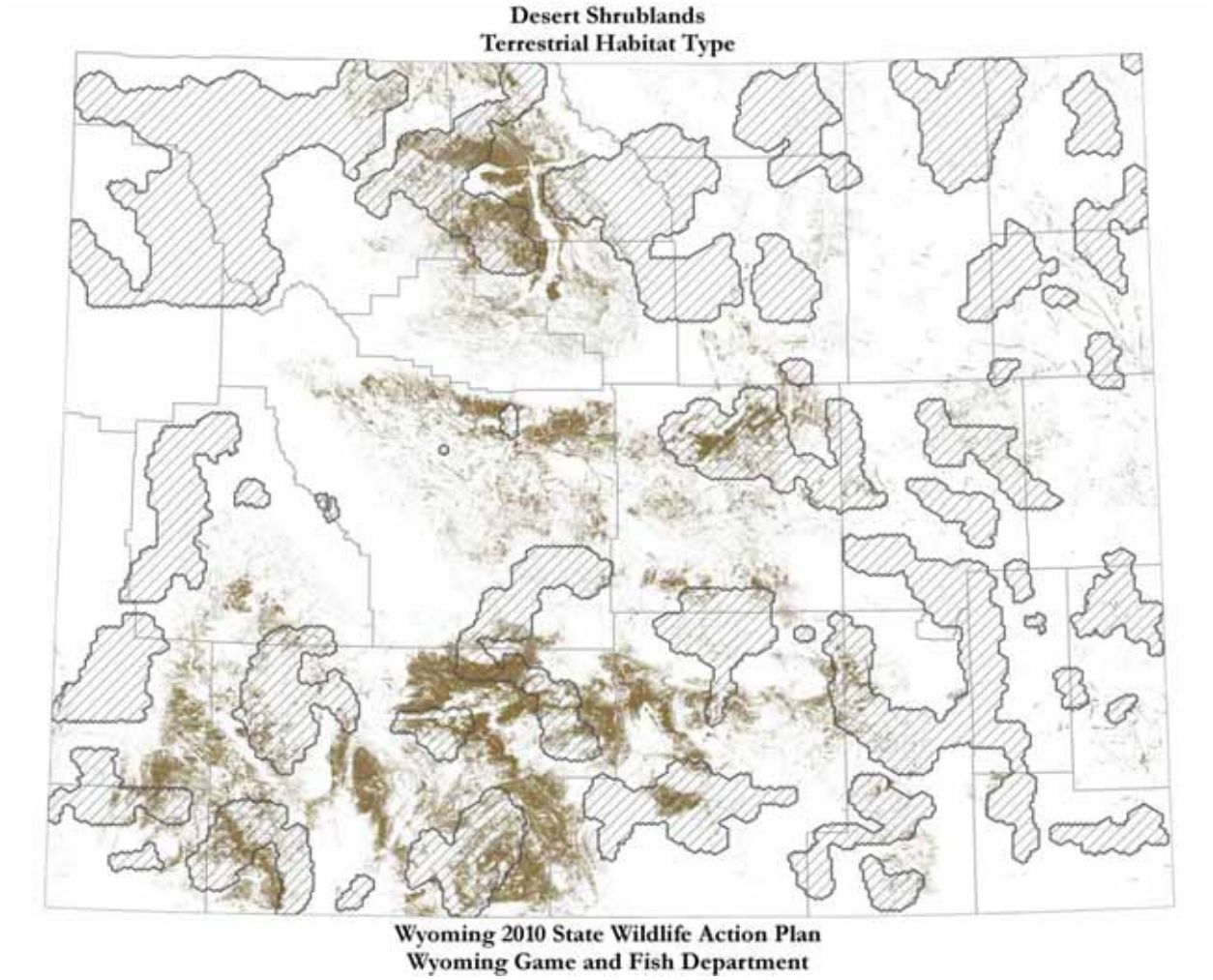

FIGURE 3. Wyoming Desert Shrublands and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 5. Wyoming Desert Shrublands NatureServe Ecological Systems[1]

1. Western Great Plains Badland
2. Inter-Mountain Basins Shale Badland
3. Northwestern Great Plains Shrubland
4. Inter-Mountain Basins Semi-Desert Shrub-Steppe
5. Introduced Upland Vegetation – Shrub
6. Inter-Mountain Basins Mat Saltbush Shrubland
7. Inter-Mountain Basins Mixed Salt Desert Scrub
8. Inter-Mountain Basins Greasewood Flat

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://www.natureserve.org/explorer.

TABLE 6. Wyoming Desert Shrublands Species of Greatest Conservation Need

Mammals
Great Basin Pocket Mouse
Vagrant Shrew
Wyoming Pocket Gopher

Birds
Mountain Plover

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

Amphibians
Great Basin Spadefoot
Great Plains Spadefoot

Desert Shrublands Wildlife

Desert shrub communities serve as habitat for wildlife that range in size from insects and small mammals to birds and large herbivores. Animals, as well as plants, exhibit wide fluctuations in productivity from year to year, largely as a result of varying weather conditions.

The Wyoming pocket gopher, Wyoming's only endemic mammal, is associated with dry, salty, low-productivity sites. Although there is some overlap, Wyoming pocket gopher habitat is distinct from northern pocket gopher habitat in terms of soils and vegetation. Specifically, Wyoming pocket gophers tend to occur on flatter slopes with ample bare ground where Gardner's saltbush and winter-fat are present and Wyoming big sagebrush is subdominant. Wyoming pocket gopher soils have higher salt and clay content and fewer coarse fragments when compared to northern pocket gopher soils (Griscom et al. 2010).

Game species found in desert shrublands habitat include mourning dove, sage-grouse, desert and mountain cottontails, pronghorn, and mule deer. Crucial winter range for pronghorn and mule deer has been designated in some desert shrublands areas. Pronghorn are more common than deer in salt-desert shrub vegetation; however, both are highly mobile and make much use of associated habitats, especially sagebrush and grasslands (Blaisdell and Holmgren 1984). Well known desert shrubland small mammals include the white-tailed jackrabbit and bushy-tailed woodrat. Common predators include coyote, bobcat, badger, great horned owl, golden eagle, Swainson's hawk, red-tailed hawks, and prairie falcon.

Mountain plover are one species of special concern due to their specific habitat needs in desert shrublands, particularly where they nest. Recently, the U.S. Fish and Wildlife Service reinstated a previously withdrawn proposal to list this species as threatened under the Endangered Species Act. Mountain plovers prefer flat terrain (less than 5% slope), with low-growing vegetation, and a minimum of 30% bare ground. Pesticide use to control grasshoppers and Mormon crickets can reduce prey availability for grassland birds, especially the mountain plover.

Invertebrates may be important to the overall wildlife value of desert shrub systems, similar to the way invertebrates operate in sagebrush systems where they may provide a crucial forage base, helping bridge seasonal shortages of protein (spring) and water (late summer, fall) for vertebrate wildlife.

Desert Shrublands Habitat Threats

Invasive plant species – High
Halogeton, Russian thistle, and cheatgrass are the three most significant invasive annual species in Wyoming desert shrublands. Alyssum, pepperweed, hound's-tongue, Russian knapweed, and whitetop are also common on bare ground.
Invasive species frequently become established in desert shrubland habitats adjacent to or within ephemeral drainages, near reservoirs, in areas of livestock overuse, or locations of high human traffic, such as roadways for recreation or energy development.

Halogeton and Russian thistle are primary invaders on clay soils in saline shrub plant communities where there is soil disturbance. Halogeton is extremely poisonous to sheep and is restricting winter grazing in some areas. The spread of halogeton could alter livestock distribution and encourage the conversion of sheep allotments to cattle allotments. These changes could further modify grazing dynamics and in turn influence plant diversity and seasonal use patterns by wildlife (A. Warren, personal communication, April 2010).

Increases in cheatgrass are considered to contribute to a shift from sagebrush dominance to greasewood dominance in some locations in Washington shrublands (Rickard 1964). Similar shifts could occur in Wyoming if cheatgrass becomes more abundant (Knight 1994). Increases in fire frequency in communities where cheatgrass is prevalent can decrease spring insect availability for birds and contribute to the spread of other invasive species.

Many invasive plant species decrease native plant diversity and reduce forage quality for wildlife and livestock that use these habitats (see Wyoming Wildlife Leading Conservation Challenges – Invasive Species). Additionally, the establishment of invasive species is correlated with increasing soil erosion and reductions in site productivity. Invasive plant species that become established in desert shrublands can serve as a seed source, facilitating their spread to nearby riparian and sagebrush habitats.

Incompatible energy development and mining practices – Moderate

Natural gas development is common in desert shrubland habitats and wind-power development is expanding. Energy development can result in direct and indirect impacts to wildlife species and their habitat (see Wyoming Wildlife Leading Wildlife Conservation Challenges – Energy Development). Direct impacts include the removal and fragmentation of desert shrubland habitats by activities such as mine excavation and the building of roads, drill pads, fences, power lines, and pipelines. Indirect impacts include increased human activity and noise. These impacts can displace animals and decrease reproductive success if animals are forced to use less productive habitats or expend more energy to avoid people. Soil disturbance from roads and other types of construction and increased vehicle traffic are significant contributors to the establishment and spread of invasive plant species.

Even more so than actual construction of energy production facilities, the establishment of roads can be problematic in desert shrubland habitats due to their length, drainage crossings, and overall change in hydrologic processes. Much of this habitat type is transected by roads and pipelines from past oil and gas explorations. Many older wells are being reworked, resulting in damage to previous mitigation efforts, which are slowly returning to pre-disturbance conditions. (E. Warren, personal communication, 12 November 2009). Mitigation can be difficult in desert shrubland habitats due to saline, fine-textured and unproductive soils, and low precipitation levels.

Off-road vehicle use – Moderate/Locally High

Off-road vehicle use, primarily by all-terrain vehicles (ATVs), is increasing in desert shrublands. Vehicle use off established roads can enhance the spread of invasive species including halogeton, alyssum, pepperweed, and cheatgrass. Tires can damage biological soil crusts leading to decreased organism diversity, soil nutrients, stability, and organic matter. This can result in greater erosion and reduced water quality. Wildlife often avoid areas of increased noise and disturbance from outdoor recreational vehicles, and riding off-road can destroy the nests, eggs, and young of ground-nesting birds. These impacts can also lead to conflicts with hunting, wildlife viewing, and other forms of nature-based recreation. Managing off-road vehicle use can be difficult and controversial in desert shrubland habitats where new trails are relatively easy to create and where some off-road vehicle users have little value for what

appears to be an unproductive and barren landscape.

Inappropriate grazing practices – Moderate
Desert shrublands are more sensitive to livestock grazing than the grasslands of the Great Plains, in part because their evolutionary history did not include large numbers of bison (Knight 1994). Cattle grazing can have profound effects on the composition of desert plant communities. Intensive, long-term grazing has been shown to decrease the abundance of perennial grasses and forbs and increase the amount of annual grasses and weeds in these areas (Rice and Westoby 1978, Brotherson and Brotherson 1981, Hanley and Page 1981, Medin and Clary 1990). Cattle grazing can also decrease the amount of litter (Milchunas et al. 1992), and moderate to intense grazing increases soil bulk density (Van Harren 1983) and decreases soil aggregate stability (Warren et al. 1986). Palatable species are most commonly damaged by late winter grazing, heavy use, or a combination of the two (Blaisdell and Holmgren 1984). Even under moderate stocking rates, the use of palatable species by livestock may be high, even if the plant is in low abundance. As a result, in overgrazed areas where a palatable species is poorly represented, its recovery can be especially difficult. When livestock graze in ephemeral riparian areas populated with rabbitbrush or greasewood, the biotic soil crusts can be damaged from trampling during wet periods, and soil compaction is common during dry periods.

Both stocking rates (Holechek 1988) and grazing season (Whisenant and Wagstaff 1991) have an influence on determining vegetation compositions and trends. In particular, these studies suggest that annual March-April grazing is an important cause of the deterioration of range conditions in some salt desert shrub ecosystem.

Wild horse numbers in the Adobe Town & Salt Wells herd management areas have been known to exceed the appropriate management level by two to three times (Bureau of Land Management 2010). Although wild horse diets typically are dominated by grasses, at high population levels and during drought, their diets shift more to shrubs, particularly winter-fat, saltbush, and sagebrush. During these periods, horse grazing may be particularly detrimental to the cover and vigor of these species.

Practices such as periodic rest, rotation of use, or adjustments in stocking rates have been demonstrated to improve range conditions in desert shrubland habitats (Blaisdell and Holmgren 1984). Desert shrubs such as shadscale and winter-fat have been known to decline following cessation of grazing, whereas perennial grasses and a few other species increase (Harper et al. 1990).

Rural subdivisions – Low
Rural subdivision and development can reduce, degrade, and fragment desert shrubland habitats (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). Houses, outbuildings, and lawns directly replace native wildlife habitat. Soil disturbance from construction, year-round grazing of horses and other hobby livestock, and the use of nonnative plants as ornamentals can facilitate the establishment of invasive species (Maestas et al. 2002).

Wildlife commonly abandons or alters use of habitats with greater human and pet activity. Increased energy expenditures in avoiding people or greater use of lower quality habitats can decrease animal health and reproductive capacity. Greater road densities and traffic volume can increase wildlife–vehicle collisions. Predation on wildlife can intensify with greater numbers of domestic dogs and cats, as well as increases in generalist predatory species such as ravens and human-commensal species such as raccoons (U.S. Department of Agriculture 2007).

Current Desert Shrublands Conservation Initiatives

Controlling invasive species has received less attention in desert shrublands, compared to other habitats, because of low productivity and poor vegetative states that can require additional forms of treatment to restore sites to their natural conditions. Also, in desert shrubland habitats herbicide use can be restricted due to extended soil residence times as a result of low organic soil content. Most of the herbicides available for use by the Bureau of Land Management (BLM) have restrictions on spraying less than 200 feet from water sources. Weed Management Areas (WMA), organized by the County Weed and Pest Districts, and Coordinated Resource Management teams (CRM), which are generally landowner-driven and facilitated by the Wyoming Department of Agriculture, have been established in various locations to control invasive species in desert shrublands.

Several efforts focused on enhancing the wildlife compatibility of energy development in Wyoming encompass desert shrub habitats. The Wyoming Landscape Conservation Initiative (WLCI) is a multi-agency and stakeholder initiative focused on data collection, monitoring, research, and facilitating land management actions in southwest Wyoming. Its purpose is to protect or enhance wildlife habitat and other resource values in the face of intensive energy development. The Jonah Interagency Office (JIO) is an example of a mitigation fund that has been established to support projects to maintain important biological areas in the vicinity of the natural gas field near Pinedale, Wyoming. Similar mitigation activities are underway for other oil and gas fields, including the Continental Divide-Creston, Hiawatha, and Pinedale Anticline.

The BLM and other partners, including the Wyoming Game and Fish Department (WGFD), are developing transportation plans for special management areas, many of which were established primarily for wildlife habitat. Enforcement of new state laws limiting the time when shed antlers can be collected west of the Continental Divide should help reduce disturbance to desert shrubland habitats in late winter and early spring when they are prone to erosion.

In general, adverse grazing impacts have been reduced in desert shrubland habitats with the adoption of grazing management practices that control grazing intensity, opportunity for recovery, and season of use. There are continuing efforts by the livestock industry, BLM, Natural Resources Conservation Service (NRCS), conservation districts, county extension, and sage-grouse working groups to promote best management practices to improve rangeland health. Some BLM grazing permittees are incorporating private monitoring efforts into their grazing operations in addition to the monitoring conducted by agencies.

Land use plans, such as the one developed by Carbon County promoting development close to existing infrastructure, help to maintain open space and wildlife habitats, as well as to provide more cost-efficient community services. Conservation easements have been acquired on desert shrubland habitats in a number of locations by land trusts operating in Wyoming.

Recommended Desert Shrublands Conservation Actions

Increase awareness about grazing best management practices in desert shrubland habitats.
Desert shrubland habitats are often used for wintering livestock, mainly sheep. Early winter grazing has less impact on desert shrubland habitats than grazing in late winter or early spring. Sheepherders should also be encouraged to not keep their camps or flocks on areas known to support sage-grouse leks and nesting habitat.

Wild horse populations should be kept at herd objectives to avoid negatively affecting plant vigor and cover. Uses by wild horses, livestock, and wildlife should be evaluated simultaneously

to address the needs of all large ungulates making use of this habitat type. Activities like grazing and events such as energy and water development, which may alter animal distribution patterns, and drought, should be taken into consideration when establishing herd objectives and grazing strategies

Increase invasive species mapping and treatment efforts in desert shrubland habitats.
Greater mapping of the locations of invasive species is needed, and new types of control technologies and treatments should be developed to advance reclamation efforts associated with energy and other forms of development. This would require additional soil testing and project trials. Greater attention should be placed on ensuring energy industry compliance with invasive species control permitting stipulations.

Enhance planning and mitigation efforts to minimize the negative impacts of energy development on desert shrubland habitats.
The development and implementation of energy development plans for oil, gas, and wind, is crucial to the success of accommodating growth in these industries while minimizing negative impacts to natural habitats and wildlife species. Mitigation plans should stress avoiding biologically sensitive areas within project sites and directing off-site mitigation funds to nearby high-value wildlife locations. Energy-development planning and mitigation efforts could be specifically benefited by:

- Developing new mitigation and reclamation techniques and technologies for the harsh, unproductive environment found in desert shrubland habitats. Due to their low productivity, desert shrubland habitats can be slow to recover from disturbance. Even with good management or complete protection, direct revegetation is often necessary. However, the harsh environment usually makes the successful establishment of vegetation difficult (Bleak et al. 1965, Van Epps and McKell 1980). Special practices such as transplanting, watering, shading, soil additives, or extremely careful selection of plant materials may be necessary.
- Continuing research on the effects of energy development on desert shrubland wildlife species and ecosystems. The Wyoming Natural Diversity Database and Wyoming Cooperative Research Unit are currently conducting research to evaluate the vulnerability of Wyoming terrestrial SGCN to oil, gas, and wind development. Vulnerability is being determined by evaluating each species' potential exposure and sensitivity to energy development. Exposure is being evaluated through a GIS analysis that overlays distribution maps of SGCN with areas of known and projected energy development. Sensitivity is being determined by examining habitat and behavioral attributes of SGCN as well as reviewing existing impact studies. Research results will not only give an indication of which species and taxonomic groups are potentially vulnerable to development, but also help direct future research to address information gaps. The project is being funded jointly by the U.S. Geological Survey, WLCI, and WGFD.
- Encouraging, where appropriate, the implementation of mitigation measures and/or best management practices detailed within the Wyoming Game and Fish Commission documents *Recommendations for Development of Oil and Gas Resources within Crucial and Important Wildlife Habitats* (Wyoming Game and Fish Department 2010a) and *Recommendations for Wind Energy Development in Crucial and Important Wildlife Habitat* (Wyoming Game and Fish Department 2010b). Sage-grouse habitat protection recommendations for uranium and bentonite mining as well as other significant surface disturbing activities are addressed in the Sage-grouse Core Population Area implementation recommendations available on the WGFD website. Development of stipulations for Sage-grouse Core Population Areas and noncore areas and the BLM's *Instructional*

Memorandum on Sage-grouse (2009) should be reviewed.

- Reviewing management actions proposed by state and federal agencies involving desert shrubland ecosystems and associated wildlife habitats, and working closely with the Wyoming Governor's office, industry, private land owners, and agency staff during early stages of energy development project planning. The SWAP, SHP, and Sage-grouse Core Population Areas should be consulted during development and mitigation planning. Maintaining connectivity between core areas will be important for the long-term conservation of sage-grouse and other desert shrubland associated species.

The enforcement of reclamation and weed treatments in BLM Resource Management Plans conditions of approval (COAs) will help ensure the maintenance or restoration of the health of desert shrubland communities.

Manage off-road vehicle use in environmentally sensitive areas or during seasons where wildlife is particularly sensitive to disturbance.
More efforts should be made on public lands to identify areas that are appropriate and inappropriate for off-road vehicle use including using Carsonite markers. Locations may vary seasonally to minimize disturbance to wildlife during critical periods such as when animals are on winter range or during nesting or fawning seasons. Public education should include increasing awareness of the ecological role of maintaining unbroken biological soil crust and the value of all types of vegetation.

Increase public awareness of wildlife values of desert shrublands.
Desert shrublands are often underappreciated and overlooked for wildlife conservation efforts due to their barren appearance and low productivity. Species such as Wyoming pocket gophers are desert shrub obligates while others species such as sage-grouse, loggerhead shrikes, pronghorn, and mule deer are seasonally dependent upon this habitat. Educational efforts should include increasing awareness about the importance of biotic soil crust to desert shrubland plants and ecology.

Desert Shrublands Monitoring Activities

Continue monitoring population trends or changes in distribution of desert shrubland SGCN and other obligates in order to infer changes in habitat quality or other threats.

More inventory and monitoring data for specific sites within Wyoming are needed to fully understand current plant communities, their health, and the effects of management practices upon desert shrubland habitats.
Basic long-term monitoring of desert shrublands condition can be accomplished by a combination of photo points (a series of photographs taken at specific points to identify vegetative changes) and monitoring residual plant cover. More long-term monitoring of the biotic integrity and the hydrologic function of desert shrubland sites can be determined through a combination of data collected by the belt transect method and either line-point intercept or gap intercept methods (Herrick et al. 2005). Long- and short-term monitoring efforts should occur at the same locations.

Monitor the size and landscape distribution of desert shrubland habitats through remote sensing.
Remote sensing is useful in tracking the size and distribution of desert shrublands in Wyoming. Information gathered would contribute to determining the cumulative impacts of activities and events such as energy development, rural subdivision, road construction, and the spread of invasive species. Special attention should be given to monitoring desert shrubland habitats in SWAP SGCN priority areas (Figure 3). Monitoring should be conducted in relation to the possible effects of climate change.

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Foothill Shrublands

Photo courtesy of Jerry Altermatt, WGFD

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Habitat Description

The foothill shrublands habitat type, commonly known as mixed mountain shrubs, comprises diverse plant communities dominated by an equally diverse list of shrub species. NatureServe (2010) estimates over 4.1 million acres of foothills shrublands systems in Wyoming when the Inter-Mountain Basins Montane Sagebrush Steppe system is included. Typically found in patches of pure or mixed stands, predominant shrub species include true mountain-mahogany, curl-leaf mountain-mahogany, serviceberry, antelope bitterbrush, skunkbush sumac, currant, gooseberry, and snowberry. Mountain big sagebrush and silver sagebrush are also common. Choke cherry may also be present, sometimes in abundance in moist sites. Associated grasses and forbs include arrow-leaf balsam-root, bluebunch wheatgrass, hairy golden-aster, Junegrass, and lupine (Knight 1994).

Two types of mountain-mahogany commonly occur in Wyoming. True mountain-mahogany, a deciduous species, is found in the Black Hills and across the southern half of the state, while curl-leaf mountain-mahogany, an evergreen species, is in the foothills of the Bighorn Mountains and to the west and south (Knight 1994). These shrubs form dense thickets on rocky or shallow soils from the western Great Plains up, to an elevation of 7,800 feet. Both species have the ability to fix nitrogen, which improves soil fertility over time (Hoeppel and Wollum 1971, Lepper and Fleschner 1977). Mountain-mahogany also plays an important role in erosion control because the shrubs are long-lived, produce extensive root systems, and survive well on dry steep slopes. Additional information on these two species has been compiled by Blauer et al. (1975); some is available on the Nature Serve (2010) web site, within the summary for the Inter-Mountain Basin Curl-leaf Woodland and Shrubland ecological system.

Saskatoon serviceberry is a common foothills shrub, but is scattered throughout the state. Utah serviceberry is found in drier foothill habitats in southern and western Wyoming at elevations from 5,000 to 9,000 feet (Harrington 1954). It is primarily found on dry ridges and slopes in association with big sagebrush, piñon pine, juniper, and aspen. Antelope bitterbrush is found in many of the same locations as serviceberry, including central Wyoming, but is often more confined to areas where snow accumulates, such as ravines, or in areas with higher precipitation. Snowberry is found along stream banks in Wyoming, in swampy thickets, moist clearings, and open forests at elevations from about 4,600 to 9,200 feet.

The quality and composition, including dominant species, of foothill shrublands have varied since European settlement (Nicholoff 2003). Many stands have declined through a combination of fire suppression and overbrowsing. Fire is a naturally occurring process in lower montane and foothill shrublands. Native fire regimes in these communities probably vary widely with local site factors. Severe, high-intensity fires are probably rare under natural conditions due to low and patchy fuel loads and relatively high site moisture (Decker 2007). Historically, foothill shrublands likely burned every 50 to >100 years (J. Derner personal communication 2010). In the absence of fire, foothill shrublands are often invaded by juniper and pine, and also increase in shrub density. Both changes can increase fire intensity and hinder post-fire recovery time.

The ability of true mountain-mahogany to resprout from the crown allows it to recover relatively quickly from fires. Alternatively, curl-leaf mountain-mahogany only regenerates from seed, which can result in extremely long fire recovery times (Kitchen 2008). Fire suppression is believed to be contributing to curl-leaf mountain-mahogany encroachment into adjacent communities (Arno and Wilson 1986); however, over time, some stands become decadent and are unable to compete with conifers (Nicholoff 2003). A similar trend of expansion has occurred within antelope bitterbrush in ponderosa pine communities. Likewise, serviceberry and skunkbush sumac

have declined with increasing shade from higher densities of mature trees (Nicholoff 2003).

Foothills receive considerable recreational activity, especially in the warmer seasons, including hiking, camping, hunting, and motorized vehicle use. Some locations are also popular for housing. Livestock grazing is common. Limited oil and gas development occurs in foothill shrublands, but wind energy development is increasing.

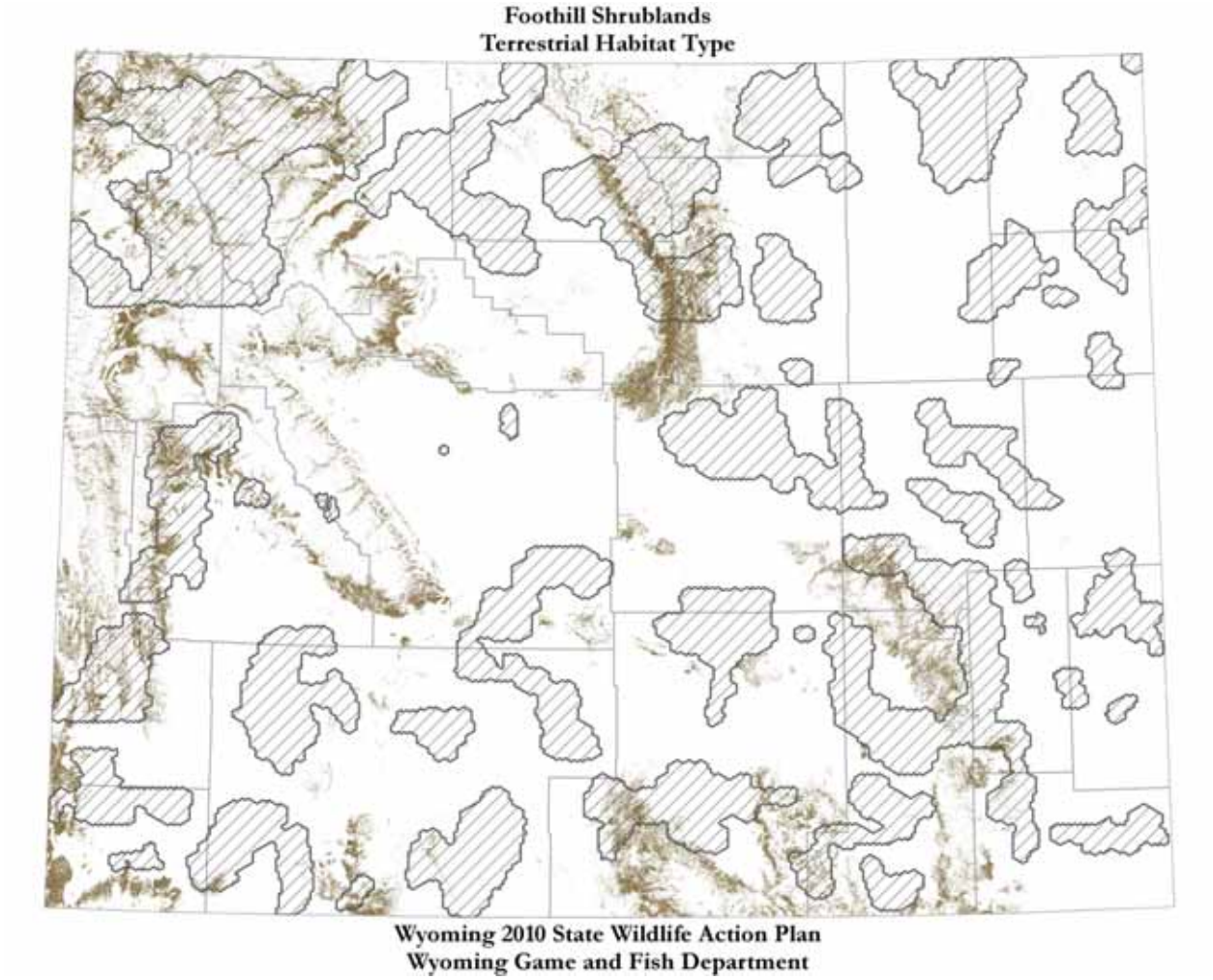

FIGURE 4. Wyoming Foothill Shrublands and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 7. Wyoming Foothill Shrublands NatureServe Ecological Systems[1]

1. Harvested forest-shrub regeneration
2. Inter-Mountain Basins Mountain-Mahogany Woodland and Shrubland
3. Northern Rocky Mountain Montane-Foothill Deciduous Shrubland
4. Northern Rocky Mountain Subalpine Deciduous Shrubland
5. Rocky Mountain Lower Montane-Foothill Shrubland
6. Western Great Plains Wooded Draw and Ravine
7. Inter-Mountain Basins Montane Sagebrush Steppe

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. http://www.natureserve.org/explorer.

TABLE 8. Wyoming Foothill Shrublands Species of Greatest Conservation Need

Mammals
Bighorn Sheep
Dwarf Shrew
Hispid Pocket Mouse
Idaho Pocket Gopher
Olive-back Pocket Mouse
Silky Pocket Mouse
Vagrant Shrew

Birds
Brewer's Sparrow
Columbian Sharp-tailed Grouse
Sage Sparrow
Sage Thrasher

Reptiles
Smooth Greensnake
Pale Milksnake
Rubber Boa
Valley Gartersnake

Amphibians
Northern Leopard Frog
Columbia Spotted Frog

Foothill Shrublands Wildlife

The mid-elevation position of foothill shrublands denotes a rather mesic environment which is not as cold and snowy as mountains, but not as dry and hot as basins. Thus, this habitat type is often more productive than the forests above it and the shrublands below it. It supports many berry-producing shrubs such as snowberry, currant, serviceberry, choke cherry, and Oregon-grape, which are important forage for many mammals, such as black bears and grizzly bears, and birds, such as dusky (blue) grouse and waxwings. Foothill shrublands also often encompass patches and stringers of trees, including aspen and conifers, that further increase cover and forage for wildlife. Frequent rock outcrops can serve as important substrates for bats, bighorn sheep, bushy-tailed woodrats, and other species. Foothill shrublands often occupy rough topography which provides cover for various wildlife, and also a high diversity of micro-climates, which in turn increases plant diversity. Many of these communities have been designated as crucial winter ranges for mule deer, elk, moose, and bighorn sheep.

Foothill shrublands provide habitats for bird species including Columbian sharp-tailed grouse, dusky (blue) grouse, Brewer's sparrow, gray flycatcher, dusky flycatcher, green-tailed towhee, common poorwill, Virginia's warbler, black-throated gray warbler, and lazuli bunting (Nicholoff 2003). Presence of substantial amounts of sagebrush, typically mountain big sagebrush, promotes occupation by several sagebrush obligate wildlife species including sage-grouse, sage sparrow, and sage thrasher. In fact, in some seasons and conditions, like late summer and during droughts, the wetter foothill shrub communities may provide better habitat for sage-grouse than lower and drier communities of pure big sagebrush.

Foothill shrublands provide particularly important habitat for big game in winter and during seasonal migrations. Both species of mahogany are particularly favored by mule deer for browsing. Curl-leaf mountain-mahogany communities provide important wintering habitat for mule deer, elk, and bighorn sheep in Wyoming (Despain 1973, Olson 1992, Kauffman et al. 2009). It tends to grow on dry, steep slopes that are typically more accessible to big game and other wildlife during deep snow conditions. Curl-leaf mountain-mahogany maintains high levels of crude protein (Welch 1981) and is one of the few shrubs that meet big game protein requirements throughout winter.

Antelope bitterbrush is another high-quality preferred forage for both big game and livestock, especially in fall and early winter (Austin and Urness 1983, Clements and Young 1997). It also provides cover for small animals and birds, including sage-grouse and Columbian sharp-tailed grouse. Antelope bitterbrush seeds are important food for rodents, including kangaroo rats and deer mice (Evans et al. 1983). These rodents play an important ecological role in the natural regeneration of bitterbrush by planting seeds in caches.

Snowberry is browsed by most wild ungulates, and its fruits are consumed by both black bears and grizzly bears, as well as many birds and small mammals (McWilliams 2000). It is particularly sought after by mule deer in spring. Skunkbush fruits, which persist through fall and winter, provide a food source when other fruits are scarce or unavailable. Serviceberry and currant are browsed by big game, and their berries are consumed by a variety of birds and small animals.

Foothill Shrublands Habitat Threats

Drought and potential climate change - High

Periods of prolonged and extreme drought can have severe effects on foothill shrub species. These species tend to be deep rooted and can normally withstand short-term drought conditions; however, prolonged drought, especially a lack of winter or early spring precipitation that depletes deep soil moisture, can cause high plant mortality. Drought conditions that persisted throughout Wyoming from 2000 through 2006 caused heavy plant mortality in many shrub stands (A. Winward, personal communication, 2008), particularly where shrubs were growing in the more xeric portions of their range.

Many shrub species may have established their current range in Wyoming under a historic period of unusually wet climatic conditions. If the climate becomes warmer and drier in Wyoming, as some climate modeling predicts (Christensen et al. 2007), the distribution of some shrub species may recede from areas where growing conditions are currently marginal (see Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Conifer encroachment - High

Juniper and limber pine have been actively expanding into true mountain-mahogany and bitterbrush shrub communities in a number of locations in the state, including the Little Snake River and North Platte River Valleys and in the Ferris and Shirley Mountains (see Terrestrial Habitat Types – Xeric and Lower Montane Forests – Juniper). Ponderosa pine has also been encroaching in foothill shrubland communities, including stands of curl-leaf mountain-mahogany, in a number of areas around the state, particularly in the Bighorn Mountains. Shrub and overall plant diversity decreases as juniper begins to dominate. Under these conditions, suitable habitat for species that depend upon true mountain-mahogany and bitterbrush, including mule deer, may decline. If juniper densities reach a point where crown fires can be sustained, the post-burn plant community can become dominated by cheatgrass. On the west slope of the Bighorn Mountains, juniper and Douglas fir have encroached into curl-leaf mountain-mahogany communities. Curl-leaf mountain-mahogany, especially where it grows in more mesic environments, may be seral to these conifer species and thus require periodic burns or other tree removal for persistence. In many areas, limber pine encroachment is receding due to infestations of white pine blister rust and mountain pine beetles (see Terrestrial Habitat Types – Montane and Subalpine Forests, Threats – Disease and insects).

Wildlife browsing pressure - High

While most shrubs are stimulated by light to moderate browsing, high browsing pressure can negatively impact some shrub species. Many of these shrub species are highly palatable and are preferred by most big game species (Blauer et al. 1975). Excessive browsing is most common during late summer and fall and into the winter months. This is particularly true with curl-leaf and true mountain-mahogany, and also bitterbrush. These species are highly desired by mule deer and used in a much greater proportion than they are found on winter range. This makes eliminating the effects of overbrowsing difficult, since deer will continue to use such preferred shrubs even at low deer densities. High browsing pressure over time reduces the recruitment of young plants, and is often accompanied by juniper encroachment, which further reduces plant diversity and habitat quality (see Terrestrial Habitat Types – Xeric

and Lower Montane Forests – Juniper). As plant understory decreases, there is an increase in bare ground, cheatgrass, and other annual weeds, as well as greater soil erosion and reduced site productivity.

Rural subdivision and development – Moderate
Rural subdivision and development can reduce, degrade, and fragment foothill shrublands habitats (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). Houses, outbuildings, and lawns directly replace native wildlife habitat. Soil disturbance from construction, year-round grazing of horses and other hobby livestock, and the use of non-native plants as ornamentals can facilitate the establishment of invasive species (Maestas et al. 2002).

Wildlife commonly abandons or alters their use of habitats with greater human, vehicle, and pet activity. Increased energy expenditures in avoiding people or greater use of lower quality habitats can decrease animal health and reproductive capacity. Greater road densities and traffic volume can increase wildlife–vehicle collisions. Predation on wildlife can intensify with greater numbers of domestic dogs and cats, as well as increases in generalist predatory species such as ravens, and human-commensal species such as raccoons (U.S. Department of Agriculture 2007). The frequent location of foothill shrublands within big game winter range and migration corridors intensifies concern about the impact of subdivisions where increases in human activity levels can significantly impact wildlife use (Feeney et al. 2004).

Invasive plant species - Moderate
Nonnative invasive plants can reduce shrub vigor and recruitment, and in some circumstances eliminate foothill shrublands communities (see Wyoming Leading Wildlife Conservation Challenges – Invasive Species). Cheatgrass is the most problematic invasive species in lower elevation bitterbrush habitats on sandy soils, as well as in true mountain-mahogany, curl-leaf mountain-mahogany, mountain big sagebrush, and antelope bitterbrush habitats.

Cheatgrass can form a dense understory that inhibits germination and survival of shrub seedlings. Additionally, cheatgrass can significantly increase fire frequency, which can result in the elimination of shrub species, especially those that respond poorly to fire such as curl-leaf mountain-mahogany and big sagebrush.

The threat of cheatgrass is reduced in some true and curl-leaf mountain-mahogany habitats with rocky substrate because bare rock limits cheatgrass establishment and the potential for fire. Serviceberry, snowberry, and mixed sagebrush/foothill shrub communities at higher elevations or on north- and east-facing slopes generally have high enough native plant cover to preclude invasion by cheatgrass.

Alyssum is an invasive plant species that has been invading lower elevation bitterbrush and true mountain-mahogany communities, particularly after prescribed burns intended to reduce mountain big sagebrush. Spotted knapweed, musk thistle, and leafy spurge are also important invasive plants in foothill shrublands communities.

Foothill shrublands are sometimes subject to prescribed burns, with the intent of increasing the cover and quality of forage species. It is critical that such treatments are conducted with an understanding of the likely responses of important invasive weeds, especially cheatgrass.

Incompatible energy development practices - Moderate
Energy development can result in the direct removal of native vegetation and habitat fragmentation through road building, well pad drilling, power line construction, buried pipelines, booster stations, and facility buildings (see Wyoming Leading Wildlife Conservation Challenges – Energy Development). Wind energy development is increasing in Wyoming and will likely have an impact on foothill habitats located on ridge tops. Habitat loss and fragmentation also occurs indirectly through

increased traffic and noise. Greater amounts of broken or bare ground, as well as greater vehicle traffic associated with the construction and production phases of energy development, can contribute to the spread of invasive plant species.

Incompatible livestock grazing practices - Moderate
Inappropriate livestock grazing can negatively impact shrub communities, particularly where livestock are grazed in areas with highly palatable shrubs. If livestock are allowed to graze for too long, especially during the hot season when they are seeking shade, shrub species such as serviceberry in wooded draws can be browsed out of existence (Girard et al. 1987). Grazing management practices that do not allow cool season grasses to recover can degrade habitat quality in foothill shrubland communities. Intensive grazing during the songbird nesting season (April through July) can increase nest loss through trampling, as well as brood parasitism by cowbirds if the grazing occurs near woody habitat (Nicholoff 2003). During late summer, fall, and early winter, browse levels on some shrub species such as mountain-mahogany and bitterbrush can be high and negatively affect plant vigor and health. However, it is also well documented that some level of browsing does prevent stagnation and increases the productivity of many shrub species.

Varying management goals, lacks of consensus on management strategies, and inadequate coordination and monitoring of management actions - Moderate
An evaluation of the effectiveness of management activities such as habitat treatments, big game herd population objectives, and livestock grazing is often hampered by a lack of baseline data, insufficient monitoring, and poorly articulated goals and objectives. There should be better coordination and planning among and between land management agencies, private landowners, and other interested groups prior to implementing management actions, including monitoring of enhancement or treatment projects.

Off-road vehicle use - Moderate
Off-road vehicle use, primarily by all-terrain vehicles (ATVs), continues to increase. Soil disturbance and the transportation of seeds can enhance the spread of invasive species, especially spotted knapweed and cheatgrass. This can lead to greater soil erosion, a reduction in water quality, and impacts to ecological processes within these systems. Wildlife often avoid areas of increased noise and disturbance from outdoor recreational vehicles, and riding off-road can destroy the nests, eggs, and young of ground-nesting birds, and fragment the habitat of area-sensitive species. These impacts can also lead to conflicts with hunting, wildlife viewing, and other forms of nature-based recreation. Off-road vehicle management generally remains controversial and difficult to manage, especially in more open and gentle terrain where new tracks are more easily created relative to forested areas or more rugged terrain. The increase in people collecting shed antlers has also increased off-road vehicle use, particularly affecting soil erosion on moderate to steep slopes as riders criss-cross the terrain to spot and retrieve antlers.

Foothill shrublands often do not accumulate enough snow to support much winter recreation such as skiing and snowmobiling, especially relative to adjacent montane systems. However, they often accumulate just enough snow to preclude road vehicle and foot-based recreation, especially relative to adjacent basin systems. This in-between character that precludes motorized use in the winter likely contributes greatly to the value of foothill shrublands as winter habitat for big game.

Current Foothill Shrublands Conservation Initiatives

Foothill shrublands have not been a primary focus of any statewide initiatives; however, this habitat type has been identified as a target habitat in the Wyoming Game and Fish Department (WGFD) Strategic Habitat Plan

(SHP) (2009a) and The Wyoming Mule Deer Initiative (2009b). Localized management actions and projects, which provide direct or indirect benefits, are more common. The WGFD does some annual monitoring of shrub production and utilization on big game winter ranges within foothill shrublands systems.

Locations of invasive species infestations are often mapped and identified for treatment by the Bureau of Land Management (BLM), County Weed and Pest Districts, and/or private landowners when located. There are also a number of invasive species management efforts involving multiple land management agencies and landowners. Notable efforts include Weed Management Areas (WMA) organized by the County Weed and Pest Districts and Coordinated Resource Management teams (CRM), which are generally landowner-driven and facilitated by the Wyoming Department of Agriculture. Most of these collaborative efforts focus on managing or eradicating one or more invasive plant species and promoting native vegetation. Project areas are generally along watershed boundaries.

The Southeast Wyoming Cheatgrass Partnership was formed in 2005 to promote education, coordination, and communication between partners about research, monitoring, and cheatgrass control projects in Laramie, Goshen, Platte, Albany, and Carbon counties. Current membership includes representatives from the WGFD, U.S. Forest Service, BLM, Natural Resources Conservation Service (NRCS), various County Weed and Pest Districts, local conservation districts, as well as University of Wyoming and Colorado State University faculty and researchers.

There are continuing efforts from within the agricultural industry and by the BLM, NRCS, conservation districts, county extension, and sage-grouse working groups to promote best livestock management practices to improve rangeland health. Some holders of federal grazing leases are incorporating shrublands monitoring efforts into their grazing operations, in addition to monitoring conducted by agencies.

The use of prescribed burns, mechanical treatments, and chemical treatments are common in foothill shrublands systems to increase shrub production, improve stand age and structural diversity, and treat invasive species. Juniper removal and thinning is often a component of these treatments. Private land treatments to reduce big sagebrush and improve cattle forage within big game winter/spring ranges have locally led to increased amounts of mountain shrubs and more diverse shrub communities. Greater diversity of mountain shrubs may also be achieved on public lands with additional efforts such as the seeding or plantings of desired species. The use of prescribed burns in some locations is being re-evaluated due to the potential to spread cheatgrass, alyssum, or other invasive species. In these locations, tebuthiuron (Spike) is frequently used to avoid increasing invasive species.

The WGFD Mule Deer Working Group (MDWG) was established in 1998 to explore solutions to the many challenges confronting mule deer conservation and management. Crucial habitats for mule deer often encompass foothill shrublands ecosystems. Among other topics, the initiative is addressing habitat issues pertaining to improving crucial mule deer habitats through collaborative efforts, providing funds to assist private landowners with habitat restoration, implementing strategies to minimize negative impacts from energy development, and monitoring crucial habitats to ensure deer populations do not negatively impact browse species.

Highway underpasses such as the one installed north of Baggs on Highway 789 and those in Nugget Canyon near Kemmerer U.S. Highway 30 are part of on-going efforts to modify fences and improve highway passage for big game. These activities may help reduce animal concentrations and browse-use levels in some areas of crucial winter range. Enforcement of new state laws limiting the time when shed antlers can be collected west of the Continental Divide should help reduce disturbance to big game and foothill shrublands systems when they

are prone to erosion in late winter and early spring.

The Wyoming Game and Fish Commission documents *Recommendations for Development of Oil and Gas Resources within Crucial and Important Wildlife Habitats* (Wyoming Game and Fish Department 2010a) and *Recommendations for Wind Energy Development in Crucial and Important Wildlife Habitat* (Wyoming Game and Fish Department 2010b) provide guidelines for reducing the impacts of energy development on wildlife and their habitats. While energy companies are required to perform reclamation and mitigation, these activities are often difficult in arid habitats and during drought conditions.

Conservation easements are being used in some foothill shrublands habitats to maintain the open space, wildlife habitat, and agricultural land uses. Land use plans, such as those developed in Carbon County, promote development close to existing infrastructure, both to maintain open space as well as to provide more cost efficient public services (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development).

The BLM and other partners, including the WGFD, will be involved in developing transportation plans for special management areas on BLM lands, many of which were established primarily for wildlife and habitat conservation. The WGFD was a recent state cooperator with the Bridger-Teton National Forest in the development of summer travel management plans.

Recommended Foothill Shrublands Conservation Actions

Increase invasive species control efforts for foothill shrublands communities.
Specific activities to enhance invasive species control include:

- Continue watershed-scale weed management efforts, such as Weed Management Areas and Coordinated Resource Management teams, and initiate new efforts where they are needed. Larger scale, valley-wide planning and project implementation efforts are needed for effective long-term invasive species management.
- Increase funding of invasive plant management and continue to build partnerships to advance these efforts.
- Conduct inventory of invasive plants and prioritize areas that have the highest risk of shrub community replacement so projects can be directed to these locations.
- Where wildfire could be detrimental to shrub communities, especially where invasive plants that respond well to fire are present, implement projects such as fuel breaks and prescribed grazing to reduce fire risk. Tebuthiuron should be used for sagebrush control, instead of prescribed fire, in these locations.

Provide information, technical, and financial assistance to improve livestock grazing practices in foothill shrublands communities.
The Wildlife Habitat Incentives Program (WHIP) and the Environmental Quality Incentives Program (EQIP) are two USDA Farm Bill programs administered by the NRCS that can provide resources and assistance to landowners to implement habitat improvement projects and grazing plans. On public lands or areas with mixed private and public ownership, cooperative habitat improvement projects should be established with federal agencies, private landowners, and livestock grazing permittees. The WGFD trust fund, wildlife conservation organizations, and other sources have been used to fund such projects.

Prescribed fire or mechanical habitat treatments should be used to duplicate historic disturbance regimes to increase plant health, native species composition, structural diversity, and historic ecosystem processes and functions.

Habitat treatments should have clearly stated objectives and monitoring plans. Habitat treatments are particularly needed for true mountain-mahogany and bitterbrush habitats in transition and crucial big game winter ranges to improve habitat diversity and alleviate browsing pressure.

Big game populations should be managed within herd objectives to meet forage utilization levels.
Accomplishing this objective will require greater monitoring of production and utilization of important shrub stands. Utilization objectives for each shrub species should be set and adjustments to big game herd population made if they are consistently exceeded. Herd population objectives should be set to account for preferred utilization levels, but if herd numbers cannot be reduced to meet utilization objectives, habitat treatments such as prescribed burns should be considered on adjacent habitat to entice animals away from these shrub communities.

Consult wildlife habitat priority areas and best management practices to improve energy development planning and mitigation design.
Energy-development mitigation plans should stress avoiding biologically sensitive areas within project sites and directing off-site mitigation funds to nearby high-value wildlife locations. SWAP SGCN priority areas identified in Figure 4 and WGFD SHP crucial areas can help guide these efforts. The implementation of mitigation measures and/or best management practices detailed within the Wyoming Game and Fish Commission's *Recommendations for Development of Oil and Gas Resources within Important Wildlife Habitats* (Wyoming Game and Fish Department 2010a) and *Recommendations for Wind Energy Development in Crucial and Important Wildlife Habitat* (Wyoming Game and Fish Department 2010b) should be encouraged. Mitigation plans should consider the need to reduce fragmentation of important habitats by using tools such as conservation easements in areas of high biological value. Management actions proposed by state and federal agencies involving foothill shrublands systems should be reviewed, and working closely with the Wyoming Governor's Office, industry, private land owners, and agency staff is recommended during early stages of energy development project plans.

Pursue conservation easements on high-wildlife-value foothill shrublands with willing landowners.
Conservation easements can be an effective and long-term method of securing and enhancing management of foothill shrublands systems on private lands while retaining ranching, outdoor recreation, and other compatible land uses (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). The development of stewardship plans for conservation easement lands can contribute to effective long-term habitat management.

Increase educational effort to agencies, private landowners, and the public about the importance of various shrubs to wildlife and the factors that threaten the integrity of shrub communities.

Foothill Shrublands Monitoring Activities

Continue monitoring foothill shrublands SGCN in order to detect population trends or changes in distribution that may reflect habitat problems. This information should be used to guide future monitoring and research.

More inventory and monitoring work should be conducted to document current locations, habitat conditions, and the effects of management practices upon foothill shrublands communities.
More intensive mapping of foothill shrublands habitats is needed. Past large-scale mapping efforts often lump foothill shrublands species with sagebrush community types. Voluntary

monitoring efforts on private land should be encouraged.

Monitor the landscape distribution and habitat intactness of foothill shrublands through remote sensing.
Remote sensing is useful in tracking the size, distribution, and fragmentation level of this habitat in Wyoming. Information gathered would be helpful in determining the cumulative impacts of activities and events such as energy development, rural subdivision, and wildfire. Special attention should be given to monitoring the level and location of these activities in relation to SWAP SGCN priority areas that have a high proportion of foothill shrublands habitat type (Figure 4). This technique will require the further development of monitoring protocols and the identification of sample sites.

Monitor the establishment and spread of invasive plant species in cooperation with County Weed and Pest Districts and other federal and state agencies.

In cooperation with state and regional research entities, monitor the effects of climate change including extended periods of drought or pluvial cycles.
All of Wyoming's habitat types may be impacted by changing climate conditions. Wildlife and habitat managers may be better positioned to develop and implement mitigation and/or adaptation strategies with a better understanding of how changing climate factors are impacting the resources and landscapes that they manage.

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Montane and Subalpine Forest

Photo courtesy of WGFD

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Habitat Description

Montane and subalpine forests cover about 22% of Wyoming and generally occur at elevations greater than 7,000 feet where temperature, moisture, and nutrient conditions are sufficient to allow for tree seedling establishment (Comer et al. 2003, Knight 1994). At higher elevations, snow accumulation combined with lower evaporation rates due to cooler temperatures create a more mesic environment than in lowland habitats. While there can be considerable overlap in vegetation zonation, vegetation communities within the montane and subalpine forest habitat type often follow a predictable elevational distribution. Douglas-fir generally can be found at lower elevations; lodgepole pine at mid-elevations; and Engelmann spruce, subalpine fir, and whitebark pine at higher elevations. Ponderosa pine is also found at low elevations, in eastern portions of the state, sometimes in association with Douglas-fir. Limber pine, which grows from low elevations up to treeline, is another subalpine tree species. Both ponderosa pine and limber pine are addressed in the Xeric and Lower Montane Forests section of the SWAP, page III-11-1. Intermingled with these coniferous forests in the montane and subalpine habitat type are mountain grasslands and meadows, aspen groves, wetlands, riparian areas, and mountain shrublands with mountain lakes and streams. Aspen is addressed in the Aspen and Deciduous Habitat Type, page III-1-1. Additional information and descriptions of the 10 ecosystem types listed in Table 9 are available from the NatureServe web site (2010).

Vegetation is largely influenced by temperature, given the short, cool, and often dry growing season which limits photosynthesis, with frosts possible throughout the year. Plant species such as evergreens have a number of adaptations for extended photosynthesis in spring and fall, and for cold tolerance. Additionally, all trees have mycorrhizae root systems to extract nutrients from the upper soil layers where nitrogen is more available in the young nutrient-poor mountain soils. Soil water, often frozen, with frequent freeze-thaw cycles can cause soil disturbance and displacement. Vegetation patterns are heavily influenced by elevation, aspect, soil type, snow accumulation, and major disturbances such as fire, windstorms, insect outbreaks, and human activities such as logging (Knight 1994). Due to solar effects, south slopes are generally warmer and drier, and north slopes are generally cooler and more mesic. Large stands of conifers with greater canopy cover are generally located on slopes with northerly aspects. Persistent aspen stands, low-density conifer stands, and mountain shrublands occur most often on south aspects.

In Wyoming, 53% of the forest land is administered by the U.S. Forest Service; 17% is privately owned, including Indian Trust land; 15% is administered by the National Park Service; 11% is administered by the Bureau of Land Management (BLM); and the remaining 4% is owned by state, county, and other federal agencies (Wyoming State Forestry Division 2009)[1]. Especially at lower elevations, land ownership in Wyoming is often a checkerboard pattern with considerable intermixing of federal, state, and private forested lands. This pattern can complicate management and create land-accessibility issues for management activities.

In 1976, 78% of forest products were derived from public lands, with only 22% derived from private lands. By the year 2000, the volume of materials harvested had declined by 78%, but most significantly 73% of those materials came from private forests (Wyoming State Forestry Division 2009). The 2000 tree harvest equaled 15.4 million cubic feet, not including trees removed for land clearing or land use conversions (The Conservation Fund 2009). In that year, 66% of the saw log harvest was composed of ponderosa pine with lodgepole pine contributing only 21.3% (Wyoming State Forestry Division 2009).

Aside from its value for raw materials, because of its high wildlife, scenic and recreational qualities, Wyoming's montane and subalpine

[1] Forested lands cover all forests in Wyoming including those associated with the montane and subalpine, aspen and deciduous, xeric and lower montane, and riparian habitat types addressed in this document.

forest habitat type receives significant human use including hiking, camping, hunting, bird-watching, skiing, and snowmobiling. Most water in Wyoming, which is used by agriculture, industry, and municipalities, originates in montane and subalpine forests as snowfall.

Douglas-fir

Douglas-fir makes up 8% of the forested area in Wyoming (Wyoming State Forestry Division 2009). Douglas-fir and ponderosa pine coexist at low elevations, usually below 8,500 feet (Knight 1994). Typically, Douglas-fir is found at slightly higher elevations and more mesic sites than ponderosa pine and is also found on limestone or sedimentary soils. Ponderosa pine is not found in western Wyoming, where Douglas-fir forests usually occur above foothill vegetation and below or intermixed with lodgepole pine forests. Like ponderosa pine, mature Douglas-fir has a thick, fire resistant bark so it can survive many surface fires and it is often a pioneer species post-fire.

Douglas-fir forests can be separated into two groups: 1) cool dry Douglas-fir, and 2) moist Douglas-fir. Cool dry stands generally have scattered to open canopies and typically experience low-to moderate-intensity fires which rarely kill mature Douglas-fir. Fire frequency is usually 30–70 years (LANDFIRE 2007). Cool dry stands of Douglas-fir generally occur on steep, south-to southwest-facing slopes and ridges in the lower parts of drainages. They provide important big-game winter and spring habitat due to an understory of abundant grasses, forbs, and shrubs. Large mature trees provide important roost and nesting sites for raptors and cover for ungulates in winter and early spring.

Moist Douglas-fir sites have more variable fire frequencies and intensities. Lower intensity fires have been documented to occur every 50–100 years and stand-replacing fires at 200–400 year intervals (U.S. Forest Service 2004b). Overstory trees are relatively fire-resistant to low intensity surface fires due to a thick bark. Moist Douglas-fir types are different from the cool dry Douglas-fir types in terms of understory composition, stand structure, the type of sites they occupy, and how they function within disturbance regimes. Common understory species are Rocky Mountain maple, pinegrass, heartleaf arnica, pachistima, white spirea, and blue huckleberry (Steele et al. 1983). Lodgepole pine, aspen, and limber pine may be major secondary species (Bradley et al. 1992).

Lodgepole pine

Lodgepole pine forest is the most abundant forest type in Wyoming, covering over 2.6 million acres (23%) of forest land (Wyoming State Forestry Division 2009). Lodgepole pine is capable of growing over a broad range of environmental conditions including high soil temperatures, low air temperatures, and water-saturated soils (Volland 1984); however, forests dominated by this species occur most commonly at middle elevations of from 5,900 to 10,500 feet in northern Wyoming and 7,000 to 11,500 feet in southern Wyoming (Green and Conner 1989).

Commonly considered a pioneer species, Lodgepole pine displays the characteristics of low shade tolerance, the ability to grow on almost any forest site, quick regeneration following a disturbance, and the rapid growth of young trees (Cole et al. 1985). Without disturbance, lodgepole pine forests often progress to a mixed-conifer community including subalpine fir, Engelmann spruce, Douglas-fir, and whitebark pine (Koch 1996a). Lodgepole pine forests can persist as a climax community on cool, dry, nutrient-poor sites, or where repeated disturbances or inadequate seed sources prevent other trees from becoming established (Cole et al. 1985, Koch 1996b).

Lodgepole pine possesses both serotinous and non-serotinous cones, providing the tree with a unique method of seed dispersal. Serotinous cones can remain closed for many years until opened by intense heat, typically fire or intense sunlight. Following a fire, large numbers of accumulated seeds are able to germinate with the exposure of bare mineral soil and low competition for resources from other plants, which creates favorable conditions for seedling

survival. The rapid establishment of lodgepole pine after a disturbance can result in dense, structurally uniform, even-aged stands often referred to as dog-hair stands. Serotinous cones are especially important for the survival of lodgepole pines whose thin bark causes them to be easily killed by fire (Knight 1994).

Non-serotinous cones can release their seeds without the aid of fire, allowing them to regenerate following non-fire disturbance. There is evidence that younger trees, before the age of 20 to 30, tend to produce non-serotinous cones (Lotan 1976). The proportion of serotinous and non-serotinous cones varies between stands. Serotinous cones are in higher proportion in areas where the last disturbance was a stand-replacing fire (Lotan 1973, Tinker et al. 1994, Muir 1985, Nyland 1998).

The mean fire-return interval for lodgepole pine forests ranges from 100 to 300 years (Knight 1994). While most fires cover tens of acres, infrequent fires during dry years can cover thousands of acres and have major impacts on landscape vegetation patterns. With the mountain pine beetle epidemic that has been escalating in magnitude over the past decade, fire intervals and other natural ecosystem processes will likely be altered as the forest landscape changes (see Montane and Subalpine Habitats Threats – Disease and Insects, below).

Engelmann spruce-subalpine fir

Spruce-fir forests cover 1.8 million acres (16%) of Wyoming and are the second most abundant forest type (Wyoming State Forestry Division 2009). Engelmann spruce and subalpine fir can tolerate low temperatures and have relatively low water-use efficiency (Knight 1994). These attributes restrict their growth to cooler, wetter environments, such as timberline, on north-facing slopes, and along streams and ravines at lower elevations.

Spruce-fir forests are considered a climax community as both species are shade-tolerant and are frequently found in the understory as well as the overstory, meaning vegetation assemblages will progress to the dominance of these species following a disturbance. This attribute results in spruce-fir forests with uneven aged trees. As disturbances occur, lodgepole pine and aspen are often pioneer species and they can coexist with spruce and fir for a century or more (Knight 1994). Successional pathways for spruce-fir forests depend on the nature and intensity of disturbances, prior species composition, and site characteristics (Knight 1994). The rate of succession back to spruce-fir forest is influenced by fire suppression and the moisture level of the site (Romme and Knight 1981).

The proportion of spruce and fir varies. Subalpine fir is more common, and trees are often smaller and younger. Subalpine fir may have 10 to 20 times more seedlings than Engelmann spruce (Knight 1994). Subalpine fir is also capable of vegetative reproduction. When low branches are pressed into the ground by snow they begin to develop roots and the branch grows upright into a new tree (Knight 1994). Engelmann spruce compensate for their lower reproductive rate through longevity. They tend to be the oldest and largest trees and may live 500 years or more (Alexander 1987).

Stand-replacing fires are estimated to occur at intervals of about 300 years in dryer stands and longer intervals of 350 to 400 years for more mesic sites (Romme and Knight 1981). Fires in the subalpine forest are typically stand-replacing, resulting in the extensive exposure of mineral soil and initiating the regeneration of new forests. Modern fire suppression has increased the abundance as well as the homogeneity of these forests in terms of age and structure diversity. There is evidence in the pollen record that suggests a pattern of landscape dominance by spruce-fir alternating with dominance by lodgepole pine through several cycles reflecting climate changes or successional phases (Hanson 1940).

Whitebark pine

Whitebark pine comprises 5% of Wyoming's forests (Wyoming State Forestry Division 2009). Whitebark pine is a slow-growing, long-lived conifer of high-elevation forests and timberlines of the northwestern United States and

southwestern Canada. In Wyoming, whitebark pine exists, often in association with limber pine, in the western part of the state from the Commissary Ridge area into Yellowstone National Park. Whitebark pine seeds are largely dispersed by Clark's nutcracker. The tree's multi-stem form results from seeds sprouting from Clark's nutcracker caches, commonly in burned areas or wind-swept ridges. The fire-return interval in whitebark pine communities is between 50–300 years (Arno 1986, Arno and Hoff 1989). Without fire, subalpine fir and Engelmann spruce increase and support fire events which can set back succession, again favoring whitebark pine. While its distribution is small, whitebark pine is considered a keystone species at high elevations throughout the northern Rocky Mountains due to its abundant seed production which is an important food source for wildlife. Recent surveys suggest that the mortality of whitebark pine in the Greater Yellowstone Ecosystem may be as high as 80% as a result of mountain pine beetle and blister rust infestations (see Montane and Subalpine Habitats Threats – Disease and insects, below).

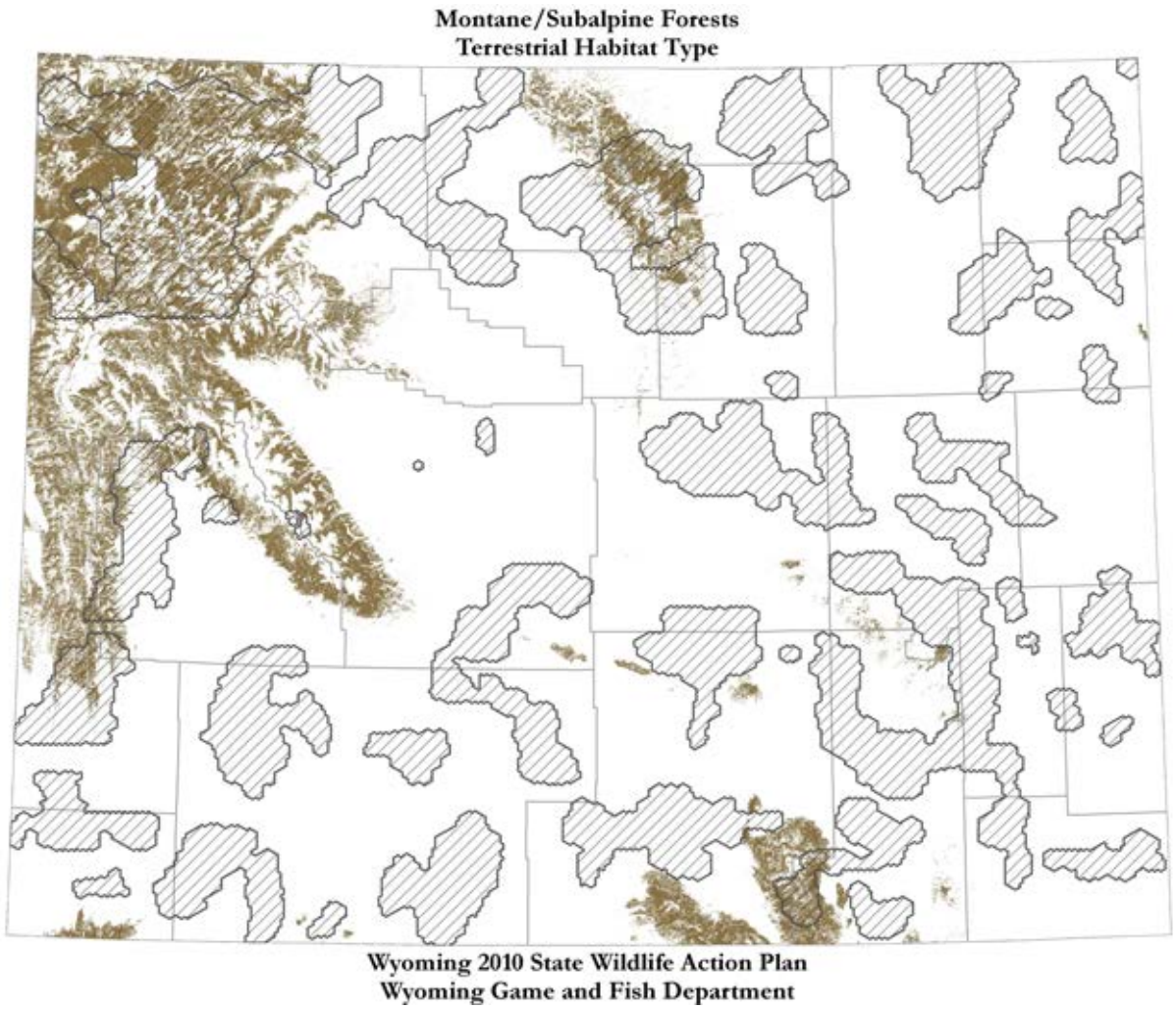

FIGURE 5. Wyoming Montane and Subalpine Forests and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 9. Wyoming Montane and Subalpine Forests NatureServe Ecological Systems[2]

1. Northern Rocky Mountain Subalpine Woodland and Parkland
2. Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
3. Rocky Mountain Lodgepole Pine Forest
4. Rocky Mountain Subalpine Dry-mesic Spruce-Fir Forest and Woodland
5. Rocky Mountain Subalpine Mesic-wet Spruce-Fir Forest and Woodland
6. Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
7. Rocky Mountain Poor-site Lodgepole Pine Forest
8. Recently Burned Forest
9. Harvested Forest-tree Regeneration
10. Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland

[2] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://www.natureserve.org/explorer.

TABLE 10. Wyoming Montane and Subalpine Forests Species of Greatest Conservation Need

Birds
American Three-toed Woodpecker
Barrow's Goldeneye
Black-backed Woodpecker
Boreal Owl
Common Loon
Great Gray Owl
Harlequin Duck
Northern Goshawk
Northern Pygmy-owl
Trumpeter Swan

Mammals
American Marten
Big Brown Bat
Canada Lynx
Dwarf Shrew
Eastern Red Bat
Fisher
Fringed Myotis
Hayden's Shrew
Long-eared Myotis
Long-legged Myotis
Moose
Northern Flying Squirrel
Northern Myotis
Pygmy Shrew
Uinta Chipmunk
Vagrant Shrew
Water Vole
Western Small-footed Myotis
Wolverine
Yellow-pine Chipmunk

Amphibians
Boreal Toad
Columbia Spotted Frog
Wood Frog

Reptiles
Northern Rubber Boa
Smooth Greensnake

Montane and Subalpine Forest Wildlife

Montane and subalpine forests in Wyoming contribute to the overall wildlife species diversity of the state, as higher elevation forests form a continuation of subarctic forests that extend across most of Canada and Alaska. A number of bird and mammal species in Wyoming that occur in this habitat type are at or near the southernmost extensions of their ranges. Many wildlife species only occupy this habitat in spring, summer, and fall, such as big game and passerine birds, which migrate to lower elevations and latitudes in the winter.

Because these forests are restricted to mountains they are regionally fragmented, and as a result, forest-adapted wildlife species are often genetically isolated. In fact, several Wyoming montane and subalpine forest mammals have evolved into distinct subspecies. Examples include Bighorn Mountain snowshoe hare (*Lepus americanus seclusus*), Bighorn Mountain montane vole (*Microtus montanus zygomaticus*), Black Hills marmot (*Marmota flaviventris dakota*), and Black Hills red squirrel (*Tamiasciurus hudsonicus dakotensis*).

Subalpine forests that include large components of coarse, woody debris and have high structural diversity are particularly important to forest carnivores such as American marten, wolverine, Canada lynx, and fisher. These habitats create subnivian spaces for thermoregulatory shelter and foraging sites in the winter.

Subalpine conifer forests are usually more diverse and provide more roost sites for bats than high-elevation forests. Some types of mid-elevation stands, especially lodgepole pine, sometimes form pure, dense, dog-hair stands of trees with small diameters and slow rates of growth. Stands in this condition probably do not provide ideal bat habitat (Hester and Grenier 2005).

Coarse, woody debris in the form of standing snags and downed logs is an important physical substrate for many forest species. Much of the primary productivity in forest stands is in the form of wood, which is indigestible to most vertebrates. Thus, wood-digesting invertebrates, fungi, and microbes often represent critical foods for many animals including the southern red-backed voles, red squirrels, and northern flying squirrels, all of which depend on forest fungi in their diets. Snags, which are dead standing trees, are

important habitat for many cavity-nesting and insect-feeding birds. They also provide cavities, crevices, and exfoliating bark that serve as maternity colonies and roost sites for bats and may play a central role in determining the distribution and abundance of forest-roosting species (Hester and Grenier 2005). Additionally, dead wood is important in building forest soils.

Whitebark pine seeds are an extremely important wildlife food in high mountain ecosystems for grizzly bears, red squirrels, black bears, ground squirrels, chipmunks, woodpeckers, nuthatches, Steller's jay, raven, and pine grosbeak (Kendall and Arno 1990). During years of cone abundance, grizzly bears in the Greater Yellowstone Ecosystem can feed almost exclusively on whitebark pine seeds; conversely during years of low abundance, grizzly bears often move down in elevation where they have a greater chance of coming into conflict with humans (Mattson et al. 1992). Whitebark pine also serves an important role as a nurse tree in facilitating the establishment of other types of vegetation. Its growth in alpine areas helps to stabilize soil and accumulate snow which retards spring runoff, reduces flooding, and improves water quality.

Spruce-fir forests provide hiding and thermal cover for moose and elk, forage for wintering moose, and important winter habitat for snowshoe hare, which is the principal prey of lynx. Mule deer often use montane and subalpine forests as summer and transitional ranges.

The Rocky Mountain Subalpine Dry-Mesic Spruce Fir Forest and the Rocky Mountain Mesic-Wet Spruce Fir Forest in conjunction with the lower-elevation mixed conifer and lodgepole pine forests are some of the most important ecological systems to Wyoming Species of Greatest Conservation Need (SGCN) occupying the montane and subalpine forest habitat type. While these two ecological systems make up less than 42% of the montane and subalpine forest habitat type, they are critical for maintaining the breeding populations of 13 species classified as SGCN in Wyoming.[3]

Montane and Subalpine Forest Habitat Threats

A "perfect storm" of the combined effects of fire suppression, drought, and large-scale bark beetle infestations are currently resulting in landscape-scale changes to the flora in many Wyoming montane and subalpine forests. These threats are interrelated and often magnify the impacts of other disturbances.

Fire suppression – High
Fire-suppression management strategies to protect timber, property, and human safety have been used since around 1890, shortly after European settlement of the West (Crisp, personal communication, 7 July 2010). Fire suppression has had a significant influence on montane subalpine habitat in some locations, although upper-elevation forests with infrequent fire regimes may have experienced variable impacts ranging from significant to negligible. Fire suppression has contributed to a loss of age, structural, and species diversity, increased stand densities, and the buildup of live and dead fuels. Timber patch size has remained unchanged, but due to suppression of surface and moderate intensity fires, forest openings or small breaks have either decreased in size or do not exist (Agee 1998).

These changes have resulted in a more homogeneous forest landscape pattern (Barrett 2004), which has contributed to a number of forest health concerns including intensifying the current bark beetle outbreak (see Montane and Subalpine Habitats Threats – Disease and insects, below). Tree mortality from bark beetles is occurring on an unprecedented scale,

[3] American Three-toed Woodpecker, Barrow's Goldeneye, Black-backed Woodpecker, Boreal Owl, Canada Lynx, Great Gray Owl, Marten, Northern Goshawk, Northern Pygmy Owl, Preble's Shrew, Water Shrew, Water Vole, Western Heather Vole.

which is leading to a buildup of fuel loads. High fuel loads are creating conditions more favorable to large-scale, high intensity fires. Such fires may cause significant impairment to regeneration, loss of valuable seed trees, loss of relict stands of mature trees and remnant populations of locally uncommon wildlife and floral species, and further promote homogeneous landscape patterns. In some areas, catastrophic fires may result in the long-term conversion to non-forest landscapes. For some important forest community types, such as whitebark pine and aspen, perpetuation is dependent on occasional disturbance, most commonly by fire.

Disease and insects – High

Montane and subalpine forest habitats are home to a variety of beetles, which under normal circumstances are a natural component of forest ecology and serve the purpose of renewing a forest by killing older trees. However, in recent decades, the populations of several types of beetles have exploded to epidemic levels affecting trees in a variety of age classes.

Continued high population levels of bark beetles are resulting in large-scale tree mortality among several pine species, Douglas-fir, true firs, and Engelmann spruce forests in the Rocky Mountain Region (U.S. Forest Service 2004a). Bark beetle-caused tree mortality has significantly affected the Medicine Bow, Shoshone, Uinta-Wasatch-Cache, and Bridger-Teton National Forests. Other areas, such as the Bighorn and Black Hills National Forests and surrounding state and private lands are also experiencing increasing levels of tree mortality caused by bark beetles (Wyoming State Forestry Division 2009). In some locations, there is a near complete loss of mature forests and considerable mortality in immature stands (U.S. Forest Service 2004a).

Bark beetle outbreaks are believed to be facilitated by a combination of factors. Years of successive droughts have likely weakened some trees. Additionally, many forests consist of significant amounts of aging, denser stands, which are susceptible to bark beetles. Some historic logging practices and large fires, especially fires during the European settlement era 100–150 years ago, contributed to large areas dominated by even-aged stands of lodgepole pine. Activities such as thinning, sanitation, salvage, and regeneration harvest, associated with commercial timber management, have also been discontinued in some areas. Finally, fire suppression can also lead to increased stand densities by allowing understory trees to survive and mature. Adding to these forest conditions are warmer winter temperatures and earlier snow melt, which may allow bark beetle populations to expand rapidly (see Montane and Subalpine Habitats Threats – Drought and climate change, below).

Bark beetle-caused tree mortality can provide important habitat for some species of wildlife, provide coarse woody debris to streams, and contribute to nutrient recycling. The ongoing mountain pine beetle epidemic will probably result in increased aspen regeneration in many parts of the state as competition from conifers is reduced (Wyoming State Forestry Division 2009). However, large-scale bark beetle outbreaks may also have negative effects on wildlife, including loss of hiding cover and older tree habitat that is crucial for some species of threatened and endangered wildlife (Samman and Logan 2000).

Lodgepole and ponderosa pine are attacked and killed most often by mountain pine beetle and pine engraver beetles. More than 1.5 million acres of lodgepole pine forest in northern Colorado and southern Wyoming are affected by a mountain pine beetle epidemic that was triggered by an extended drought in the late 1990s and early 2000s (U.S. Forest Service 2010). If weather conditions remain favorable to the beetles, it is predicted that by 2012, they will have killed nearly all of the mature lodgepole trees in this area, affecting water flows and watersheds, future timber production, wildlife habitat, recreation sites, transmission lines, and scenic views. Where succession is more advanced, some beetle-killed stands of lodgepole pine will be replaced mainly by subalpine fir, although future fires may take

stands back to lodgepole pine where serotinous cones predominate (Perry and Lotan 1979). If high-intensity fires occur in lodgepole pine stands with low numbers of serotinous cones, the seed source may be lost and it may take decades before lodgepole pines return (Schoennagel et al. 2003).

The most important insect of mixed forests of Engelmann spruce and subalpine fir is the spruce beetle. Usually these beetles are restricted to recently wind-thrown trees or trees weakened by root disease, but they can reach epidemic levels if the right stand structure and climatic conditions are present (Romme et al. 2006). There is significant scientific evidence that epidemics of spruce beetles have killed trees over extensive areas in past centuries (Veblen et al. 1991, Veblen et al.1994). Douglas-fir beetle has affected scattered stands that have been stressed by drought, fire, root rot, defoliation by western spruce budworm, or windfall. Noted outbreaks have occurred in the North Fork of the Shoshone River, on the west side of the Bighorn National Forest, and in lower elevations of the North Platte watershed on the Medicine Bow National Forest (Wyoming State Forestry Division 2009).

Mountain pine beetle is killing mature whitebark pine at a high rate similar to the 1930s outbreak which killed most of the mature whitebark pine in Yellowstone National Park (Gibson 2006). Mountain pine beetle usually kills larger cone-producing trees thus reducing regeneration potential (Keane 2001).

White pine blister rust (*Cronartium ribicola*) is either well established or becoming established within almost all Wyoming whitebark pine and limber pine stands. Only five percent of whitebark pine trees have genetic resistance to white pine blister rust (Tomback 2009). Historically, mountain pine beetle mortality would cause an increase in fuel loads and large fires that would create opportunities for natural regeneration. Blister rust has changed this normal progression by killing young whitebark pine and reducing cone crops by killing cone-bearing branches and tops. Recently, the U.S. Fish and Wildlife Service was petitioned to list the whitebark pine as a threatened or endangered species due to white pine blister rust, mountain pine beetles, and climate change. The U.S. Fish and Wildlife Service is currently conducting a status review of the species to determine whether or not its listing under the Endangered Species Act is warranted.

In combination, white pine blister rust and mountain pine beetle form a decline complex. Both seed production and the opportunity for germination have been reduced. Since whitebark pine regeneration is reduced, less natural selection for blister rust occurs (Waring and O'Hara 2005). Blister rust is a significant threat because no tactics are available to limit its spread.

The occurrence and severity of fire following an insect infestation will depend on the forest type, intensity of the outbreak, and time since the last outbreak (Black et al. 2010). Although it is widely believed that insect outbreaks set the stage for severe forest fires, the scientific evidence for this is mixed. A few studies that support this idea report only a small effect, while other studies have found no increase in fire following outbreaks of spruce beetle and mountain pine beetle (Black et al. 2010). It has been hypothesized that the risk of fire may increase only during and immediately after outbreaks of bark beetles when the dry red needles are still on the trees, or that two periods of increased fire risk occur, with an additional peak when trees begin to fall in large numbers, which may occur decades after mortality (Romme et al. 2006). Once large amounts of fuel accumulate on the ground, the risk of fire and the resulting damage to other resources such as soils and water are expected to be greater than pre-epidemic risk (Hayes and Lundquist 2009). For more information on bark beetle in the Rocky Mountain Region, visit http://www.fs.fed.us/r2/bark-beetle/index.html.

Drought and climate change – High
Elevated temperatures reduce beetle winter mortality as well as the time needed for beetles to complete a life cycle, both of which allow

populations to grow quickly (Bentz et al. 2008). Increasing temperatures associated with climate change may fundamentally alter beetle-forest dynamics through significantly increasing beetle population numbers and enabling beetles to attack healthier trees (Bentz et al. 2008) at higher elevations and latitudes. Some climate models for Wyoming predict a continued trend of warming seasonal temperatures (Christensen et al. 2007), which, regardless of changes in precipitation patterns, may result in more frequent and severe drought and increasing frequency and extent of wildfire (see Wyoming Leading Wildlife Conservation Challenges – Climate Change). Some researchers have predicted that climate warming will increase the scope of mountain pine beetle infestations in whitebark pine (Six 2010, Tomback 2009).

Conflicting timber-harvesting practices and forest-management objectives – Moderate
In some locations, past timber-management practices such as commercial harvest, thinning, post-harvest treatments, and road construction have resulted to varying degrees in the loss and fragmentation of mature and old-growth forest habitats outside of wilderness areas and national parks in Wyoming. These harvesting activities selectively removed the most productive stands of larger trees that were easily accessible and located at lower elevations on moderate slopes, habitat that is preferred by several wildlife species.

Timber-management plans are constructed to take into account numerous natural resource considerations. The effects of timber harvesting vary by method and by wildlife species and can have both negative and positive consequences. Negative consequences that can occur for certain species include: loss of habitat for cover, nesting, denning, and foraging; loss of certain tree and understory species for decades following treatments; decreased patch size of mature and old growth forests; invasion of exotic plant species; increase in more open country and common species that compete or prey on forest species; loss of travel and dispersion corridors; and increased disturbance resulting from the creation of roads that remain open for use in summer and winter.

It is not well understood how most montane and subalpine forest-associated species respond to habitat alteration and fragmentation. Also, it is often difficult to analyze harvest activities using a regional landscape perspective, which is needed for wildlife species that exist at low densities and have large home ranges. Timber-management treatments may result in long-term benefits to wildlife if based on ecological principles and landscape-level analysis. Without proper safeguards, salvage logging following wildfires may negatively affect nutrient recycling and snow retention, and remove and reduce important habitat features that affect some wildlife species including lynx and lynx prey, and post-fire dependent woodpeckers.

Tree-dwelling bats, forest owls, northern goshawk, red-backed voles, snowshoe hare, Canada lynx, and other wildlife species may be negatively impacted by forest-management practices that favor even-age, monospecific stands, have short rotation times, decrease the proportion or alter the structure of old-growth stands, and selectively remove snags and older, larger trees (Nicholoff 2003, Hester and Grenier 2005).

Current Montane and Subalpine Forest Conservation Initiatives

The Wyoming State Forestry Division completed a Statewide Forest Resource Assessment in 2009 and a Statewide Forest Resource Strategy in 2010. Completion of both the assessment and strategy were requirements of the 2008 Farm Bill in order to receive State and Private Forestry (SPF) funds. Both the assessment and the strategy were to incorporate existing state plans including State Wildlife Action Plans. As states are proceeding with assessments, there is also a national assessment process in development. The national assessment will be used, along with the national themes, to establish broad-scale priorities for

the future investment of SPF funding and resources.

Required elements of statewide forest resource assessments include an evaluation of forest resource conditions, trends, threats, and priorities. In Wyoming, this was completed largely through GIS analysis and shared with a variety of stakeholders, including the Wyoming Game and Fish Department (WGFD), for input.

The Wyoming Statewide Forest Resource Strategy outlines long-term comprehensive, coordinated strategies for investing state, federal, and local resources in addressing priority landscapes identified in the Statewide Forest Resource Assessment and designated national priorities. National priorities include conserving working forest lands for multiple uses; protecting forest from catastrophic events including fire, insect and disease outbreaks, and invasive species; and enhancing public benefits from forests: including air and water quality, biological diversity, forest products, renewable energy, and wildlife. Threats and conservation actions identified in Wyoming's Statewide Forest Resource Assessment and Forest Resource Strategy were reviewed in developing this habitat section of the 2010 SWAP.

Both the U.S. Forest Service and Bureau of Land Management (BLM) develop multi-resource management plans for the lands they administer including forested habitats. Under the 1976 National Forest Management Act (NFMA) and the 1969 National Environmental Policy Act (NEPA), forest land and resource management plans, generally referred to as forest plans, are to be developed by the U.S. Forest Service for each national forest and/or grassland and are to be revised every 10–15 years. Since forest plans are practical documents with recommendations and actions that are meant to be implemented on national forest land, an Environmental Impact Statement (EIS) is necessary.

Forest plans serve several functions: they establish forest-wide multiple-use goals and objectives, standards and guidelines, and management area direction; they determine areas of land that may be used for timber production, rangeland uses, recreation, and oil and gas leasing; they establish monitoring and evaluation requirements; and they recommend wilderness designations, wild and scenic river designations, and other special designations.

Forest plans set forth general guidelines and management directives; however, implementing the plan requires both decision-making at a more local level and site-specific analyses to evaluate the potential impacts of specific actions on resources including wildlife. Timber-harvesting on national forest land may be included in the forest plan, but the potential impacts of slash disposal, road construction, and general habitat disturbance must be considered for a range of species that inhabit the harvest area. Similarly, the forest plans allow for the development of recreation projects such as campsite construction, facility buildings, and trail building. Site-specific research is needed to determine the potential impacts of these actions, including increasing numbers of human visitors and subsequent anthropogenic impacts, on local wildlife and habitat.

The BLM is directed to develop land use plans by the Federal Land Policy Management Act (FLPMA) of 1976 and also NEPA. BLM land-use planning is guided by many principles including managing the land for multiple uses and sustained yield, using an interdisciplinary approach to consider all aspects of public land management, and identifying, designating, and protecting areas that are deemed to be areas of critical environmental concern. The agency must balance the use of the land for its economic values such as energy development and recreation, its biological value to wildlife, its physical open-space value, and social values for human enjoyment of natural landscapes and aesthetics. Each of Wyoming's BLM field offices has a resource management plan (RMP) that guides agency land-management activities throughout the state.

In Wyoming, the BLM and U.S. Forest Service, along with state cooperators, utilize the National Fire Plan (NFP) as the overarching plan to

guide all fire-management activities. The NFP primarily focuses on ensuring state capacity to address wildfire prevention, fire preparedness and suppression, and post-fire stabilization and rehabilitation. As one of many objectives, the NFP includes elements of both duplicating historic fire regimes and benefitting wildlife habitat (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes – Fire). Community Wildfire Protection Plans (CWPP) have been developed at the county level for 20 of Wyoming's 23 counties. The CWPPs identify priority areas for wildfire mitigation and fuel reduction projects and make recommendations for how projects should be implemented.

There is a regional effort involving the U.S. Forest Service, BLM, National Park Service (NPS), Colorado State University, and the Rocky Mountain Research Station to identify and grow white pine blister rust-resistant limber pine and whitebark pine through seed collection and breeding. It is expected that it will initially take five or six years to develop seedlings for planting. Due to the decline in whitebark pine, the National Resources Defense Council has petitioned the U.S. Fish and Wildlife Service to list this species under the Endangered Species Act.

Of the approximately 1.9 million acres of private forest lands in Wyoming, 410,295 acres (~22%) have management plans developed through the Assistance Forestry program (Wyoming State Forestry Division 2009). Management plans have been developed as a guide for landowners to help achieve their stated objectives. The information gathered through initiating this program has contributed to the development of the State Forest Resource Assessment. Recently, the U.S. Forest Service has collaborated with the Ruckelshaus Institute of Environment and Natural Resources at the University of Wyoming to develop a Private Lands Conservation Toolkit for Wyoming's public land managers. The toolkit is intended to encourage public land managers to participate, partner, and assist with local and county land-planning processes and voluntary, private land conservation efforts.

The Forest Legacy Program (FLP) was established in the 1990 Farm Bill to identify and protect environmentally important working forests from conversion to non-forest uses through voluntarily acquired conservation easements. The program is administered by the U.S. Forest Service in cooperation with state, regional, and local agencies. Timber harvesting is allowed on properties conserved through the Forest Legacy Program, but must be done in compliance with a State Forest Stewardship Plan and, for this state, Wyoming State Forestry's Best Management Practices for road construction and timber harvesting (The Conservation Fund 2009).

Recommended Montane and Subalpine Forest Conservation Actions

Efforts should be made to maintain, restore, and or duplicate the effects of historic fire regimes.

Increased human and property safety concerns resulting from greater development in and adjacent to forest lands has restricted the use of fire as a forest habitat management tool in many areas. This trend, along with unprecedented high fuel loads, will require forest managers to continue to develop alternative methods to duplicate the desirable effects of fire and to be more strategic in the application of the following methods.

- In consultation with appropriate fire authorities and with a fire-use plan approved by all affected parties, utilize natural fires under approved burning conditions to duplicate historic fire regimes. In designated areas, allow surface and moderate severity fires to play their natural role in breaking up homogeneous landscape patterns. In order to maintain stand-replacing dependent ecosystems, including serotinous-cone lodgepole pine stands, large

infrequent severe fires should be considered in fire-management plans (Turner et al. 2003). Weather conditions are the main driver of stand-replacing fire regimes in conifer forests, and thinning or low intensity fires are not appropriate to restore natural crown-fire regimes (Turner et al. 2003).

- Use prescribed fires to reduce fuel loads and increase tree age-class diversity across the landscape. Increasing age- and size-class diversity will reduce the potential for whole landscapes being replaced by a single stand-replacing event such as a bark beetle outbreak or fire. Furthermore, it is desirable to set back succession in some areas to maintain aspen communities. Younger age classes generally produce more herbaceous and browse forage than advanced aged communities, which is needed for maintaining high quality big game transition and winter ranges. Agencies and landowners must work collaboratively to facilitate cross- boundary implementation of prescribed fire, including the use of "Good Neighbor Authority."[4] Wyoming's Statewide Forest Resource Strategy (2010) contains recommendations to enhance the use of prescribed fire treatments in Wyoming.
- The wildland-urban interface is expanding in Wyoming, as in most of the West, which reduces opportunities for both natural and prescribed fires. In these circumstances, duplicating the desired effects of historic fire regimes can sometimes be better obtained through mechanical treatments that allow managers to determine residual stand complexity and density as well as species and age selection, including retaining valued stand components such as snags. Thinning can accelerate the development of structural characteristics typically found in old-growth stands, preserve the largest and most valuable roost trees and snags, and create natural gaps in the canopy used by bat species that forage in more open habitats (Hester and Grenier 2005).

Develop and implement bark beetle management strategies.

Most direct bark beetle control efforts, such as spraying and removal of infected trees, have had little effect on the final size of outbreaks, although they may have slowed beetle progress in some cases and prolonged outbreaks in others (Hughes and Dreveri 2001). While control of such outbreaks is theoretically possible, it would require treatment of almost all infected trees (Hughes and Dreveri 2001), which may be possible only for localized areas. Long-term bark beetle management actions that can help restore forests, lessen negative impacts to wildlife, and reduce susceptibility to future beetle outbreaks include:

- Evaluate sites as they regenerate after beetle epidemics to determine appropriate long-term species composition.
- Evaluate future management of regenerated stands, post-beetle epidemic, to determine management strategies to avoid the development of another generation of large-scale, old, even-aged stands.
- Carefully plan the management of residual stands of larger trees to keep those stands healthy. Active management may be needed to achieve overall forest health objectives in those stands.
- Intensively manage younger regenerated stands to accelerate growth into larger size classes and promote long-term diversity.
- Where practical, use artificial regeneration where natural regeneration has failed.
- Reduce beetle-induced fuel loads to protect vulnerable regeneration, seed trees, remnant populations of mature trees and isolated populations of locally sensitive wildlife species and uncommon flora.

[4] Good Neighbor Authority refers to Congress authorizing the U.S. Department of Agriculture's Forest Service to allow the State Forestry Agencies to conduct certain activities, such as reducing hazardous vegetation, on U.S. Forest Service land when performing similar activities on adjacent state or private land. Efforts are being made to expand "Good Neighbor Authority" to other western states including Wyoming.

- Manage some stands to reduce future tree densities to lessen the risk of future bark beetle epidemics.
- Monitor salvage operations and fuel reduction projects on the landscape level. Road closures or removals would have to be carefully managed to avoid negative impacts on some wildlife species.

Encourage timber-management practices that benefit wildlife.

- Promote active forest management on suitable lands across all ownerships to achieve and/or maintain natural ecological processes and functions and associated appropriate age class, structural distribution, and plant diversity. Manage for vertical and horizontal heterogeneity, multiple layers of native plants, forest floor complexity, and a variety of age classes in forest and woodland habitats to provide for a diverse insect community, nesting and foraging sites, and roosting opportunities needed by birds and bats (Nicholoff 2003, Hester and Grenier 2005).
- For landscape-level planning, incorporate planning for species associated with older forests such as northern goshawk, forest owls, and Canada lynx to make sure that remaining patches of older forests are adequate in size and connectivity to support viable populations of these low-density wildlife species and their prey (Reynolds et al. 1992). Review management actions proposed by federal agencies in mature and old-growth forests and work closely with agency staff during early stages of project planning
- Retain large-diameter snags and roost trees for cavity-nesting birds and bats. Where possible, it is recommended that all snags used by bats and cavity-nesting birds, all soft snags, and at least six hard snags per 2.5 acres (1 hectare) are retained (Oakleaf et al. 1996). Retain both evenly distributed snags and those in clusters to maximize diversity and mimic historical conditions (Nicholoff 2003). A minimum 500-feet radius buffer of intact forest around roosts is recommended to avoid altering airflow and thermal regimes at roost sites (Hester and Grenier 2005).
- Research the effects of past logging and increased recreational levels on SGCN species occupying the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and the Rocky Mountain Mesic Spruce-Fir Forest NatureServe ecological systems.
- Promote species diversity on lands capable of growing multiple tree species.

Conduct direct management and intervention activities to ensure the future persistence of whitebark pine and reverse recent losses.

Management actions that should be considered include:

- Restoration and maintenance of native fire regimes. This recommendation could be the single most important management action to ensure persistence of whitebark pine (Keane and Arno 2001).
- Management of adjacent stands that are being impacted by bark beetles through timber harvest and prescribed or natural fire to reduce the impacts from beetles on whitebark and limber pine stands.
- Collection and archiving of seed from isolated whitebark pine communities that may possess rust-resistance genetics, and planting of rust-resistant seedlings.
- Propagation of naturally rust-resistant trees where possible. Increase natural regeneration for greater selection of possible rust resistance and in areas where cone-bearing trees are at risk.
- Thinning whitebark pine stands to improve individual tree vigor, reduction of interspecies competition, increasing individual tree resistance to white pine blister rust, and decreasing disease transmission.
- Disseminating information on the status and distribution of whitebark pine.

- Selectively retaining whitebark pine in aspen enhancement projects.

Begin preparing for the potential influences of climate change on Wyoming's forests.

- Encourage research and monitoring to better understand the extent and effects of climate change on Wyoming's forests.
- Forest management should focus on maintaining healthy, diverse forests which are naturally resilient to many threats including climate change. Use adaptive management strategies to mitigate impacts resulting from climate change and to account for species adaptation.
- Adapt water-management techniques to accommodate changes in flow and timing as a result of climate change.
    - Manage forests to increase snow capture and retention, as well as to reduce the risk of flooding and excessive runoff. Manage canopy closure to influence snow accumulation. In created openings, maintain sufficient surface roughness to allow snow capture and retention.
    - On currently drier sites, manage for species with the greatest tolerance for dry conditions.
    - Adjust residual stocking levels to promote healthy forest conditions and promote water retention.
    - Adjust slash disposal requirements, utilization standards, and harvest design to accommodate any biomass utilization opportunities.
- Prepare for a likely increase in fire frequency and severity.

Encourage management agencies and research organizations to conduct studies on the ecology of snowshoe hare, forest grouse, tree squirrels, pocket gophers, and other species that form the base of the predator food chain in the montane and subalpine forest habitat type.

Montane and Subalpine Forest Monitoring Activities

Continue monitoring population trends or changes in distribution of montane and subalpine forest SGCN and other obligates in order to infer changes in habitat quality or other threats.
The U.S. Forest Service should be encouraged to survey for northern goshawks, boreal owls, great gray owls, and northern pygmy-owls using systematic survey techniques at least two years prior to proposed timber harvest treatments, prescribed fire, or other large-scale management activities. The Northern Goshawk Management Recommendations for the Southwest should be used as a guideline and adjusted based on available regional data to plan for nesting and foraging habitat for goshawks and associated prey species (Reynolds et al. 1992). This approach would provide long-term conservation of mature forest habitat for many other species of birds and mammals.

Monitor the landscape distribution and habitat intactness of montane and subalpine forests through remote sensing.
Remote sensing is useful in tracking the size, distribution, and fragmentation level of montane and subalpine forest habitat in Wyoming. Information gathered would be helpful in determining the cumulative impacts of activities and events such as insect outbreaks, logging, fires, and forest regeneration and succession. Special attention should be given to monitoring the level and location of these activities in relation to SWAP SGCN priority areas that have a high proportion of the montane and subalpine forest habitat type (Figure 5). This technique may require the further development of monitoring protocols and identification of sample sites.

In cooperation with research entities, monitor the effects of climate change including extended periods of drought. Special attention should be given to the effects of climate change on hydrologic regimes, insects and disease outbreaks, and fire frequency.

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Mountain Grasslands and Alpine Tundra

Photo courtesy of WGFD

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Habitat Description

For Wyoming's 2010 State Wildlife Action Plan (SWAP) mountain grasslands are defined as grasslands in montane landscapes typically above 6,500 to 7000 feet in elevation and alpine areas above timberline. These grasslands are frequently referred to as parks or mountain meadows, while alpine areas are referred to as turf fellfield or dwarf-shrubland. Within the mountain grassland, and interspersed with montane and subalpine forest types, are small, but unique tall forb communities. Tall forb communities are typically dominated by wild geranium, nettleleaf, arrowleaf balsamroot, western coneflower, asters, fleabanes, yarrow, with some sedges, alpine timothy, mountain brome, and a few plants of mountain big sagebrush, or dwarf willows and snowberry. NatureServe (2010) lists and provides descriptions of the five ecosystems characterizing these habitat types (Table 11).

Within mountain grassland types, species composition varies with elevation, moisture, soil depth, and soil type. Bluebunch wheatgrass, needle-and-thread, Junegrass, Sandberg's bluegrass, and fringed sagebrush are common at lower elevations. As elevation increases, Idaho fescue, bearded wheatgrass, green needlegrass, other needlegrasses, bluegrasses, tufted hairgrass, sedges, lupine, sticky geranium, prairie smoke, hawk's-beard, and pale agoseris become more prevalent (Tweit and Houston 1980, Knight 1994). Wet meadows are found along streams and in areas where snow melt provides abundant moisture. Mountain big sagebrush, mountain silver sagebrush, shrubby cinquefoil, and various dwarf willows are common shrubs in mountain meadows.

The absence of trees in mountain grasslands is often the result of fine textured soils and their moisture-holding characteristics. Such soils are often too wet during the growing season to allow for the establishment of conifer seedlings. On steeper south-facing slopes, fine textured soils can be too dry to support trees. In other locations, soils can be too shallow for trees, or persistent snow drifts can preclude tree growth. Competition from established herbaceous plants as well as cold-air drainage or frost pockets may also restrict tree establishment (Knight 1994). Lastly, disturbances such as forest fires, avalanches, and tree blowdowns can create conditions favorable to the establishment and persistence of mountain grasslands. Clearcut timber harvests often regenerate as mountain grasslands for several years before succeeding back into seedling/sapling stage forests.

Alpine tundra exists at the highest elevations where winds are severe and temperatures too low during the growing season to allow for adequate photosynthesis needed to support larger plants (Knight 1994). This often occurs where either the mean July temperature is lower than 50˚ F or the mean July maximum temperature is lower than 52˚ F (Tranquillini 1979, Arno and Hamnerly 1984). In Wyoming, subalpine forests and Krummholz give way to the treeless alpine tundra at elevations ranging from about 11,480 feet in the Medicine Bow Mountains in the south to about 9,840 feet in the Beartooth Mountains in the north (Nicholoff 2003). Alpine soils can be very dry as a result of severe cold, persistent strong winds, intense ultraviolet radiation, low vapor pressure at high altitudes, and reflective solar radiation from snowbanks. These effects can impair photosynthesis and limit growth of woody vegetation (Knight 1994).

Alpine tundra is more diverse than the lower elevation mountain grasslands. Common species include sheep fescue, spike trisetum, kobresia, tufted hair grass, alpine bluegrass, alpine avens, dwarf willows, and numerous cushion plants and sedges. Alpine plants tend to have much more root and rhizome biomass than shoots, leaves, and flowers. This feature not only aids in water and nutrient absorption, but also plays a very important role in over-winter carbohydrate storage (Nicholoff 2003). Reproduction in alpine plants is largely vegetative due to difficulties of seedling establishment in such a harsh environment.

Alpine vegetation generally occurs in a mosaic of small patches with widely differing environmental conditions. Changes in topography of as little as one foot or less may mean the difference between a windswept area and an area of protective snow accumulation, which can have a dramatic effect on the composition and productivity of the local plant community (Nicholoff 2003). Recovery after disturbance in alpine tundra is long, due to a very short, cold growing season and extremely slow soil formation.

Most mountain grasslands in Wyoming are under federal management. Roughly 98% of alpine tundra is publicly owned, and 72% is in wilderness areas (Nicholoff 2003). Important human uses of the mountain grassland and alpine tundra habitats include livestock grazing, recreational hiking, hunting, fishing, photography, rock climbing, camping, off-road vehicle travel, skiing, horse-packing, and mining. Mountain grasslands and alpine tundra also play important roles in water collection and storage, mostly through snow accumulation and melting, which is slowly released into Wyoming's streams and rivers throughout the summer in the form of runoff.

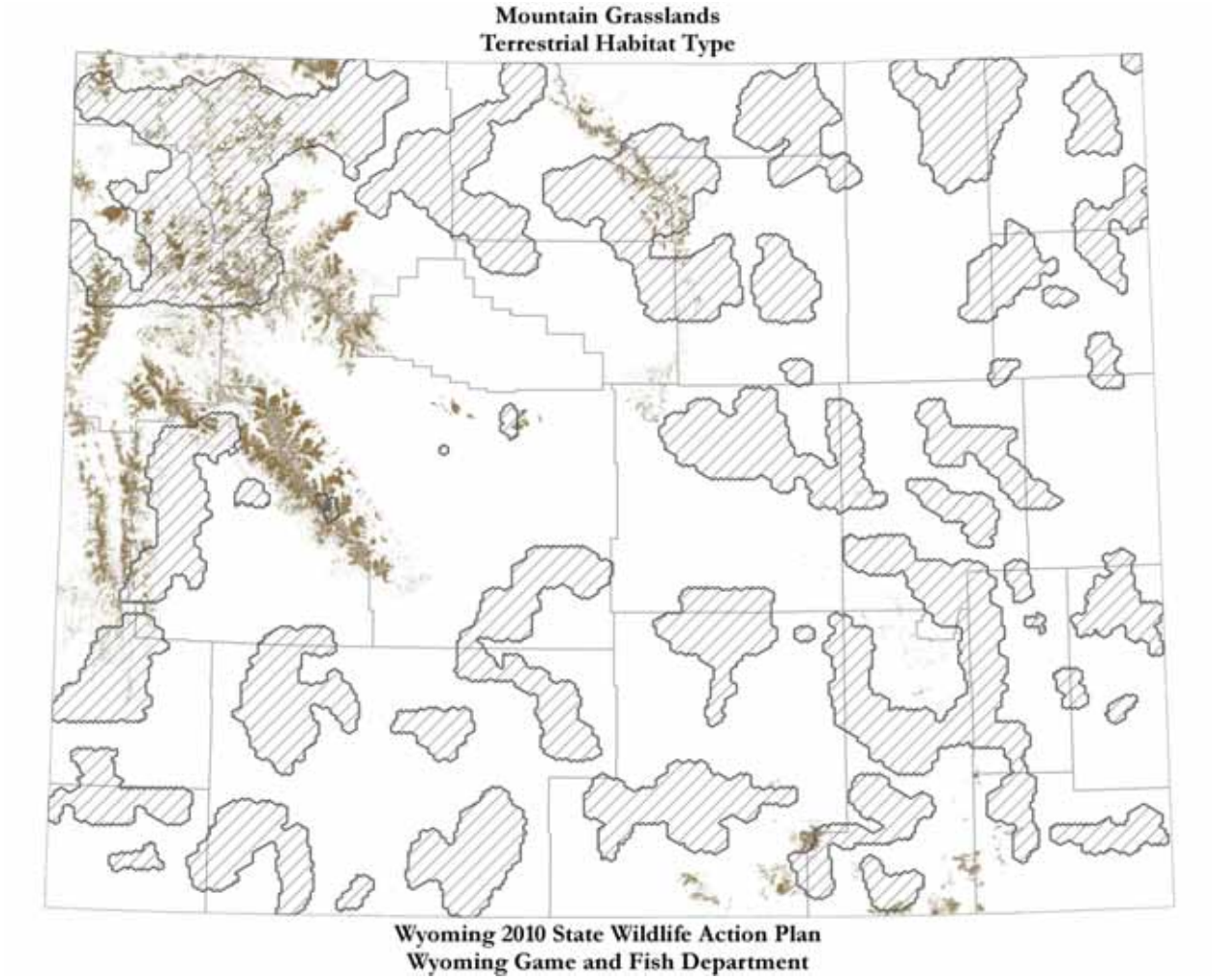

FIGURE 6. Wyoming Mountain Grasslands and Alpine Tundra and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 11. Wyoming Mountain Grasslands and Alpine Tundra NatureServe Ecological Systems[1]

1. Northern Rocky Mountain Subalpine-Upper Montane Grassland
2. Rocky Mountain Alpine Turf
3. Rocky Mountain Alpine Dwarf-Shrubland
4. Rocky Mountain Subalpine-Montane Mesic Meadow
5. Southern Rocky Mountain Montane-Subalpine Grassland
6. Harvested forest-grass regeneration

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://www.natureserve.org/explorer.

TABLE 12. Wyoming Mountain Grasslands and Alpine Tundra Species of Greatest Conservation Need

Mammals
American Pika
Bighorn Sheep
Dwarf Shrew
Moose
Preble's Shrew
Vagrant Shrew
Water Vole
Uinta Chipmunk
Yellow-pine Chipmunk

Birds
Black Rosy-finch
Brown-capped Rosy-finch

Reptiles
Northern Rubber Boa
Red-sided Gartersnake
Smooth Greensnake
Valley Gartersnake

Amphibians
Columbia Spotted Frog
Wood Frog

Mountain Grasslands and Alpine Tundra Wildlife

Wildlife in mountain grasslands and alpine tundra is often limited in the winter by deep snowpack. Many species, including big game and passerine birds, migrate to lower elevations and latitudes in the winter, occupying this habitat type only in the spring, summer, and fall.

Mountain grasslands can be characterized as patches of high primary productivity (i.e., forbs and grasses) embedded within a generally low-productive forest matrix. This combination provides critical forage patches in close proximity to tree cover. For example, mountain grasslands provide important summer forage for elk, mule deer, and bighorn sheep. Mountain goats, which are not native to Wyoming, use this habitat year round. Small mammals found in mountain grasslands and alpine tundra include water vole, montane vole, long-tailed vole, short-tailed weasel, and yellow-bellied marmot. The northern pocket gophers plays a keystone role in this environment through constant soil disturbance and root herbivory, which facilitates nutrient cycling, air and water penetration into the soil, and creates a fine-grained patchwork of understory plant communities in various stages of vegetational succession. In addition to plants, mountain grasslands are an important source of insects, which further contribute to the forage base for vertebrate wildlife.

Due to the severe climate, few vertebrate species, including birds, are able to breed in the alpine tundra. Although the avifauna of the alpine tundra is small compared to those of other habitats, these species (e.g., brown-capped rosy-finch, black rosy-finch, and American pipit) are typically specialized and endemic, and are not found in other habitats during the breeding season. Both rosy-finch species are SGCN and breed above timberline in barren, rocky, or grassy areas, including cirques, talus slopes, and alpine areas that have cliffs, snowfields, or glaciers nearby. The American pipit is a well known breeder in arctic and alpine tundra, using coastal beaches and marshes, stubble fields, recently plowed fields, mudflats, and river courses during migration and winter. Mountain grasslands below the tundra zone support a more diverse avifauna, with many tree-nesting species using adjacent grasslands as foraging patches.

Considerable data gaps exist for many of the SGCN mammals found in these habitats. However, some key habitat components can be identified, such as high structural diversity of alpine grasslands, high diversity in invertebrates, and proximity of grasslands to water, which increase the value of these habitats for these mammals. The American pika is a Wyoming SGCN that is found in the mountain grasslands and alpine tundra habitat type. It has been petitioned several times for protection under the Endangered Species Act, most recently regarding concerns that it may be negatively impacted by climate change.

Mountain Grasslands and Alpine Tundra Habitat Threats

Human disturbances have been of relatively low intensity and localized in the alpine zones because a majority of this habitat type is within designated wilderness. However, any disturbance above treeline may have lasting effects because of harsh growing conditions and low productivity. Because of their generally easier access and higher productivity, the lower elevation mountain grasslands have received greater human-related impacts.

Invasive plants – High
The potential for invasive plant spread in the mountain grasslands has dramatically increased since the 1960s. This is particularly evident in drier grasslands dominated by bluebunch wheatgrass and Idaho fescue. Spotted knapweed, leafy spurge, cheatgrass, yellow toadflax, Dalmatian toadflax, orange hawk's-beard, oxeye daisy, and nonnative thistles pose a serious threat to plant diversity and land productivity. Alpine tundra areas tend to be more resistant to noxious weed invasion due to harsh growing conditions and fewer vectors.

Climate change – Moderate
There are concerns over long-term persistence of alpine and subalpine meadows under climate warming scenarios. Rising global temperatures may lead to drier environmental conditions in mountain meadows and alpine tundra plant communities, which could cause shifts in species composition and the loss of high elevation wet meadows, which function as important natural water storage features and hydrological flow regulators. Warming surface temperatures are expected to be most pronounced at high elevations and latitudes. Changes in species diversity may be most apparent in alpine landscapes as warmer conditions encourage lower elevation species to expand their range upward in elevation and northward in latitude (Walther et al. 2002). The redistribution of vegetation into alpine tundra will depend on a variety of factors, including temperature extremes and water limitations. Subalpine conifers have been documented as infilling these areas—a trend that is suspected to be related to changing climate conditions (Joyce et al. 2007). Lower elevation mountain grasslands may become threatened by cheatgrass and other invasive species, which are more tolerant to changing climate conditions and varying levels of soil moisture, that currently occur below the subalpine zone.

Changing dynamics of animal communities linked to changing climate conditions have also been observed and documented in areas of high elevation and/or latitude. Terrestrial species that are associated with alpine tundra and mountain grasslands may be impacted by warmer temperatures, changing precipitation patterns, and mountain snow runoff, which could affect climate-sensitive behaviors, abundance, and diversity, and potentially cause habitat fragmentation and lead to isolated populations. Similarly, high elevation fisheries may be impacted by changing climate conditions that lead to alterations in water temperature, chemistry, or quality and quantity (see Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Overgrazing by ungulates - Moderate
At proper stocking levels, grazing regimes can be compatible with alpine tundra/grassland maintenance and improvement despite the short snow-free season, low productivity, and slow ecosystem recovery after disturbance. However, improper grazing practices can eliminate vegetation, cause soil erosion and compaction, encourage invasion of noxious plants, and change vegetation composition. Grazing within associated tall forb communities has led to loss of soil, stream sedimentation, and changes in plant species; and may require decades of rest and management to reverse these trends.

The degraded condition of some alpine areas in the West is the result of uncontrolled grazing, mainly by domestic sheep, which occurred in the late 19th and early 20th centuries (Winward 1998, Belsky and Blumenthal 1997). Early

grazing operations herded sheep in tightly grouped bands, continuously bedded them in the same location for several nights, and drove them to and from water. These practices reduced forage through trampling and overgrazing, especially near water, and damaged soil through excessive trailing and compaction. Alpine ranges are still grazed by domestic sheep, but in some instances the intensity is much lower.

Some cattle grazing still occurs in alpine habitat due to the conversion of domestic sheep allotments to cattle allotments. Recreational livestock use (i.e., pack stock) can also have detrimental localized effects through soil compaction and overgrazing. Wild ungulates also graze alpine habitats, and overgrazing is not uncommon in localized areas.

The WGFD sets big game herd unit population objectives based on a variety of factors including habitat condition within the herd unit, hunter demand, landowner input, and biological potential. These considerations result in mixed opinions as to what the objective should be. All objectives are taken to the public for review and approved by the Wyoming Game and Fish Commission. Although the WGFD collects habitat data across the state, seldom is it specific enough to tie the habitat condition directly back to a specific number of animals. Such data is useful; however, in understanding whether big game populations are within the limits of what the habitat can support. The WGFD strives to have populations that are in balance with the majority of the habitats within the herd unit.

Recreation – Low to Moderate
Recreational activities such as camping, hiking, biking, horse-packing, and off-road travel can degrade mountain grasslands and alpine tundra. Recreationists may trample plants, compact the soil, increase soil erosion, and contribute to the establishment of invasive plant species. Human activities may also disturb animals, including birds, especially during breeding season (Nicholoff 2003). Recreational activities appear to be most detrimental when concentrated and repeated on the same ground, such as is found near trails, trailheads, and developed campsites, and they have less effect when dispersed. Road development in mountain landscapes brings more people, livestock, exotic plant species, generalized disturbance, and pollution into the ecosystem. Motorized vehicles, including ATVs and snowmobiles, can have significant impacts on wildlife and plant communities.

Current Mountain Grasslands and Alpine Tundra Conservation Initiatives

Land exchanges and purchases have occurred on some mountain grassland habitats in Wyoming to consolidate land and facilitate more efficient land management for both private landowners and public agencies, or to protect in-holdings or adjacent lands with high ecological and/or recreational value.

The Nature Conservancy (TNC) works in several areas of Wyoming where mountain grassland and alpine meadow landscapes are prevalent. The organization works with private landowners and public land managers to protect the integrity of these areas where important alpine plants species are found and high elevation terrestrial and aquatic animals inhabit seasonally or year round. TNC has used conservation easements, land exchanges, and grazing and invasive plant management techniques to conserve high elevation landscapes and species, including the American pika and bighorn sheep, in the Absaroka, Bighorn, and Wind River Mountains.
As part of a larger effort to reduce invasive species, certified weed-free hay is required for livestock producers and recreational horseback riders using many federal lands, including National Parks and U.S. Forest Service lands. Early Detection and Rapid Response strategies to prevent the establishment of invasive species are being developed for both public and private lands.

Teton County Weed and Pest and Grand Teton National Park have worked cooperatively on the Snake River Project, which is aimed at controlling and ultimately eliminating noxious weed infestations along the Snake River, which rises in the Rocky Mountains in western Wyoming. The project emphasizes weed control, community involvement, and education to control the spread of noxious weeds such as spotted knapweed and Canada thistle. The project has utilized biological controls and mechanical controls (community weed-pulling events). Although higher elevation areas may not be heavily impacted by these noxious weeds, the proactive nature of the project is essential to the preservation of the integrity of mountain and alpine landscapes in this region.

The Wyoming Natural Resources Conservation Service (NRCS) is working with the Wyoming Association of Conservation Districts (WACD) to use Light Detection and Ranging (LiDAR) technology to acquire statewide elevational data that will benefit Wyoming's natural resource managers. LiDAR has the potential to provide state resource managers with high resolution Digital Elevation Models (DEMs) that cover large areas with highly accurate data. This effort will have many positive implications for effectively modeling and monitoring state hydrology, vegetation, soil, and other surface features, which could be particularly useful as changing climate conditions alter high elevation landscapes.

Recommended Mountain Grasslands and Alpine Tundra Conservation Actions

Grazing plans for mountain grasslands and alpine tundra should be developed and evaluated on a case-by-case basis to address specific site conditions.
Leaving 70–80% residual herbaceous for major species is recommended for alpine tundra grazing strategies (Nicholoff 2003). The fall date of removing livestock from alpine areas should be carefully monitored to avoid trampling damage to soil that has been moistened by snow but is not yet solidly frozen; to avoid damage to preformed flower buds, which could influence plant growth the following growing season; and to avoid livestock losses to early fall snowstorms. Big game grazing impacts should be considered when setting herd population objective levels.

Appropriate grazing guidelines that will allow restoration of tall forb communities should be established. An initial attempt to establish grazing guidelines for tall forb communities through species composition of five key plant species and ground cover has been made (O'Brien et al. 2003). This work needs to be refined to include additional species and focus on species composition by occurrence versus canopy cover. Tall forb sites with low amounts of remnant species may restore themselves, providing grazing management is such that seedlings can be sustained. Where no remnant desirable species remain, artificial reintroduction of native forb species will be required (Winward 1998).

Use minimum impact fire suppression tactics in mountain grasslands and alpine tundra.
Although fire is an important successional influence at lower elevations, it is not usually as influential in the alpine zone. In general, alpine communities are usually too wet to burn, or the plants are too widely spaced to carry a fire. Wildfire management at lower elevations, however, can have profound effects on mountain grasslands. Some fires should be allowed to burn unless they pose a significant risk to human lives or structures. When fighting fires the use of fire retardants, fire lines, and other tactics which may damage fragile vegetation and soils should be limited. Forest and fire managers should consider the long-term impacts of existing clearcuts succeeding into forest. There may be some situations in which new clearcuts are not planned and wildfire, or prescribed fire, would be needed to maintain important mountain grasslands.

Create recreation plans for mountain grasslands habitats.
Consider potential disturbances to wildlife and plant communities when planning or locating trails, camping sites, picnic areas, and other sites of concentrated human activity within mountain grasslands and alpine tundra. In recreational use plans for alpine habitats, considerable attention should be given to the kinds of vegetation and soils present and their susceptibility to change and destruction. Buffer zones should be established between roads and recreational facilities. Road networks in general are the main vector of disturbance into these habitats; thus, travel plans and road maintenance/retirement plans will figure largely in their future distribution and quality.

Rehabilitate degraded sites, including heavily-used recreation sites.
Where possible, restore disturbed sites to native plant communities. Revegetation minimizes erosion and associated reduced water quality and aids in reestablishing native plant communities. Seed mixes should reflect local plan diversity. Local seed stock is preferred and nonnative plants should be avoided. Revegetate alpine disturbances in the fall. Most high-elevation areas remain inaccessible in the spring until large snowdrifts melt. By the time access and site conditions are suitable, the optimum conditions for seed germination and seedling development may be passed (Nicholoff 2003). Fall revegetation ensures that seeds and amendments will be in place when conditions are ideal for germination the following spring as snowmelt occurs (Nicholoff 2003).

Mountain Grasslands and Alpine Tundra Monitoring Activities

Continue monitoring mountain grasslands and alpine tundra SGCN in order to detect population trends or changes in distribution that may reflect habitat problems.
Implement mountain grasslands and alpine tundra monitoring programs to establish baseline data and identify changes in habitat quality (both positive and negative) over time. This information should be used to guide future monitoring and research, as well as to identify and address habitat conservation needs.

Continue to monitor the distribution and condition of mountain grasslands and alpine tundra through remote sensing and ground surveys.
Remote sensing is useful in tracking the size and distribution of this habitat in Wyoming. Information gathered would be helpful in determining the cumulative impacts of activities and events such as road and trail building, effects of adjacent forest fires and beetle outbreaks, and the possible effects of climate change. Special attention should be given to monitoring mountain grasslands and alpine tundra habitats in SWAP SGCN priority areas (Figure 6).

Monitor the effects of individual grazing strategies in mountain grasslands and alpine tundra to check progress toward established objectives.
Record how key alpine plant species and the overall alpine tundra and mountain grassland ecosystems respond to grazing management (Nicholoff 2003). Collecting basic range analysis data is essential to be able to evaluate the effects of natural and human activities on habitat conditions over time. Annual photographs taken from the same point are helpful (Nicholoff 2003).

In cooperation with research entities and the Wyoming State Climatologist, monitor the effects of climate change.
Changing climate conditions, including warming temperatures and changing precipitation patterns, may cause observable impacts to high elevation and high latitude landscapes. These impacts will affect both the terrestrial and aquatic species that inhabit alpine tundra and montane grassland habitat. Efforts should be made to monitor changes in seasonal temperatures, temperature extremes, season length, and precipitation variability.

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Prairie Grasslands

Photo courtesy of WGFD

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Habitat Description

In Wyoming, prairie grasslands are typically below 7,000 feet in elevation and are predominantly located in the eastern portions of the state, although they are also common in basins of south central and southwestern portions of Wyoming. In eastern Wyoming, prairie grasslands have among the warmest and longest growing seasons of Wyoming's habitat types, as well as relatively deep and well developed soils. Their location in eastern Wyoming allows them to receive relatively high summer precipitation, ultimately derived from weather systems originating in the Gulf of Mexico which are blocked by the mountains from the basins of western Wyoming. These factors result in grasslands having high primary productivity when compared to other Wyoming habitat types.

Most of Wyoming's grasslands are classified as either shortgrass prairie or mixed-grass prairie. Shortgrass prairie occurs mainly in the southeast corner of the state and extends south into Colorado. Buffalo grass and blue grama are the two predominant grass species in shortgrass prairie. Mixed-grass prairie is common across much of eastern Wyoming. It typically receives more moisture and has greater plant species diversity than shortgrass prairie. Common mixed-grass prairie plant species include needle-and-thread, western wheatgrass, blue grama, Sandberg's bluegrass, prairie Junegrass, upland sedges, and Indian ricegrass (Knight 1994).

Grasslands are characterized by frequent and occasionally intense natural disturbances including drought, fire, grazing, and occasionally short growing seasons (Nicholoff 2003). These factors have encouraged the predominance of perennial grasses with a substantial number of sedges and herbaceous forbs. These types of plants have their buds at or just below the surface, making them less susceptible to damage by surface fire and grazing (Knight 1994). Historically, regular disturbances created patches of vegetation in various stages of recovery. The size and location of patches often shifted across the landscape through time resulting in a mosaic of habitat diversity (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes). In addition to disturbances, water availability, often related to the location of snow drifts, influenced the local composition of prairie plant communities.

Prior to European settlement, fires on the Great Plains occurred at intervals of approximately 2–25 years (Wright and Bailey 1980). Wyoming grasslands likely burned less frequently because they are more arid than the mesic grasslands of the Great Plains and thus did not accumulate fine fuels as quickly (Knight 1994).

Much of Wyoming's prairie grasslands are unsuited for farming; however, the abundant grazing resource led to the establishment of cattle and sheep ranches. Today, the majority of Wyoming's prairie grasslands are incorporated within privately owned ranches. The predominance of large ranches and Wyoming's relatively low population density have allowed grasslands to persist in a relatively intact state when compared to other regions of the country. Properly managed, livestock grazing can duplicate the natural influences of native species like bison. The future of this habitat type in Wyoming will be closely tied to the ability of organizations to engage private landowners in conservation efforts and the persistence of ranching as an economically viable land use within the state. In addition to ranching, wildlife habitat, oil and gas extraction, wind power, recreation, and housing development are important land uses in the grasslands habitat type.

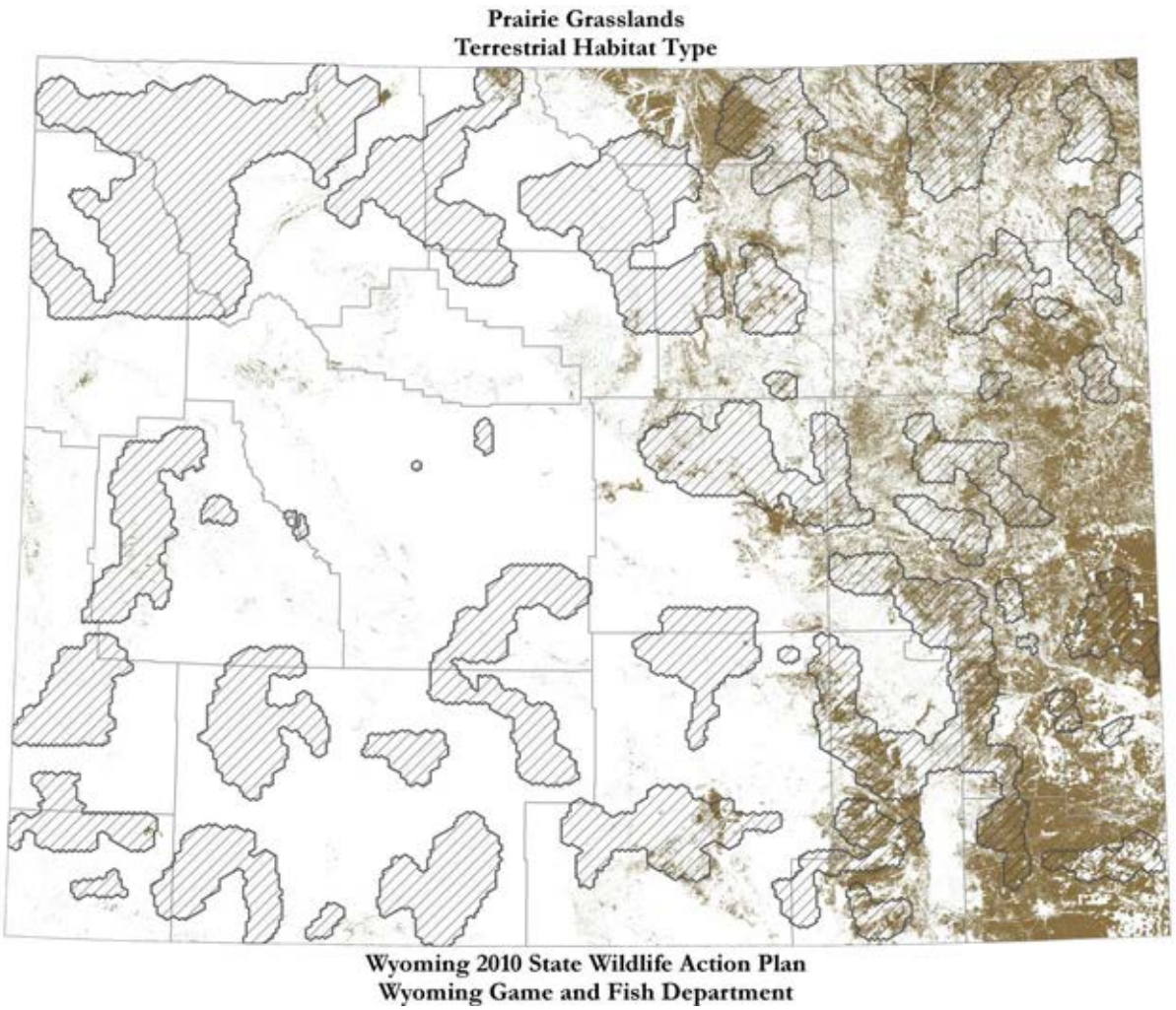

FIGURE 7. Wyoming Prairie Grasslands and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 13. Wyoming Prairie Grasslands NatureServe Ecological Systems[1]

1. Inter-Mountain Basins Semi-Desert Grassland
2. Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland
3. Northwestern Great Plains Mixed-grass Prairie
4. Western Great Plains Foothill and Piedmont Grassland
5. Western Great Plains Sand Prairie
6. Western Great Plains Shortgrass Prairie
7. Introduced Upland Vegetation – Forbland
8. Introduced Upland Vegetation – Annual Grassland
9. Introduced Upland Vegetation – Perennial Grassland
10. Recently burned grassland

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://www.natureserve.org/explorer.

TABLE 14. Wyoming Prairie Grasslands Species of Greatest Conservation Need

Mammals
Black-footed Ferret
Hispid Pocket Mouse
Olive-backed Pocket Mouse
Plains Harvest Mouse
Plains Pocket Mouse
Plains Pocket Gopher
Silky Pocket Mouse
Spotted Ground Squirrel
Swift Fox

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

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

Amphibians
Great Plains Spadefoot
Great Plains Toad
Plains Spadefoot

Prairie Grasslands Wildlife

Grasslands are known to support large numbers of wildlife. They are sometimes described as grazer systems, because photosynthesis entrains solar energy into grass, which is digestible by a wide range of animals. In contrast, forests, sometimes described as decomposer systems, direct solar energy into wood, which is digestible only by specialized fungi, microbes, and insects.

Historically, a number of animal species had a significant influence on shaping the plant and animal composition of prairie grassland habitats. Estimated bison numbers prior to European settlement vary considerably, from 15–20 million (Cushman and Jones 1988, Shaw 1995) to 30–60 million (Samson et. al 1996). Certainly, large numbers of bison altered grasslands by grazing some areas intensively, which contributed to patches of open habitat and reduced encroachment by trees.

Prairie dogs, often thriving in areas recently grazed by bison, lived in large colonies, digging burrows and cropping vegetation. These burrows and the open patches of ground resulting from the colonies create habitat for other wildlife species, including the black-footed ferret, burrowing owls, long-tailed weasel, mountain plover, and swift fox (Kotliar et al. 1999, Kotliar 2000). Prairie dogs also provide a prey base for carnivores including black-footed ferrets, ferruginous hawks, and golden eagles.

Burrowing mammals such as prairie dogs increase the structural diversity of grassland habitats by providing subterranean cover from the elements. Soil burrows are warmer in winter, cooler in summer, more humid year-round, and essentially windless compared to the ground surface. This burrowing activity is parallel to the function that primary cavity excavators such as woodpeckers provide in forest habitats. Most Wyoming prairie grasslands have a strong shrub component in addition to grasses. Shrubs also contribute to the structural diversity of prairie grasslands habitat by providing sites for perches, snow-capture structures, wind breaks, nest cover, and an additional forage base for ungulates. Key habitat components, such as high structural diversity of grasslands, high diversity in invertebrates, and diversity of seed crops, will increase the value of these habitats for these mammals, especially pocket mice.

Prairie grasslands are home to some of Wyoming's best known wildlife species

including the pronghorn and the western meadowlark, Wyoming's state bird. Prairie sharp-tailed grouse are a popular game species found in grasslands. Many birds such as rough-legged hawk, hoary redpoll, Lapland longspur, snow bunting, and even the occasional snowy owls and gyrfalcons, which breed in the Arctic or boreal Canada, winter on Wyoming grasslands. Prior to European settlement, elk were commonly found in prairie grasslands, but then retreated to more mountainous habitats with human encroachment. In some areas of Wyoming this trend is now reversing.

Wyoming once represented the western periphery of many species' continental ranges (e.g., mountain plover, swift fox, ferruginous hawk, and pronghorn). Intensive conversion of grassland in the Great Plains resulted in the loss of these habitats outside of Wyoming. Consequently, populations in Wyoming have remained largely intact, and the core of these species' distributions is now considered to be in Wyoming.

Prairie Grasslands Habitat Threats

Energy development – High

Coal mining, oil, natural gas, and wind are common forms of energy development in Wyoming grasslands (see Wyoming Leading Wildlife Conservation Challenges – Energy Development). Wyoming is the nation's leading producer of coal (National Mining Association 2008). About 96% of Wyoming's coal originates in northeastern Wyoming[2] where grasslands predominate (Lyman and Jones 2005). Wyoming is also ranked fifth in natural gas production, eighth in crude oil production (Lawrence 2007), and, after factoring in land status and environmental constraints, seventh in wind-power generating potential (Elliott et al. 1991).

Based on a recent compendium of public land statistics, 175,980 acres of public lands are currently leased for coal extraction, and oil and gas leases total more than 8.8 million acres in Wyoming (BLM 2008). Over 42,000 oil and gas wells were in production as of April 2008 (Barclay et al. 2008) and nearly 10,000 applications for permits to drill (APDs) were approved from January 2008 through May 2009 (Wyoming Oil and Gas Commission data, at http://wogcc.state.wy.us/). Natural gas production in Wyoming is projected to more than double from its current level by 2035 (Surdam undated).

Energy development in grasslands results in direct removal of native vegetation and habitat fragmentation through road building, well pad drilling, power line construction, buried pipelines, booster stations, and facility buildings. In addition to habitat loss and fragmentation, wildlife is impacted by increased traffic, human activity, and noise. Broken or bare ground and greater vehicle traffic associated with the construction and production phases of energy development can also contribute to the spread of invasive plant species.

Wind-energy development is a growing industry in Wyoming and will likely affect significant acreage in the near future. Wind development, individually and cumulatively, can impact food, cover, and special habitat needs for native grassland species. The location of sage-grouse core areas (see Terrestrial Habitat Types – Sagebrush Shrublands – Current Sagebrush Shrublands Conservation Initiatives) and the state strategy to place wind development east and north of I-25 have increased wind development pressures on portions of the state occupied by grasslands.

Little research has been conducted to quantify wind-energy development impacts on grasslands wildlife species. Bird and bat strikes are commonly known to occur in wind-energy facilities, but the behavioral responses and resulting population performance are largely unknown for species such as pronghorn and sage-grouse that preferentially inhabit open landscapes, area-sensitive species such as the grasshopper sparrow, dickcissel, and bobolink, and species that perform aerial displays during courtship such as the long-billed curlew, upland

[2] Campbell, Converse, and Sheridan Counties.

sandpiper, chestnut-collared longspur, and McCown's longspur. Some researchers have proposed similar impacts on wildlife from wind-energy infrastructure and associated human activity as those documented for oil and gas development (Becker et al. 2009).

Invasive plant species – High
Noxious and invasive plants can spread aggressively and dominate plant communities (see Wyoming Leading Wildlife Conservation Challenges – Invasive Species). This can reduce native plant diversity, which in turn decreases food and cover for wildlife.

Cheatgrass, the most prevalent invasive plant species in Wyoming's prairie grasslands, is an annual brome from Eurasia whose abundance has dramatically increased in the Intermountain West over the last several decades. Cheatgrass rapidly expands in areas with bare ground and soil disturbance (Mack 1981, Bradford and Lauenroth 2006). These conditions can be facilitated by drought, overgrazing, and road development. Cheatgrass dominance eventually creates uniform annual grasslands perpetuated by large, frequent fires and void of patches of native plant communities (Paige and Ritter 1999).

Notable invasive forb species include Dalmatian toadflax, Canada thistle, leafy spurge, Russian knapweed, spotted knapweed, kochia, and Russian thistle. Canada thistle, which is typically found in riparian areas, is the most widespread weed in Wyoming grasslands. Leafy spurge is an important weed because it is easily spread and difficult to eliminate. It is found on tens of thousands of acres statewide, covering the most acreage in Weston, Johnson, Crook, Sheridan, Lincoln, and Fremont counties (Wyoming Pest Detection Program 2009). Although leafy spurge has generally proliferated across the state in recent years and continues to increase in some counties, it is starting to decline in some counties, namely Lincoln, Park, Sheridan, Johnson, Converse, Crook, and Weston counties. Russian knapweed is present throughout Wyoming, covering the most acreage in Fremont, Park, Big Horn, Hot Springs, Washakie, and Weston counties (Wyoming Pest Detection Program 2009). The occurrence of Russian knapweed has generally been increasing across the state, but in recent years has remained static or even declined in some counties. Spotted knapweed is not as concentrated in Wyoming as leafy spurge or Russian knapweed, but has been steadily increasing in some counties and is now found throughout the state. This weed is reportedly declining, or has been eradicated, or nearly eradicated in a few places (Wyoming Pest Detection Program 2009). Spotted knapweed currently covers the most acres in Teton and Park counties.

Continued construction from energy and rural development, increased interstate travel, and potentially shifting weather conditions associated with climate change are likely to intensify the spread of invasive plants species. Additionally, while there are some effective treatment methods, particularly in grasslands with a predominance of alkaline and sodic soils, the re-establishment of native plant species can be difficult.

Off-road vehicle use – Moderate/Locally High
Off-road vehicle use, primarily by all-terrain vehicles (ATVs), is increasing in grassland habitats. Vehicle use off established roads can enhance the spread of invasive species including halogeton, alyssum, pepperweed, and cheatgrass. Tires can damage biological soil crusts leading to decreased organism diversity, soil nutrients, stability, and organic matter. This can result in greater erosion and reduced water quality. Wildlife often avoid areas of increased noise and disturbance from outdoor recreational vehicles, and riding off-road can destroy the nests, eggs, and young of ground-nesting birds. These impacts can also lead to conflicts with hunting, wildlife viewing, and other forms of nature-based recreation. Managing off-road vehicle use can be difficult and controversial in grassland habitats where new trails are relatively easy to create and where some off-road vehicle users place less importance on what appears to be an endless, open landscape.

Reduced vegetation structure and species diversity due to altered disturbance regimes – Moderate
Prior to European settlement, frequent fires, shifting grazing patterns by bison and other large ungulates, and extensive prairie dog colonies created grasslands with more diversity in plant structure and composition than exists today (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes). Most current livestock management practices emphasize the even distribution of livestock across the landscape. This strategy leads to uniform grazing intensities, which has pros and cons to habitat ,and may further contributes to grasslands with reduced habitat diversity. Reduced diversity diminishes habitat for some grassland wildlife species, particularly those which require either early or late succession stages following habitat disturbances. Other grassland habitats are negatively impacted by continuous heavy grazing, commonly associated with excessive livestock numbers, which can reduce residual plant cover needed by many wildlife species for nesting and avoiding predators.

Drought and climate change – Moderate
Drought can reduce plant vigor, decrease the abundance of cool and warm season grasses, and increase non-native plants, especially cheatgrass (Smith and Enloe 2006). Drought can also lead to outbreaks of grasshoppers and Mormon crickets, which can further diminish the amount of available forage for wildlife and livestock.

During drought times, livestock producers are often faced with either reducing stocking rates by selling livestock or continuing to graze at the current levels, hoping that moisture will improve. Postponing decreasing stocking rates for one season often results in little damage; however, repeated use of this option can significantly reduce the health of grasslands.

While the development of livestock drought management plans will not eliminate all issues associated with drought, well developed plans can diminish negative ecological impacts for both the habitat and financial impacts for the producer. At least several months' lead time is needed for land managers to respond in making preparations for drought.

Wyoming's climate is naturally semi-arid, and drought is a natural and historical feature of the state's climate. However, some climate models that project future climate conditions suggest that Wyoming's climate will become even drier as a result of warming seasonal temperatures leading to increased evaporation of surface waters and increased water loss from plants during transpiration. Warming trends have been documented in the Northern Great Plains region, while annual precipitation has been documented as decreasing in eastern Wyoming (Joyce et al. 2000). Climate patterns in the West are naturally variable, but continued warming of seasonal temperatures will likely lead to decreased soil moisture regardless of changes in precipitation (Joyce et al. 2000). For grasslands, decreasing soil moisture might mean the loss of some native species whose current growth is limited by annual precipitation and the establishment of new vegetative communities that may favor more tolerant invasive species. Changes in the structural diversity of Wyoming's grasslands may impact grazing practices and also impact disturbance regimes, such as the frequency and severity of wildfire. The alteration of prairie grasslands will also have direct implications for grassland obligate species (see Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Rural subdivision and development – Moderate
Rural subdivision and development can reduce, degrade, and fragment grassland habitat (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). Houses, outbuildings, and lawns directly replace native wildlife habitat. Wildlife commonly abandons or alters use of habitats with greater human and pet activity. Increased energy expenditures in avoiding people or greater use of lower quality habitats

can decrease animal health and reproductive capacity. Greater road densities and traffic volume can increase wildlife–vehicle collisions. Predation on wildlife can increase with greater numbers of domestic dogs and cats, as well as increases in generalist predatory species such as ravens and human-commensal species such as raccoons (U.S. Department of Agriculture 2007). Soil disturbance from construction, year-round grazing of horses and other hobby livestock, and the use of non-native plants as ornamentals can facilitate the establishment of invasive species (Maestas et al. 2002). Subdivision and housing development is a greater problem for grasslands habitats near Wyoming's larger towns and cities such as Cheyenne, Glenrock, Douglas, Gillette, and Sheridan.

Conversion to agriculture – Low

Approximately 5% of Wyoming's land area is in agricultural production (Census of Agriculture 2007). Dryland agriculture accounts for just under half of all agricultural activities, while irrigated farming constitutes the remainder. In addition to lands currently being farmed, there have been numerous unsuccessful attempts over the years to bring grasslands into agricultural production. Very few of these failed attempts have returned to native conditions. Reduced plant diversity associated with farmland, as well as previously cultivated fields, supports a lower variety of wildlife than is found in native habitats (Knopf 1994). In addition to reductions in habitat and habitat quality, some farming and haying practices, especially during the nesting season, can lower the reproductive success of grassland birds (Dale et al. 1997, Dechant et al. 2002).

Conversely, some wildlife species have adapted to use agricultural fields during various phases of their life cycle. Sub-irrigated native hay fields provide valuable nesting habitat for many wetland birds such as Wilson's phalarope, or grassland birds such as the long-billed curlew. This is especially true for fields that have not been leveled and are not under intensive management with machinery and chemical treatments. Pronghorn and mule deer use these areas during certain times of the year too. Dryland cultivated fields with low vegetation and little topographical variation can provide nesting habitat for the mountain plover in parts of its range (Knopf 1994).

United States Department of Agriculture (USDA) Farm Bill programs, such as the Conservation Reserve Program (CRP)[3], has provided incentives for planting farmland back into permanent cover. The amount of cropland in Wyoming has decreased by 413,700 acres between 1982 and 1997 (U.S. Department of Agriculture 2000) partially in response to CRP and other Farm Bill programs. While this has benefited many grasslands species of wildlife, the heavy use of non-native grasses, including bromes and tame wheatgrasses, along with the lack of forb species in reseeding mixes, have reduced the wildlife value of some CRP lands. Additionally, the fate of many CRP lands whose contracts are set to expire is uncertain.

Improper use of pesticides and herbicides – Low

The over-application of herbicides, such as Tordon for cactus control and 2, 4-D for sagebrush control, can result in a loss of perennial forbs, which reduces plant and associated wildlife diversity. The improper use of Rozol for prairie dog control can have significant impacts on non-target wildlife species (U.S. Environmental Protection Agency 2004). Pesticide use to control grasshoppers and Mormon crickets can reduce prey availability for grassland birds, especially the mountain plover.

[3] CRP was authorized by the 1985 Farm Bill as a voluntary, long-term cropland retirement program with a soil conservation orientation. The USDA pays producers an annual rental payment plus half the cost of establishing a conserving land cover in exchange for retiring highly erodible or other environmentally sensitive lands from crop production. Ninety-three percent of CRP land is planted to grass or trees under 10-year contracts.

Current Prairie Grasslands Conservation Initiatives

The Wyoming Game and Fish Department (WGFD) published *A Plan for Bird and Mammal Species of Greatest Conservation Need in Eastern Wyoming* in 2006. The overarching goal of this plan is to formalize proactive strategies that will help the WGFD work cooperatively with landowners, other agencies, and the public to address conservation needs of Wyoming's grassland and associated wildlife. The plan reviews the ecology, land uses, and threats to Wyoming's grasslands. Recommendations are presented to conserve Wyoming grasslands including information on the life histories, threats, conservation actions, and monitoring strategies for 22 grassland species designated as Species of Greatest Conservation Need in Wyoming's 2005 Comprehensive Wildlife Conservation Strategy (the previous name of Wyoming's SWAP).

A number of USDA Farm Bill Programs have targeted, or secondarily provide benefit to, grasslands habitats and wildlife species. The most notable programs include the Conservation Reserve Program (CRP), Wildlife Habitat Incentives Program (WHIP), Grassland Reserve Program (GRP), and The Farm and Ranchland Protection Program (FRPP).[4] The Environmental Quality Incentives Program (EQIP) was created to offer financial and technical assistance to install or implement structural and management practices that promote agricultural production and environmental quality. The Wyoming Natural Resource Conservation Service (NRCS) established a special initiative for at-risk wildlife species under the EQIP program. About $500,000 was allocated for this purpose in 2005–2007. Unfortunately, less than one half of this was spent on at-risk wildlife projects due to a lack of proposals (Toombs and Roberts 2009). More information about these and other USDA Farm Bill Programs that can benefit grasslands wildlife can be found at http://www.wy.nrcs.usda.gov/programs/index.html. Additionally, the Environmental Defense Fund produced a report with recommendations on how Farm Bill programs can provide greater benefit for Wyoming grasslands wildlife species. (Copies can be obtained at http://www.edf.org/documents/8015_WyomingRangePracticesWildlife.pdf.)

Grasslands were identified as one of eight priority habitats to enhance or maintain within the WGFD's Strategic Habitat Plan (SHP). First created in 2001 and revised in 2009, the purpose of the SHP is to strategically guide WGFD habitat improvement and protection activities. Regional priority areas for conservation work were identified, including crucial areas, necessary for maintaining terrestrial and aquatic wildlife populations, and enhancement areas, where there is the potential to enhance or improve important wildlife habitats that have been degraded. Narratives for both crucial and enhancement areas describing the location, boundaries, values, issues, species, and solutions/actions were prepared (http://gf.state.wy.us/habitat/PriorityAreas/index.asp).

A number of wildlife agency programs focus on implementing projects and management plans with private landowners to benefit wildlife. These include the WGFD Public Lands/Private Wildlife Program, Landowner Incentive Program and Habitat Extension Services, as well as the U.S. Fish and Wildlife Service Partners for Fish and Wildlife Program. These programs often form partnerships with local communities and other conservation organizations in accomplishing their mission. Grasslands habitat enhancements commonly include the development of grazing systems that benefit wildlife and livestock. Payments to offset management costs, invasive plant treatments, water developments, fencing, and cattle guards

[4] WHIP offers both technical assistance and up to 75% cost-share assistance to establish and improve fish and wildlife habitat. GRP is designed to protect grasslands from conversion through 10-year, 15-year, or 20-year contracts or perpetual conservation easements. FRPP is another conservation easement program that has been used to conserve grasslands.

are among incentives used to encourage participation from landowners.

Landscape Conservation Cooperatives (LCCs) are being established by the U.S. Fish and Wildlife Service to provide science support to enhance conservation actions in the face of climate change and other regionally shared conservation priorities. Wyoming includes portions of five LCCs. The Plains and Prairie Potholes and Northern Great Plains Landscape Conservation Cooperative encompass significant amounts of Wyoming's grasslands and have the conservation of grasslands and grassland species among their principal focuses.

Among the most notable partnerships between landowners, natural resource agencies, and non-profit organizations is the Thunder Basin Grasslands Prairie Ecosystem Association. The Association was established in 1999 as a landowner-driven effort to develop an ecosystem management plan for species of concern while balancing these needs with sustainable economic and social activities. Members in the association include private property owners within a designated 931,192-acre landscape in eastern Wyoming. Areas of interest include management activities related to ranching, coal, coal-bed methane, oil, and gas production.

The Shirley Basin-Laramie Rivers Conservation Action Plan (CAP) was completed in 2008 by The Nature Conservancy in cooperation with the Medicine Bow and Laramie Rivers Conservation Districts. The plan describes important species and habitats in the area, threats to their persistence, and strategies and actions to abate those threats. Participants included local ranchers and individuals representing the WGFD, U.S. Fish and Wildlife Service, Albany and Carbon County Weed and Pest, County Commissioners, Audubon Wyoming, Trout Unlimited, Wyoming Natural Diversity Database, Sonoran Institute, NRCS, BLM Rawlins Field Office, University of Wyoming Cooperative Extension Service, and the Shirley Basin-Bates Hole Sage-Grouse Working Group.

The Southeast Wyoming Cheatgrass Partnership was formed in 2005 to promote learning, coordination, and communication between partners about research, monitoring, and cheatgrass control projects in Laramie, Goshen, Platte, Albany, and Carbon counties. Current membership includes representatives from the WGFD, U.S. Forest Service, BLM, NRCS, various County Weed and Pest Districts, local conservation districts, as well as University of Wyoming and Colorado State University faculty and researchers.

A number of land trusts in Wyoming including the Green River Valley Land Trust, Jackson Hole Land Trust, The Nature Conservancy, and the Wyoming Stock Growers Agricultural Land Trusts are actively involved in negotiating conservation easements on grassland habitats.

Recommended Prairie Grasslands Conservation Actions

Improve planning and mitigation design for wind and other types of energy development.
Coal, oil, natural gas, and wind development are likely to intensify on Wyoming grasslands. Landscape level planning and mitigation is needed to offset the potential cumulative negative impacts from these activities. Mitigation plans should stress avoiding biologically sensitive areas within project sites and directing off-site mitigation funds to nearby high value wildlife locations. Energy development planning and mitigation efforts could specifically benefit from:

- Continued research on the effects of energy development on prairie grasslands wildlife species and ecosystems. The Wyoming Natural Diversity Database and Wyoming Cooperative Research Unit are currently conducting research to evaluate the vulnerability of Wyoming terrestrial SGCN to oil, gas, and wind development. Vulnerability is being determined by evaluating each species' potential exposure and sensitivity to energy development.

Exposure is being evaluated through a GIS analysis that overlays distribution maps of SGCN with areas of known and projected energy development. Sensitivity is being determined by examining habitat and behavioral attributes of SGCN as well as reviewing existing impact studies. Research results will not only give an indication of which species and taxonomic groups are potentially vulnerable to development, but also help direct future research to address information gaps. The project is being funded jointly by the U. S. Geological Survey, Wyoming Landscape Conservation Initiative (WLCI), and WGFD.

- Use spatially-explicit grassland habitat priority, such as those found within Wyoming's SWAP (Figure 7) and SHP to help guide energy planning and mitigation activities. This work should include continued inventory of grassland habitats for SGCN.
- Where appropriate, encourage the implementation of mitigation measures and/or best management practices detailed within the Wyoming Game and Fish Commission documents *Recommendations for Development of Oil and Gas Resources Within Important Wildlife Habitats* (WGFD 2010a) and *Wildlife Protection Recommendations for Wind Energy Development in Wyoming* (WGFD 2010b).
- Reviewing management actions proposed by state and federal agencies involving grassland systems, and working closely with the Wyoming Governor's Office, industry, private land owners, and agency staff during the early stages of energy development project plans.

Support efforts to reduce the spread and establishment of invasive plant species.
The spread of invasive plant species can be reduced by improving mitigation and restoration of disturbed sites associated with construction including roads, well pads, pipelines, and windmill towers. The establishment of livestock grazing and drought contingency plans also helps to reduce the spread of invasive species. Weed management programs, including those targeting rural acreage owners, can be promoted through local County Weed and Pest Control Districts. Some counties already have local spray days where the public can obtain chemicals and equipment for treating weeds at little to no cost. In areas of recent invasion, cooperative efforts to control cheatgrass through herbicide application, re-seeding, and livestock grazing management should continue.

Create new and more incentives for landowners to incorporate multiple natural disturbances into grasslands management plans.
Most of Wyoming's grasslands have traditionally been managed for sustainable livestock production. Today, increasing interest is being placed on coordinating livestock production with other services provided by grasslands including wildlife diversity, carbon sequestration, water quality and quantity, and aesthetics. Meeting these goals requires a diverse suite of grassland habitats with a range of vegetation structure and composition (heterogeneity). This can be achieved by incorporating multiple disturbances into land management plans such as grazing with fire, grazing with prairie dogs, and grazing and selective brush management. This approach uses livestock grazing as a tool to create desired habitat conditions in addition to a method of food production. Increasing vegetation heterogeneity provides the needed habitat complexity for a diverse array of wildlife species as well as land uses. Voluntary financial incentives may also be required to encourage retaining more residual plant cover for wildlife or supporting sufficient acres of prairie dogs to facilitate sensitive species recovery efforts.

Provide incentives, planning, and technological improvements to increase flexibility in grazing plans, including stocking rates.
Range conditions can be improved by developing and increasing awareness about forage reserve options. Options include, but are

not limited to, assisting livestock operators with moving grazing to other areas during times when habitat improvement projects are being implemented or when areas are affected by wildfires, droughts, or other natural events. These measures can reduce habitat damage through overuse and speed the recovery of grasslands after natural or human disturbances. Grassbanks, where access to grazing land is provided in exchange for conservation actions on another property, are an example of a forage reserve strategy that has been used successfully.

Included in this recommendation is the development of proactive, adaptive drought management plans. This will require improvements in the accuracy of drought forecasts and greater technical assistance to support the implementation of drought management plans. More incentives should be placed on rewarding land managers for effective drought management as opposed to solely relying on drought disaster declarations.

On a landscape scale, grazing should be used as a tool to achieve a variety of grassland cover and height conditions to benefit wildlife species with different needs. For example, mountain plovers, burrowing owls, and McCown's longspurs require short vegetation and open ground, while upland sandpipers, grasshopper sparrows, and chestnut-collared longspurs require grasslands in a climax successional stage.

Encourage grasslands conservation partnerships among natural resource agencies and non-profit conservation organizations.

The vast majority of Wyoming grasslands are under private ownership. This necessitates the ability to work effectively with private landowners as an essential element of any effective grassland conservation strategy. There are numerous USDA Farm Bill programs that can be applied to grassland conservation efforts (see Current Grasslands Conservation Initiatives in Wyoming). Partnerships with the USDA, NRCS, Farm Service Agency, and conservation districts help to ensure the benefits of these programs are maximized for grasslands wildlife. Some Farm Bill programs, such as WHIP, have been undersubscribed in recent years.

Additionally, Farm Bill grassland conservation projects are often established and administered by non-profit conservation organizations such as Ducks Unlimited, The Nature Conservancy, or Wyoming Stock Growers Agricultural Land Trust. These organizations are often very experienced in utilizing these programs and working with private landowners. Furthermore, the development of partnerships often increases the likelihood of grants being awarded and allows resources to be pooled to increase the size of projects and their chances for success.

Particular actions that have been identified to facilitate partnerships and focus grassland conservation activities include:

- Use spatially-explicit grassland habitat priority, such as those found within Wyoming's SWAP, Figure 7, to enhance coordination among partners in delivering funding to these sites.
- Improve communications between private landowners, conservation districts, the WGFD, NRCS, and private conservation organizations to ensure all available Farm Bill programs are being utilized and that agricultural practices recommended under programs reflect the most current knowledge of those that benefit wildlife. Regular partnership meetings, and active participation in Wyoming's NRCS Technical Committee, could help to advance this goal.
- Increase active management of CRP lands including incorporating fire, grazing, disking to promote the health and diversity of plant communities. CRP reseeding mixes should include native grasses and forbs. In order to meet habitat needs of specific SGCN or where native species cannot be established, diverse mixes that include well researched nonnative species should also be considered, as well as consideration for the suitability of vegetation under future climate conditions. Contracts should be renewed and new incentives provided to prevent the

conversion of CRP lands back to cropland after existing contracts expire.

A variety of entities have been successful in mediating conflicts when differences in grassland management perceptions occur. These include the University of Wyoming Cooperative Extension program, conservation districts, and local Coordinated Resource Management teams.

Pursue conservation easements on high-wildlife-value grasslands with willing landowners.
Most of Wyoming's prairie grasslands habitat type is found on private land. Conservation easements along with long-term stewardship plans are one of the most effective and long-term methods of limiting environmentally destructive development and management activities on private lands while retaining ranching, outdoor recreation, and other compatible land uses.

Enhance educational opportunities for landowners, managers, and the public relative to grassland wildlife, ecology, and management techniques.
Efforts should be made to increase educational opportunities for land managers to learn about managing grasslands for a diversity of values including but not limited to livestock productions. The Nature Conservancy is currently working with the University of Wyoming to establish the Rangeland Institute Initiative for this purpose. Educational efforts for small acreage owners should be increased through workshops, programs, and training.

Prairie Grasslands Monitoring Activities

Monitor all forms of energy development to identify and avoid potential individual and cumulative impacts and enhance future planning and mitigation.
Given a lack of existing research and the speed of wind development in Wyoming, emphasis should be placed on additional research and monitoring about its potential impacts on wildlife (see Wyoming Leading Wildlife Conservation Challenges – Energy Development).

Continue monitoring prairie grasslands SGCN in order to detect population trends or changes in distribution that may reflect habitat problems. This information should be used to guide future monitoring and research.

Monitor the landscape distribution and habitat intactness of prairie grasslands through remote sensing.
Remote sensing is useful in tracking the size, distribution, and fragmentation level of this habitat in Wyoming. Information gathered would be helpful in determining the cumulative impacts of activities and events such as insect outbreaks, energy development, rural subdivision, and the spread of invasive species. Special attention should be given to monitoring the level and location of these activities in relation to those SWAP SGCN priority areas that have a high proportion of the prairie grasslands habitat type (Figure 7). This technique may require the further development of monitoring protocols and identification of sample sites.

In cooperation with research entities, monitor the effects of climate change, including extended periods of drought.
Research should be conducted on the potential effects of climate change on native and nonnative prairie plants and their composition. Prairie grasses, shrubs, and invasive weedy species may have different responses to changing levels of atmospheric carbon dioxide. Additionally, decreasing soil moisture resulting from increasing temperatures may also impact the current structure of prairie grasslands.

Increase monitoring of multiple ecological outcomes of habitat disturbances and treatments and how these interact with one another.

Research on natural and human-caused habitat disturbances and treatments should be enhanced and an effort made to understand how historic disturbance regimes interact with human activities, such as residential and energy development.

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Riparian Areas

Photo courtesy of WGFD

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Habitat Description

Riparian areas are lands immediately adjacent to creeks, streams, and rivers. They are the interface between aquatic ecosystems and terrestrial ecosystems. Functionally, they are bounded on their outer edge by the limits of flooding and at their upper edge by the extent of the canopy vegetation (Swanson et al. 1982). While riparian definitions can be extensive and complex (e.g., Karr and Schlosser 1978, Cowardin et al. 1979), the riparian area is simply the distinct ribbon of green demarcating streams from uplands across much of the West. They are vital zones of ecosystem processes that provide linkages across landscapes, supporting diverse plant and animal communities (Gregory et al. 1991). The importance of riparian habitat to wildlife far exceeds its abundance. Less than 2% of the surface area of Wyoming, Nevada, and Montana consists of wetland and riparian systems, yet a majority of species depend upon them (McKinstry et al. 2004).

The identification, classification, and management of riparian zones received increasing attention in the 1980s and 1990s, and numerous workshops, conferences, and symposia were devoted to the topic (e.g., Johnson et al. 1985). Federal agencies formed interdisciplinary work groups to develop consistent approaches for classifying riparian areas (Gebhardt et al. 1990). For example, the Ecological Site Inventory was developed to classify riparian areas (Leonard et al. 1992), and the practice of assessing Proper Functioning Condition (PFC) followed (Prichard et al. 1998). Today, an extensive body of literature describes the ecological functions and habitat values of riparian areas (Naiman et al. 2005).

A habitat map produced for the Wyoming Gap Analysis program indicates that riparian areas cover approximately 1.2% of Wyoming (Merrill et al. 1996). In this State Wildlife Action Plan (SWAP), the eight NatureServe Ecological Systems comprising the riparian habitat type are listed in Table 15 and are fully described online (http://www.natureserve.org/explorer) (NatureServe 2009). These are diverse systems represented by well over 100 different community associations. The riparian habitat type is a sub-component of the broader wetland habitat type (i.e., wet meadows, prairie potholes, bogs, seeps, flood-irrigated fields, and the vegetative shoreline of lakes and other types of open water). Wetlands and their associated species assemblages, threats, and conservation actions are covered in a separate habitat chapter of this SWAP and in Copeland et al. (2010).

The eight NatureServe (2009) riparian ecological systems in Wyoming can be broadly segregated into mountain and lowland habitats. Mountain riparian habitats vary considerably from those found in lowlands because of steeper stream gradients, cooler temperatures, and less soil deposition (Knight 1994), with the exception of mountain areas where the topography flattens into broad meadows. Mountain riparian vegetation is often characterized by sedges and short willow shrublands (Winward 2000). As elevation decreases, alder and tall willows become common, together with Engelmann spruce, narrowleaf cottonwood, lodgepole pine, and aspen, and occasionally blue spruce and balsam poplar (Knight 1994).

Lowland riparian areas in the West are often characterized by narrow bands of trees and shrubs surrounded by uplands of vegetation of lower stature (Knopf et al. 1988, Montgomery 1996). Historically, cottonwoods have been the dominant lowland riparian tree species (Braatne et al. 1996). For seedling establishment, cottonwoods must receive full sunlight and be free from competing vegetation (Rood and Mahoney 1990, Friedman et al. 1997). Such sites often occur along river and stream banks after high spring flows that deposit or expose alluvial soils (Friedman et al. 1997). Boxelder, lanceleaf cottonwood, peachwood willow, and occasionally American elm are also common riparian tree species, particularly in eastern Wyoming (Jones and Walford 1995). Understory shrubs include chokecherry, hawthorn, rubber rabbitbrush, silver buffalo berry, silver sagebrush, skunkbush sumac, wild rose, and various species of willow (Knight 1994).

Riparian areas provide critical ecological functions (Gregory et al. 1991, Annear et al. 2004). Healthy riparian areas buffer water loss from upland drainages and recharge aquifers. The dense, diverse, and complex vegetation of healthy riparian areas filter chemical and organic wastes, trap sediment, build and maintain stream banks, reduce soil erosion, and moderate stream temperatures. The vegetation offers high quality foraging and nesting habitat, creates movement corridors for wildlife, and provides niches to a multitude of species. Riparian plant communities provide direct and indirect organic inputs to support stream ecosystems (Vannote et al. 1980), and terrestrial invertebrate inputs are often a key component of stream food webs (Saunders and Fausch 2006). Woody debris contributions from riparian areas to streams can provide habitats for fish and invertebrates and influence stream channel stability and dynamics.

Riparian areas are among the habitat types most used and altered through human activity and development. Wildlife abundance, water availability, vegetation diversity, soil productivity, and an often gentle topography attracted both Native Americans and early Europeans settlers to riparian zones. Today, accordingly, a high percentage of riparian areas are privately owned. In addition, riparian areas are used for agriculture, recreation, travel, water development, and housing. Most communities in Wyoming occur in conjunction with riparian zones.

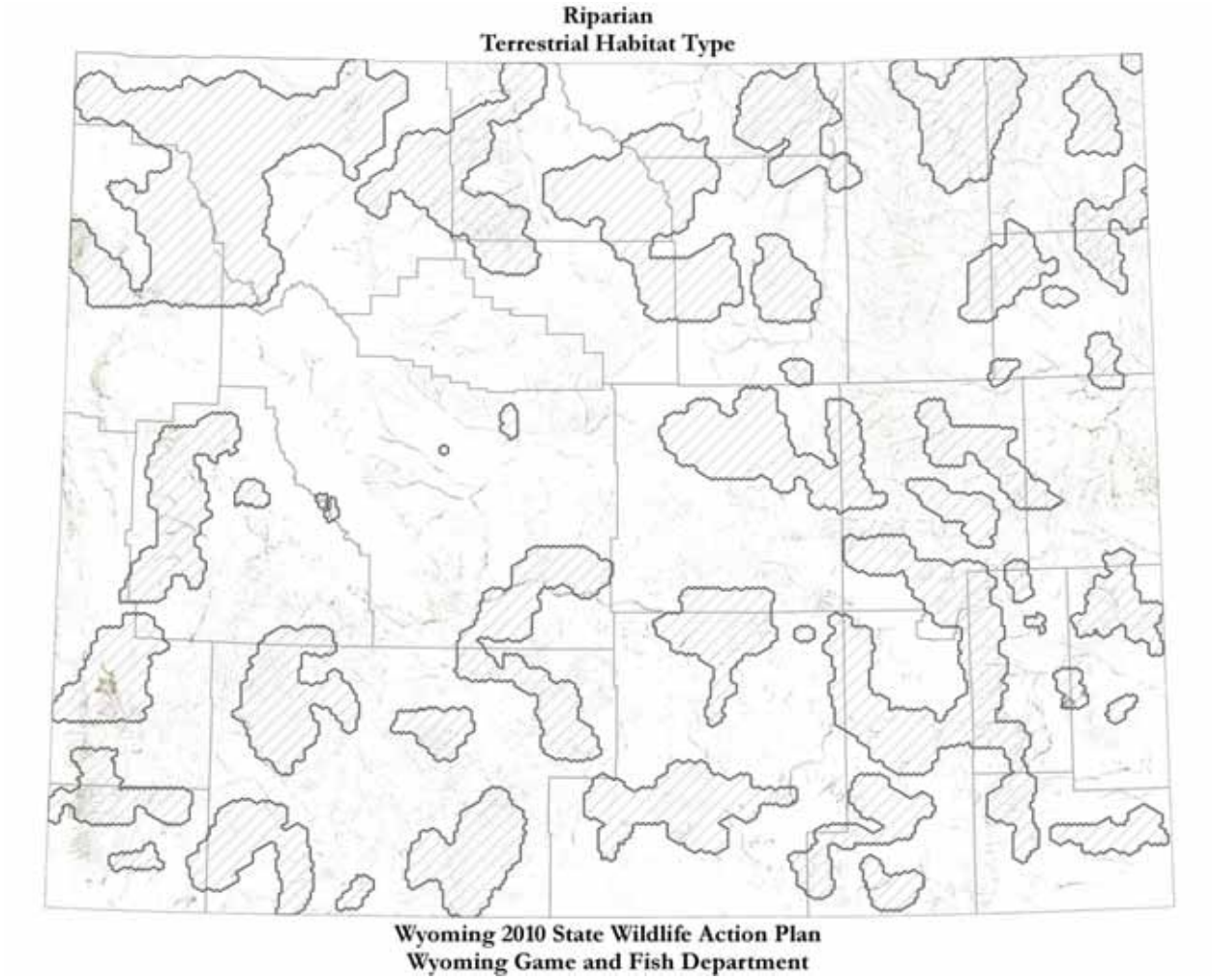

FIGURE 8. Wyoming Riparian Areas and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 15 . Wyoming Riparian NatureServe Ecological Systems[1]

1. Western Great Plains Floodplain
2. Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
3. Rocky Mountain Lower Montane Riparian Woodland and Shrubland
4. Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland
5. Rocky Mountain Subalpine-Montane Riparian Woodland
6. Rocky Mountain Subalpine-Montane Riparian Shrubland
7. Northwestern Great Plains Riparian
8. Western Great Plains Riparian Woodland and Shrubland

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. http://www.natureserve.org/explorer.

TABLE 16. Wyoming Riparian Species of Greatest Conservation Need

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

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

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

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

Riparian Area Wildlife

Riparian areas account for less than 1% of the western landscape, but have a disproportionately high value as wildlife habitat (Knopf et al. 1988, Montgomery 1996). Within Wyoming, 61% of 445 terrestrial vertebrate species are believed to show preference for riparian habitats (Olson and Gerhart 1982). This is especially true for birds. In Wyoming, approximately 73 avian species have been identified as using riparian habitats (Nicholoff 2003). Bird diversity in riparian habitats has been linked to the complex vertical structure of these habitats compared to adjacent grasslands or shrubland habitats (Slater 2006). Some riparian bird species, such as the yellow-billed cuckoo and willow flycatcher, are among the most imperiled migratory species in Wyoming (Nicholoff 2003).

Elk, moose, mule deer, white-tailed deer, pronghorn, and small mammals, as well as their predators, all have strong seasonal or year-long associations with riparian habitats (Buskirk 1991). Riparian corridors and the rivers they bound play an essential role in river otter distributions (Rudd et al. 1986). The value of riparian corridors increases for shrews and jumping mice with the presence of grassy vegetation (i.e., forage and cover) and prey (i.e., seeds and insects). Riparian areas provide crucial habitat for wildlife in the form of wildlife movement corridors and migration habitats. The forage, cover, and water of riparian areas allow birds and mammals to move across otherwise harsh prairies and desert landscapes. Bats, in particular, use riparian habitats for both commuting and migrating, and the roosts, foraging habitat, and close proximity to water afforded by riparian areas provide extremely valuable habitat for bats.

Many species of birds are excellent indicators of the condition of riparian vegetation in Wyoming and the West. Some are considered riparian obligates because they build greater than 90% of their nests in riparian vegetation or because

90% or more of their abundance occurs in riparian vegetation during the breeding season. Others are considered riparian dependent species either because 60–90% of their nests are built in riparian vegetation or because 60–90% of their abundance occurs in riparian habitat during the breeding season. All riparian species use one or more of the vegetation layers present in a healthy riparian system (i.e., understory, mid-story, and canopy).

Beaver are a fundamental factor influencing riparian landscapes. They create meadows and broaden the floodplain as they create dams. This increases sedimentation and encourages growth of riparian vegetation (Knight 1994). Beaver ponds provide important habitat for native fish species including Colorado River cutthroat trout, Yellowstone cutthroat trout, Bonneville cutthroat trout, and Snake River cutthroat trout. These ponds provide overwintering fish habitat, while supporting numerous aquatic mammals such as river otter, mink, and muskrat. Water held behind beaver dams and in surrounding banks enhances year-round stream flow and is especially important for helping maintain late season flows in many small streams. Bird densities among some beaver-influenced riparian areas have been found to be three times those of adjacent riparian habitats (Collins, 1993). Over the centuries, beaver ponds have trapped tens to hundreds of billions of cubic meters of sediment that would otherwise have been carried downstream (Naiman et al. 1988) so that today the physical character and vegetation of many meadowlands is the result of historic beaver activity.

Riparian habitat is required by many Wyoming amphibian and reptile assemblages. Amphibians rely on aquatic habitat for a portion of their life, and frogs, toads, and salamanders depend on riparian areas for breeding, prey, thermoregulation, and cover. Amphibians can be found inhabiting side channels, oxbows, sloughs, and other aquatic features. A number of reptiles are also dependant on riparian habitat. Aquatic turtles utilize loose soils within riparian areas for nesting. This habitat type is also of particular importance to native gartersnake populations.

Riparian areas provide important direct and indirect influences on Wyoming fish populations and their habitat. At higher elevations, the four native cutthroat trout subspecies and non-game species such as mountain sucker and longnose dace, depend on cool water with low sediment supply from streams with healthy riparian vegetation. Streams like Huff Creek in western Wyoming harbor native fish populations that have fluctuated through time in response to changes in the extent and function of riparian willow communities (Chaney et al. 1991, Binns 1981). Riffle-dwelling species such as longnose dace and riffle-spawning salmonids require relatively smaller, fine sediment levels associated with healthy riparian vegetation. Cottonwood gallery forests, such as those along the Powder River and its tributaries, periodically contribute logs and branches to the river channel which provides cover for fish species such as channel catfish. Woody debris accumulations provide juvenile salmonid habitat and adult overwintering habitat. In the relatively low-productivity waters of the upper Wind River drainage, higher Yellowstone cutthroat trout concentrations are consistently found associated with woody debris.

Riparian areas play a critical role in maintaining continuous flow and providing year-round aquatic habitat for fish and other species that occupy the wetted stream channel. Overbank flooding during snow melt in most years saturates riparian soils and elevates adjacent water tables. This underground water storage sustains riparian vegetation during periods when precipitation is scarce and releases water slowly into the stream (Ewing 1978). Though these flows are often small, they maintain water temperatures in suitable ranges for fish, improve water quality, and sustain isolated pools critical for fish survival (Winters et al. 1998).

Riparian Area Threats

Water development/altered flow regimes - High

Natural flow regimes in stream segments around the state have been altered by human activities including irrigation diversions and water developments for enhanced water supply, hydropower, and flood control. No comprehensive national inventory of riparian conditions or trends exists, but it has been suggested that a minimum of 95% of all western riparian habitats have been altered in some way during the past century (Ohmart 1994). In Wyoming, altered flow regimes are also a consequence of broad-scale changes in land use and management associated with agriculture, grazing, timber harvest, and housing development (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes). Flow regimes have been substantially altered in significant portions of major Wyoming waterways including the North Platte River, Green River, Wind River, Bighorn, and Snake River. The Powder River's flow regime, by contrast, is much less altered (Peterson et al. 2009, Hubert 1992).

While water development can threaten native species, some introduced species, including popular sport fisheries, have thrived in the face of water development. The simplification of natural systems by human development tends to favor species with generalized and broad habitat requirements. For example, the walleye fisheries in the North Platte River reservoirs and Boysen Reservoir depend on the consistent deep water and forage production inherent in these man-made water bodies. Stable stream flow releases from dams, with relatively low peak flows and relatively high base flows, perpetuate productive sport fisheries. The famous "Miracle Mile" trout fishery below Kortes Dam and the "Grey Reef" fishery below Alcova Dam are examples.

Water development commonly results in decreased flood frequencies, lower peak flows, and shifts in peak flow timing. In almost all cases, dams reduce peak flows associated with spring runoff and change the timing, duration, and magnitude of the natural hydrograph. Auble et al. (1994) noted that substantial changes in riparian vegetation can occur without changing the mean annual flow because riparian vegetation is especially sensitive to changes in minimum and maximum flows. Bovee and Scott (2002) also observed this phenomenon and noted that changes in peak flows can reduce seedling recruitment and lead to gradual decline of certain riparian woodlands. Mahoney and Rood (1998) described how recruitment of cottonwood seedlings is limited to a narrow zone adjacent to the river—the zone is defined at its upper margin by the limit of overbank flow and at the bottom by the potential for subsequent scouring and deposition. They noted that river water volume must decline gradually so the seedling root growth can keep pace with the capillary fringe above the water table. In Wyoming, cottonwood declines have been noted to follow closely after flow alterations on the North Platte River (Miller et al. 1995) and Bighorn River (Akashi 1988, Bray 1996)

Riparian impacts associated with the loss of high spring flushing flows on dammed rivers greatly reduce the natural cycle of sediment transport and deposition. In addition, levees and bank stabilization structures can also adversely impact riparian systems by confining water to the main stream channel. Levees and other structures that constrain natural stream channels reduce not only floodplain inundation and maintenance but also the channel processes of aggradation and degradation that promote colonization and establishment of native willows and cottonwood trees.

Conditions that restrict or limit the establishment and maintenance of native cottonwoods and willows can cause the riparian vegetative communities to transition toward communities dominated by non-native Russian olive and tamarisk (see Wyoming Leading

Wildlife Conservation Challenges – Invasive Species). Though these invasive, non-native tree species provide habitat for some organisms, their structure and ecological function are different from native riparian vegetation communities. As in most cases, when the core habitat changes, the animal species and other community components change as well. Reduction in the size and structural complexity of cottonwood stands, through a lack of tree regeneration, has been associated with declines in riparian bird species diversity (Slater 2006).

Reductions in seasonal flooding, whether by storage of high flows in dams, diversion of flow for out-of-channel purposes, or levee construction, often leads to establishment of homes, businesses, and recreational areas in the floodplain. Land-use practices associated with human development, such as removal of permanent cover, grazing, row crop agriculture, and urbanization, can accentuate high and low flows and reduce habitat diversity and length of the lateral edge between the terrestrial and aquatic environments (Schlosser 1991). Wetland drainage can increase peak flows and decrease base flows by reducing bank storage (Moore and Larson 1979). Creation of channels and dikes can increase peak flows (Gordon et al. 1992) and accentuate low flows (Karr and Schlosser 1978).

The reduction in beaver number and distribution is another major contributor to altered stream flows. Fur trapping in the 19th century greatly reduced beaver number and extirpated them from many areas. Now, in the early 21st century, beavers have re-occupied most of their historic range, but only at roughly 10% of pre-European-contact densities (Naiman et al. 1988). Beaver ponds accumulate sediment, improve water quality, reduce stream velocities, raise water tables, and increase the size of the riparian zone. These effects create and maintain both terrestrial and aquatic riparian habitats.

The need for additional water for human use will intensify in the immediate future, and that trend will be especially evident in the western U.S. A report by McCabe and Wolock (1997) projects that by the year 2020 demands on water for human use will increasingly exceed the available supply in the Colorado River basin. This trend has multi-faceted consequences for fish and wildlife and the habitats upon which they depend. In Wyoming, efforts have already begun to consider trans-basin water diversions. Energy diversification, including hydropower development, may increase as the nation's energy demands rise. Warmer conditions with more erratic precipitation—which some predict for Wyoming's future climate—may heighten the need for additional water development (water storage) for municipal and agricultural purposes. The likely trend will be water development projects closer to the delivery point and conveyance via pipelines instead of stream channels. Additional emphasis will likely be placed on lining irrigation ditches and other practices to more efficiently use water for consumptive purposes. The net effect of all such water management practices will be to reduce intra- and inter-annual variability in Wyoming's streams and associated riparian corridors (see Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Drought and climate change - High

Changes in precipitation patterns under various climate change scenarios are predicted to produce peak flows earlier in the yearly cycle and to lower base flows (Barnett et al. 2004). Such drought conditions can be stressful to riparian habitats. Drought can increase browsing and grazing pressure on riparian areas from-ungulates, thus reducing the vigor and structural diversity of riparian vegetation. Drought lowers water tables, leading to reduced plant growth and reproduction. Lower water levels increase water temperatures and reduce the living space available to fish and other aquatic wildlife. All these conditions can be detrimental to the health and reproductive success of all riparian wildlife species.

In riparian habitats, climate change may increase air and surface water temperatures, alter the magnitude and seasonality of precipitation and run-off, and shift the reproductive phenology and distribution of plants and animals (Seavy et

al. 2009) (see Wyoming Leading Wildlife Conservation Challenges – Climate Change). Riparian habitats will likely play a leading role in wildlife conservation adaptation strategies to climate change by providing travel corridors, including along altitudinal gradients; linking aquatic and terrestrial ecosystems; providing thermal refugia for wildlife; and providing resilience to natural disturbances (Seavy et al. 2009).

Invasive species – High

Tamarisk (commonly known as *saltcedar*) and Russian olive are the two invasive plant species that currently have the most significant negative impact on Wyoming's riparian habitats (see Wyoming Leading Wildlife Conservation Challenges – Invasive Species). Tamarisk is an aggressive colonizer that often outcompetes and can completely replace willows, cottonwoods, and other native riparian vegetation. The stems and leaves of mature tamarisk plants secrete salt which forms a crust above and below ground that inhibits other plants (Sudbrock 1993). Tamarisk consumes large amounts of water which can lower ground water levels, drying up springs and marshy areas. Infestations of tamarisk have a detrimental impact on wildlife, as although it provides some shelter, its foliage and flowers provide little food value for native wildlife species.

The problems associated with Russian olive are similar. It can outcompete native riparian vegetation, interfere with natural plant succession and nutrient cycling, and tax water reserves. The spread and establishment of Russian olives has been accelerated by water development projects. These projects have reduced flushing flows and the associated formation of point bars which are necessary for the regeneration and establishment of native vegetation such as willows and cottonwoods. Although Russian olives can provide food and cover, they typically replace native vegetation favored by many wildlife species. Studies indicate that Russian olives harbor fewer bird species than native vegetation (Brown 1990, Knopf and Olson 1984).

Where Russian olive or tamarisk occurs, the risk of wildfire can increase their detrimental impact. Both species are vigorous sprouters and usually gain the upper hand over native species after a fire. The expansion of Russian olive and tamarisk has reached a point in many Wyoming riparian habitats, especially the low elevation larger stream systems, that expensive restoration efforts are needed to re-establish native riparian shrub communities.

Other invasive species also impact riparian areas including leafy spurge, Dalmatian toadflax, whitetop, Canada thistles, black henbane, and spotted knapweeds. Options to control Russian olive and tamarisk and other invasive species can also negatively impact native vegetation and complicate management of riparian forests.

Ungulate grazing and browsing – High

Proper grazing management can be effective habitat management tools and compatible with riparian area maintenance and improvement. However, improper grazing in riparian areas can eliminate vegetation and associated wildlife, widen stream channels, cause soil erosion, increase water sediments loads, raise water temperature, encourage the spread of invasive plan species, change stream bank configuration, and lower surrounding water tables (Chaney et al. 1991, Nicholoff 2003). Uncontrolled livestock can congregate in riparian areas where they find water, succulent forage, and favorable microclimates including shade, wind reduction, and higher humidity (Clary and Webster 1989, Belsky et al. 1999).

Overbrowsing by wildlife, especially native ungulates, can negatively impact riparian vegetation. The most notable impacts are from elk, moose, and white-tailed deer. As with livestock grazing, impacts tend to be site-specific, where herd numbers exceed management objectives, or where animals congregate to escape hunting and other forms of predation, or as a result of other causes. For Wyoming's riparian SGCN, special attention needs to be given to grazing management to ensure that adequate understory vegetation and mid-story shrubs are present. Cottonwood

regeneration is important for providing nesting trees including mature decadent trees for cavity nesters.

The WGFD sets big game herd unit population objectives based on a variety of factors including habitat condition within the herd unit, hunter demand, landowner input, and biological potential. These considerations result in mixed opinions as to what the objective should be. All objectives are taken to the public for review and approved by the Wyoming Game and Fish Commission. Although the WGFD collects habitat data across the state, seldom is it specific enough to tie the habitat condition directly back to a specific number of animals. Such data is useful; however, in understanding whether big game populations are within the limits of what the habitat can support. The WGFD strives to have populations that are in balance with the majority of the habitats within the herd unit.

Rural subdivision and development – Locally High / Moderate

The high visual and recreational appeal of riparian habitats results in these habitats being desirable locations for home construction and other forms of human development. Houses, outbuildings, and lawns directly replace native wildlife habitat. Wildlife commonly abandon or alter their use of habitats with greater human and pet activity. Increased energy expenditures or greater use of lower quality habitats in order to avoid people can decrease animal health and reproductive capacity. Greater road densities and traffic volume can increase wildlife–vehicle collisions. Predation on wildlife can intensify with greater numbers of dogs and cats, as well as increasing numbers of generalist predatory species such as ravens. Soil disturbance from construction, the year-round grazing of horses and other hobby livestock, and the use of non-native plants as ornamentals can facilitate the establishment of invasive species (Maestas et al. 2002). Pesticide and herbicide concentrations may increase in runoff from nearby lawns. Loss of agricultural operations to rural residential development can result in a loss of irrigated meadows that are important to many wildlife species (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development).

Due to the limited size and distribution of riparian habitats relative to other landscape features and their critical role as corridors for both aquatic and terrestrial species, fragmentation of this habitat can severely compromise its value for wildlife. Maintaining the integrity of riparian areas will become increasingly important in preparing for the possible influence of climate change to enable species to travel to more suitable habitats as ecosystems change (see Wyoming Leading Wildlife Conservation Challenges – Climate Change). Riparian areas in relatively lower elevation areas in Wyoming (e.g., around Cheyenne, Star Valley, and the Snake River) are at greatest risk for future change due to rural development (Copeland et al. 2010).

Incompatible energy development practices - Moderate

Energy development can result in the direct removal of native vegetation and habitat fragmentation through road building, well pad drilling, power line construction, buried pipelines, booster stations, and facility buildings. Habitat fragmentation and loss also occurs indirectly through increased traffic and noise. Greater amounts of disturbed or bare ground, as well as greater vehicle traffic associated with the construction and production phases of energy development, can contribute to the spread of invasive plant species (see Wyoming Leading Wildlife Conservation Challenges – Energy Development).

Energy development can have a variety of effects on stream and lake hydrology and water quality. There can be drawdowns of streams and ponds by tanker trucks for water use at well sites. Surface discharge of poor quality ground water, as a byproduct of coalbed methane (CBM) extraction, can raise salinity levels and negatively impact riparian and aquatic organisms. Salts from CBM-produced water can accumulate in the roots of riparian

vegetation and upper soil layers, stunting plant growth. CBM discharge water can also negatively affect the movement of water into and through soils and limit plant hydration. Changes in flow regimes and soil salinity may facilitate the replacement of native species by invasive species including tamarisk, Russian olive, and leafy spurge.

Runoff from roads and construction sites can reduce water quality through higher sedimentation and contamination from spills. Riparian areas in southwest and northeast Wyoming are at a relatively higher risk from future oil and gas development (Copeland et al. 2010).

Current Riparian Conservation Initiatives

Some habitat improvement programs, which can apply to riparian habitats, including the 1995 Statewide Comprehensive Outdoor Recreation Plan (SCORP), Intermountain West Joint Venture, and U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program, are covered in the 2010 SWAP wetlands habitat type.

Collectively, several ongoing activities in Wyoming are maintaining or improving riparian areas. Individual habitat protection and restoration projects, especially a bloom of projects conducted since the inception of the Wyoming Wildlife Natural Resources Trust, provide significant benefits. Federal Farm Bill programs and the agencies that implement them are actively working to benefit riparian areas. All of these efforts are possible only through the interest and cooperation of private landowners. Water management actions, both by individual irrigators and by federal and state agencies, are at times benefitting riparian areas. Instream flow water rights provide an ancillary riparian protective benefit. Comprehensive water planning efforts are ongoing and will include additional riparian elements in the future. Finally, protection of existing riparian areas through careful development practices is promoted through the consistent and thorough environmental commenting practices of the Wyoming Game and Fish Department (WGFD).

Many riparian habitat improvement, management and protection projects have been conducted in recent years under the direction of the WGFD's Strategic Habitat Plan (SHP). For example, the WGFD, working with conservation partners, completed seven projects on 339 acres in 2009 specifically focused on riparian habitat protection, enhancement, and management (Wyoming Game and Fish Department 2010a). This number does not include additional riparian protection or upland projects that ultimately translate to improved riparian areas. Projects often entail establishing woody plants like cottonwood and willows (Anderson 2009).

In 2009, 49 beavers were transplanted to augment and improve riparian function. A significant portion of over $9 million dollars expended in habitat projects in 2009 will benefit riparian habitat (Wyoming Game and Fish Department 2010a). Annual WGFD habitat reports, such as Wyoming Game and Fish Department 2010a, have been produced since 2003 and highlight hundreds of projects completed to benefit riparian and other habitats. Many of these projects contain a component funded by the Wyoming Game and Fish Department Trust Fund, established in the late 1980s and now yielding over $1 million annually for habitat restoration work.

Another and more significant funding source is the Wyoming Wildlife Natural Resources Trust (WWNRT). Beginning with the first allocation of project dollars in June 2006, the WWNRT has funded 160 projects in all 23 counties of the state (Wyoming Wildlife and Natural Resource Trust 2010). Just over $14 million has been allocated from WWNRT funds, with a total project value on the ground in excess of $105 million.

The WGFD's SHP recognizes riparian habitat maintenance, protection, management, and restoration priorities (Wyoming Game and Fish

2009) with specific goals and objectives. Regional priority areas for conservation work were identified, many of which include a specific focus on riparian areas and issues (http://gf.state.wy.us/habitat/PriorityAreas/index.asp). For example, in the Cody region, riparian areas were prioritized as *crucial* areas and *enhancement* areas. These priority areas encompass broad portions of the Bighorn River and tributaries, and actions to maintain or improve riparian values and issues are identified in specific narratives (e.g., http://gf.state.wy.us/habitat/Narratives/CY_G1_C_ExtensiveRiparianAreas.pdf).

Improving livestock management practices in riparian habitats through grazing management, off-site water placement, and other techniques are common. Since 1975, Coordinated Resource Management (CRM) teams have used a collaborative, stakeholder-based approach to address land management issues in Wyoming. Currently, the state has approximately 40 CRM teams composed of ranchers, land and wildlife management agency personnel, conservation organizations, and sportsmen. Many CRMs include a focus on riparian areas.

The Wildlife Habitat Incentives Program (WHIP) and the Environmental Quality Incentives Program (EQIP) are two United States Department of Agriculture (USDA) Farm Bill programs which provide resources and assistance to landowners to implement riparian habitat improvement projects and grazing plans. The Continuous Conservation Reserve Program (CRP) program administered by the Farm Service Agency (FSA) and Natural Resources Conservation Service (NRCS) creates buffer zones along riparian areas that exclude grazing on a 10–15-year contract basis. The Wetland Reserve Program (WRP), which predominantly focuses on wetland conservation through permanent or 30-year easements, has been used for some riparian restoration and restoring wetlands associated with riparian systems.

Together with the Bureau of Reclamation, State Engineer's Office, and Wyoming Water Development Commission (WWDC), the WGFD has worked to develop formal and informal water management strategies for managing some reservoirs. These agreements benefit aquatic wildlife, including sport fisheries, while still serving the project's legislatively authorized purposes. Examples include the Snake River below Jackson Lake Dam, Shoshone River below Buffalo Bill Dam, Green River below Fontenelle Reservoir, Bighorn River below Boysen Reservoir, and the North Platte River below Kortes, Pathfinder, Grey Reef, and Glendo Dams. Any benefits to riparian areas that accrue, however, are secondary to a traditional focus on flow releases to benefit sport fisheries and recreation. Release schedules specifically tailored for riparian habitat have not been identified or implemented.

Water management associated with traditional agricultural flood irrigation practices is often cited by ranching interests as beneficial for riparian zone maintenance. There is no doubt that riparian areas in some areas are locally created and maintained through irrigation practices though a formal and systematic evaluation of such riparian areas has not been conducted. Riparian vegetation communities can be strongly influenced by the type, timing and extent of irrigation. Conversion from flood to center pivot has been known to change riparian characteristics. Technological changes like side role systems and gated pipe deliver water more efficiently to agricultural crops and have the potential to conserve water for other uses like maintaining stream flows. The influence of improved irrigation efficiency on riparian characteristics is complex and dependent on site characteristics.

Instream flow water rights provide some certainty that the state can protect natural flow regimes up to designated base levels for fisheries and, by association, may benefit riparian corridors along instream flow segments. The WGFD began evaluating various methods and quantifying instream flow needs for fish in 1979. In 1986, the state legislature enacted a statute (41-3-1001 to 41-3-1014) that formally recognizes opportunities to maintain or improve instream flow as a "beneficial use." Because

water rights can only be issued for uses that have been officially recognized as "beneficial", this designation is of critical importance. Since inception of the water right program, the WGFD has employed two (and at times three) full-time biologists to identify priority areas and quantify instream flow regime needs for fish habitat. Additionally, the WGFD has assisted the development of more than 100 instream flow water rights applications through the WWDC. Every five years the program is reviewed and a plan devised with explicit goals for upcoming efforts.

The state has undertaken a comprehensive water planning effort that, while not focused on riparian habitats, closely relates to the fate of riparian areas in Wyoming. The 1999 Legislature approved the recommended planning framework and authorized the Bear and Green River Basin Plans (Wyoming Water Development Office 2010). In the years that followed, the Legislature authorized funding for the five remaining river basin plans. The Platte River Basin Plan was the last plan completed in May 2006. Anticipating completion of the individual river basin plans, the 2005 Legislature authorized funding for the Statewide Framework Water Plan. The purpose of this plan was to summarize the results of all seven river basin plans and provide recommendation for future updates. The plan includes an inventory of the state's water resources and related lands, a summary of the state's present water uses, a projection of future water needs, and an identification of alternative decisions to meet the indicated future water needs. It also provides future water resource planning direction to the State of Wyoming. In early 2010, consultant selection was underway at the Wyoming Water Development Office to explore further developing the environmental and recreational components of the plan, including riparian habitat.

Mapping of invasive species is ongoing throughout much of the state by county, state, and federal agencies along with private landowners. County cost-sharing programs are available to help landowners control invasive plant species. A number of large, multi-agency cooperative projects are focused on controlling Russian olive and tamarisk and replacing them with native vegetation. Notable projects include Yellowtail, Shell Valley, and Grass Creek Coordinated Resource Management Teams (CRMs). In another example, the WGFD is working with Seedskadee National Wildlife Refuge and the Wyoming Landscape Conservation Initiative to map and develop treatment project recommendations for Russian olive and tamarisk infestations along the Green River below Fontenelle Reservoir in southwest Wyoming. Recently, the WGFD fashioned guidelines to prioritize and direct efficient use of WGFD funds to Russian olive control efforts (Wyoming Game and Fish Department 2010d).

The WGFD has an environmental protection role to maintain wildlife habitats, including riparian areas, and the department provides comments on the anticipated effects of proposed developments. A document was recently produced outlining Best Management Practices (BMPs) and monitoring practices to detect sediment and runoff issues from the roads and stream crossings associated with wind energy development (Wyoming Game and Fish Department 2010b). Similar approaches for avoiding or mitigating impacts to riparian zones associated with oil and gas development were also developed (Wyoming Game and Fish Department 2010c). Under the oil and gas recommendations, no surface occupancy and a 500-foot buffer zone around riparian areas are recommended (Wyoming Game and Fish Department 2010c).

The success of ongoing and enhanced riparian conservation and restoration work in Wyoming will depend on the interest and commitment of private landowners. European settlers were attracted to riparian areas to develop farms, ranches, and town sites because of the rich soils and relatively flat topography. Today, some of the most extensive riparian areas, especially in eastern Wyoming, occur on privately held lands. With continued cooperation and communication, projects that benefit riparian areas and their host of wildlife species, while at

the same time benefiting the landowner's interest, can continue or even accelerate.

Recommended Riparian Conservation Actions

Continue implementing riparian habitat management, treatment, and protection projects.

- Treat decadent stands to promote regeneration and re-establish lost species and cover through planting and seeding.
- Promote or mimic natural disturbances such as seasonal flooding, erosion, and deposition.
- Encourage riparian buffers to promote regeneration.
- Remain actively involved with various partners, CRMs, initiatives, and programs.

Enhance efforts to control riparian area invasive species.
Specific actions to more effectively control riparian invasive plant species include:

- Increase coordination between agencies and private landowners, especially Weed and Pest Districts, to better align goals and priorities.
- Coordinate with water management agencies such as the WWDC and the Bureau of Reclamation to identify and implement water management strategies to create, maintain, or restore riparian vegetation communities along streams below existing dams. Special effort should be employed to include favorable flow regimes as part of the annual operating plans for new dams or diversion projects in the future.
- Increase legislative funding for removing riparian invasive plant species and re-establishing native willow and cottonwood stands through Weed and Pest Districts and Conservation Districts.
- Improve mapping of the location and spread of invasive species infestations to assist in prioritizing sites for treatment. This information should be captured centrally in a GIS and be made available publicly.
- Enhance landowner, agency, and public awareness and knowledge about riparian invasive species and control techniques. Focus special attention on communicating:
  - the value of seasonally appropriate flood irrigation in riparian corridors
  - the importance of protecting native willow and cottonwood stands
  - the negative impacts of Russian olive and tamarisk and the need to control those species whenever possible
- Follow WGFD Russian olive management guidelines and project ranking scheme to direct project funding and activities to important riparian areas where the greatest benefits will accrue.

Support research on instream flow and overbank flow regimes.
Research on instream flow and overbank flow regimes is needed to facilitate the management of native willow and cottonwood communities. Additionally, research on water uptake and bank stability characteristics of riparian plant species, especially tamarisk and Russian olive, would be beneficial for riparian area management.

Increase GIS mapping of riparian areas.

- Update and make available through online sources spatially explicit riparian priority sites found within the SWAP (Figure 8) and WGFD's Strategic Habitat Plan. Long-term riparian inventory and mapping as to the quality and vulnerability of riparian habitats will help managers prioritize future habitat protection and improvement projects and target SGCN conservation activities. Emphasize designing mapping efforts to support maintaining the connectivity of riparian habitats. Retaining the role of riparian habitats in providing travel corridors for wildlife will become an

increasingly important component of effective mitigation plans for human development as well as climate change. Riparian corridors are critical to supporting the seasonal migration of wildlife and to retaining the future ability of wildlife to relocate to more suitable habitats. The WGFD will continue to work with the Wyoming Geographic Information Science Center (WyGISC) on various modeling and mapping efforts associated with riparian systems.

Continue developing techniques that minimize negative impacts of energy development and reward the implementation of existing best management practices to maintain or restore riparian communities and habitat.

- In mitigation plans, stress avoiding biologically sensitive areas within project sites and direct off-site mitigation funds to nearby high-value wildlife locations.
- Continue researching behavioral and population responses of riparian species to energy development, including wind.
- Encourage implementation of mitigation measures and/or best management practices as detailed in the Wyoming Game and Fish Commission documents *Recommendations for development of oil and gas resources within crucial and important wildlife habitats* (Wyoming Game and Fish Department 2010c) and *Wildlife protection recommendations for wind energy development in Wyoming* (Wyoming Game and Fish Department 2010b).
- Review and update riparian setbacks and buffer recommendations and identify specific buffers for sensitive fish, amphibians, reptiles, birds, or mammal species as outlined in the WGFD *Recommendations for development of oil and gas resources within crucial and important wildlife habitats* (2010c). Compare Wyoming buffer recommendations to those used in other western states and consider new approaches for addressing buffer width for energy development.
- Review management actions proposed by state and federal agencies involving riparian habitats, and work closely with the Wyoming Governor's office, industry, private land owners, and agency staff during early stages of energy development project planning.

Provide incentives, planning, and technological improvements to enhance livestock management in riparian habitats.

- Additional incentives, including financial, planning, and technical assistance, should be provided to encourage private landowners to participate in projects to improve the natural function and wildlife habitat values of riparian habitats. The Wildlife Habitat Incentives Program (WHIP) and the Environmental Quality Incentives Program (EQIP) are two existing USDA Farm Bill programs which already provide some resources and assistance to landowners to implement riparian habitat improvement projects and grazing management plans. The WGFD trust fund program and Fish Wyoming program also provide assistance.
- Research should be conducted to enable federal grazing lease regulations to be more outcome-oriented as opposed to prescriptive in achieving desired riparian habitat conditions. This would encourage greater innovation and adaptation to local site conditions.
- Develop more forage reserves to assist in implementing habitat improvement projects. Forage reserves operate by providing ranchers access to substitute land or forage in order to allow rest from grazing, or the establishment of habitat improvement projects, on land they currently own or rent for grazing.
- Implement riparian grazing recommendations in the *Wyoming Bird Conservation Plan, Version 2.0* (Nicholoff 2003).

In cooperation with land management agencies and private landowners, reintroduce beavers into stream systems where they have been extirpated or occur at low densities and have appropriate food, security, and dam-building vegetation.

- Reintroduce beavers. Beaver dam-building activities can increase the size and quality of riparian habitats for both terrestrial and aquatic species (see Wyoming Leading Wildlife Challenges – Disruption of Natural Disturbance Regimes).

- Use enhanced GIS mapping of riparian areas (recommended above) or other means to identify suitable reintroduction locations. Careful consultation should occur with landowners on or adjacent to reintroduction sites prior to reintroductions to minimize unintended economic losses.

- Restore watersheds and develop aspen to levels that will support beaver in targeted areas.

Continue efforts to manage native ungulate populations to avoid overbrowsing of riparian habitats.

- Continue and enhance local efforts to identify sustainable stocking rates of native ungulates and keep populations within established herd objectives. High concentrations of elk, moose, and white-tailed deer, in particular, can cause damage to riparian areas. Accomplishing this goal will include maintaining hunting opportunities, especially on private land, and increasing educational efforts about the importance of doe and cow harvest for population management.

- Maintain or increase landowner cooperation in managing big game herd numbers since animals can congregate on lands where hunting is prohibited or limited. Specialized hunting seasons with weapons that have reduced trajectories, including archery, muzzleloader, and shotgun seasons, may be needed in some areas. Public education about the purpose and value of these seasons in locations close to residential areas may be needed.

Increase educational efforts about the ecological, economic, and social values of riparian habitats and associated conservation tools and management techniques.

Enhance educational efforts in the following key areas:

- Increase awareness among natural resource agency employees about the importance of historic flow regimes to properly functioning aquatic systems, riparian habitats, and riparian wildlife species.

- Increase knowledge levels about the threat of invasive plant species, particularly Russian olive and tamarisk, to riparian habitats and wildlife.

- Continue to improve private landowner awareness of opportunities to jointly improve livestock, water, and wildlife habitat management. Marketing programs could:

  - Survey, on a regular and systematic basis, specific target audiences to determine their views, values, and knowledge of riparian issues and opportunities.
  - Maintain an up-to-date website with regular, focused messages about riparian issues and opportunities.
  - Develop targeted audience email lists to provide needed information (based on surveys) about riparian issues, funding opportunities, and WGFD assistance.
  - Develop reference materials for managers and landowners.

Enhance coordination among natural resource agencies, private landowners, and nonprofit conservation organizations to identify and implement shared riparian habitat management objectives.

- Enhance coordination through development of an interagency riparian management task force made up of at least one representative from each state and federal agency with an interest or responsibility for managing riparian habitats.
  - At a minimum, this task force should consist of representatives from each federal land management agency, the Bureau of Reclamation, U.S. Fish and Wildlife Service, State Land Board, Parks and Recreation, State Engineers Office, Weed and Pest District(s), Wyoming Department of Agriculture,Conservation District(s), private landowner representatives, and appropriate NGO representatives including the Wyoming Stock Growers and Wyoming Wool Growers Associations.
  - This group should meet at least annually to discuss riparian trends, priority areas, identify effective management practices, present the results of current research, and share information on the availability of financial assistance for riparian management.
  - A critical function of this team should be identifying funding assistance opportunities for private landowners. The Wildlife Habitat Incentives Program (WHIP) and the Environmental Quality Incentives Program (EQIP) are two existing USDA Farm Bill programs which already provide some resources and assistance to landowners to implement riparian habitat improvement projects and grazing management plans.
- Support and promote research through the University of Wyoming Fish and Wildlife Cooperative Research unit on:
  - instream flow and overbank flow regimes needed to manage for native willow and cottonwood communities
  - water uptake and bank stability characteristics of riparian species, especially tamarisk and Russian olive.

Increase conservation easement acquisition with willing landowners on riparian habitats.

- Increase conservation easement acquisition. A high proportion of Wyoming's riparian habitats are privately owned. Conservation easements are one of the most effective long-term methods of limiting environmentally destructive development and management activities on private lands while retaining ranching, outdoor recreation, and other compatible land uses (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). Land values for riparian habitats are typically the highest of any habitat type. Increased funding for conservation easements will be needed to conserve riparian habitats on a broad scale.

Evaluate avoidance and mitigation options for riparian habitat associated with new water development proposals.

- Coordinate WGFD personnel (Water Management, Wildlife Biological Services, and Habitat Protection) who work with WWDC or other water development interests to specifically quantify riparian habitat impacts and mitigation needs for all new water development projects.

Riparian Monitoring Activities

Continue monitoring riparian SGCN in order to detect population trends or changes in distribution that may reflect habitat problems. This information should be used to guide future monitoring, conservation, and research.

Conduct additional inventory and monitoring work to document the locations of riparian habits, habitat conditions, and the effects of management actions.
Include the following recommended specific inventory and monitoring activities:

- Monitor the establishment and spread of invasive plant species, particularly Russian olive and tamarisk, in cooperation with Weed and Pest Districts, local conservation districts, private landowners, and other state and federal agencies
- Track the number, type, and location of water development projects on Wyoming rivers and streams and their influence on historic flow regimes and wildlife movement.
- Establish monitoring sites and protocols to evaluate the potential effects of climate change, including its potential influences on flow regimes and assemblages of riparian plants and animals.
- Document sites of vestigial diversity and promote their protection and expansion.
- Establish the probable state, extent, diversity and complexity of pre-settlement riparian forest to provide guidance for restoration efforts.
- Record the location, size, and type of riparian habitat enhancement and conservation projects.
- Quantify grazing and browsing levels by livestock and wild ungulates in key areas of known impact. Target this monitoring to key locations in riparian corridors where disruptions in the riparian corridor affect wildlife movement opportunities over relatively high distances in larger river systems like the Green River, Bighorn River, and Powder River.
- Monitor dam-building success, pond characteristics, riparian vegetation community patterns and water retention associated with beaver reintroduction efforts.

These monitoring activities can help prioritize sites for habitat improvement and conservation projects, assist with refining riparian management techniques, and contribute to quantifying current successes.

Monitor the landscape distribution and habitat intactness of riparian habitats through remote sensing.
Remote sensing is useful in tracking the size, distribution, and fragmentation level of riparian habitats in Wyoming. This information could help determine the cumulative impacts of activities and events such as rural subdivision, energy development, historic flow regime alteration, and the spread of invasive species. Special attention should be given to monitoring the level and location of these activities in relation to SWAP SGCN priority areas (Figure 8). This technique will require the further development of monitoring protocols and the identification of sample sites.

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Sagebrush Shrublands

Photo courtesy of WGFD

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Habitat Description

Sagebrush is an icon of Wyoming's landscape and open spaces. Sagebrush habitats are found in cold, semi-desert climates across the Intermountain West, and Wyoming has more sagebrush than any other state. Estimates vary on the amount of sagebrush dominated communities, but range from 23.5 million acres (Knight 1994) to approximately 37 million acres (Beetle and Johnson 1982). NatureServe (2009) lists seven ecological systems associated with this habitat in Wyoming (Table 17). Scores of different associations have been identified within these ecological systems. In sagebrush dominated areas, winters can be long, summers are hot and dry, and winds are persistent. A defining attribute of sagebrush ecosystems is a high proportion of annual precipitation occurring in the winter as snow or as early spring rain (Knight 1994). Summer storms can be brief and intense, and most precipitation runs off or evaporates (Paige and Ritter 1999).

The distribution of sagebrush on the landscape depends upon the response of individual species and subspecies to soil moisture, salinity, depth, and texture, as well as to climatic factors. Species/subspecies location patterns are accentuated over short distances by wind, topography, and abrupt changes in soil conditions (Knight 1994). Sagebrush communities may range from less than 4,000 to over 9,500 feet in elevation, with annual precipitation varying from a minimum of approximately 6 inches to over 20 inches. Sagebrush occurs on a variety of aspects from basins and valley bottoms, to undulating terraces and foothills, to steep slopes and mountainous areas. Likewise, it is found in a variety of mostly xeric soil types and a variety of soil textures and depths.

Natural disturbances also play an important role in determining the pattern, age structure, and species composition of sagebrush stands. Fire has played a role in shaping the sagebrush communities in Wyoming since the last ice age (Bohne et al. 2007). The historic ecological role and frequency for fire in sagebrush communities is debated. Research indicates that fire frequency in big sagebrush community types may range from 10 to over 110 years (Wyoming Sage-Grouse Working Group 2003); while others contend that in many Wyoming big sagebrush communities the time frame maybe closer to 100 to 240 years (Baker 2006, Cooper et al. 2007), and in more xeric types, such as low sagebrush, 325 to 450 years (Baker 2006). Rates of sagebrush canopy recovery following fire also greatly vary across the landscape and between different sagebrush community types ranging from 100 to 120 years (Baker 2006) to as few as 10 years (Sturgis 1994). Patchy fires appear to have been common in many sagebrush communities while larger fires at lower frequencies occurred in other areas, depending on climate, topography, plant composition, and aridity. In addition to fire, herbivory from wild ungulates, insects, rodents, and rabbits; precipitation, particularly drought; plant disease; and the effects of burrowing animals are important natural disturbances in sagebrush habitats.

Sagebrush stands can vary from large patches dominated largely by a single species or subspecies of sagebrush to a mosaic of multiple species where sagebrush is intermixed with other shrubs, such as rabbitbrush, antelope bitterbrush, greasewood, shadscale, winter-fat, and spiny hop-sage (Paige and Ritter 1999). Stands of sagebrush can be dense, patchy, or sparse. In tall sagebrush types, sagebrush cover commonly ranges from 5–30% or greater on some sites (Dealy et al 1981). Sagebrush communities often contain three or four vegetative layers: 1) a shrub layer, 12–40 inches tall, 2) forbs and caespitose grasses, 8–24 inches, 3) low-growing grasses and forbs of less than 4–8 inches tall, and 4) a biological soil crust (Miller and Eddleman 2000). The biological soil crust is composed of blue-green algae, bacteria, fungi, mosses, and lichens. Research indicates the crust may play an important role in some dry regions through stabilizing soils from wind and water erosion, contributing to soil productivity, influencing nutrient levels, retaining moisture, altering soil temperature, and aiding seedling establishment (Paige and Ritter 1999).

Other plant communities such as aspen, mountain shrubs, salt desert shrubs, and open conifer occur in association with sagebrush communities (Wyoming Interagency Vegetation Committee 2002). Major sagebrush species that dominate or co-dominate sagebrush systems in Wyoming include big sagebrush, including Wyoming, subalpine, mountain and basin subspecies/varieties; two varieties of silver sagebrush; low sagebrush; black sagebrush; two varieties of three-tip sagebrush; early sagebrush; birdsfoot sagebrush; spiked sagebrush; bud sagebrush; sand sagebrush; and fringed sagewort. Unlike other plants, most varieties of big sagebrush lack the ability to sprout from roots or root crowns and thus are killed when the crown is removed by fire or mechanical treatments such as mowing. This attribute increases the importance of longevity and seed production for the species. Big sagebrush seedlings only become established during favorable precipitation years or following a disturbance that reduces competition from neighboring plants (Knight 1994). While the subspecies/varieties of big sagebrush have some common characteristics, they also present characteristics unique to each taxon (Winward 2004). Wyoming big sagebrush grows on the most xeric sites of all the big sagebrush taxa. Basin big sagebrush, the tallest of the western sagebrushes, is found on deep, well-drained soils, often alluvial soils. Mountain big sagebrush grows on mid-to-upper elevation (6,800–8,500 ft.) mesic sites, and subalpine big sagebrush grows at high elevations (8,500–10,000 ft.) (Winward 2004). Understanding the differences between these taxa is important to management; an issue further complicated by varying degrees of hybridization.

Silver sagebrush is a common species in the lowlands (Knight 1994). Silver sagebrush often occurs in ravines or on floodplains in areas where Wyoming big sagebrush dominates the uplands. Silver sagebrush and three-tip sagebrush resprout from the root stock when the crown is removed, and they are fire tolerant (Adams et al 2004, Winward 2004). Black sagebrush often occurs on ridge tops on drier, coarser-textured, and shallower soils than either silver or big sagebrush (Knight 1994). Low sagebrush is usually less than 10 inches tall and is only found in the western part of the state such as the lowlands of Jackson Hole and Grand Teton National Park.

In addition to wildlife, sagebrush habitats are important landscapes for people. Agriculture, mining, oil, gas, coal-bed methane, wind development, outdoor recreation, and residential housing are important land uses in sagebrush habitats. About 45% of the potential sagebrush habitat in the West is no longer sagebrush due to habitat conversion to cropland or pasture, development, conifer encroachment, and conversion to annual grasslands as a result of wildfire and exotic weed infestations (Connelly et al. 2003). A large percentage of sagebrush habitats are administered by public land management agencies, particularly by the Bureau of Land Management (BLM). Throughout the West, less than 30% of all sagebrush lands are privately owned (Raphael et al. 2001). Consequently, public land use policies and decisions will have a significant influence on the future of sagebrush habitats and associated species.

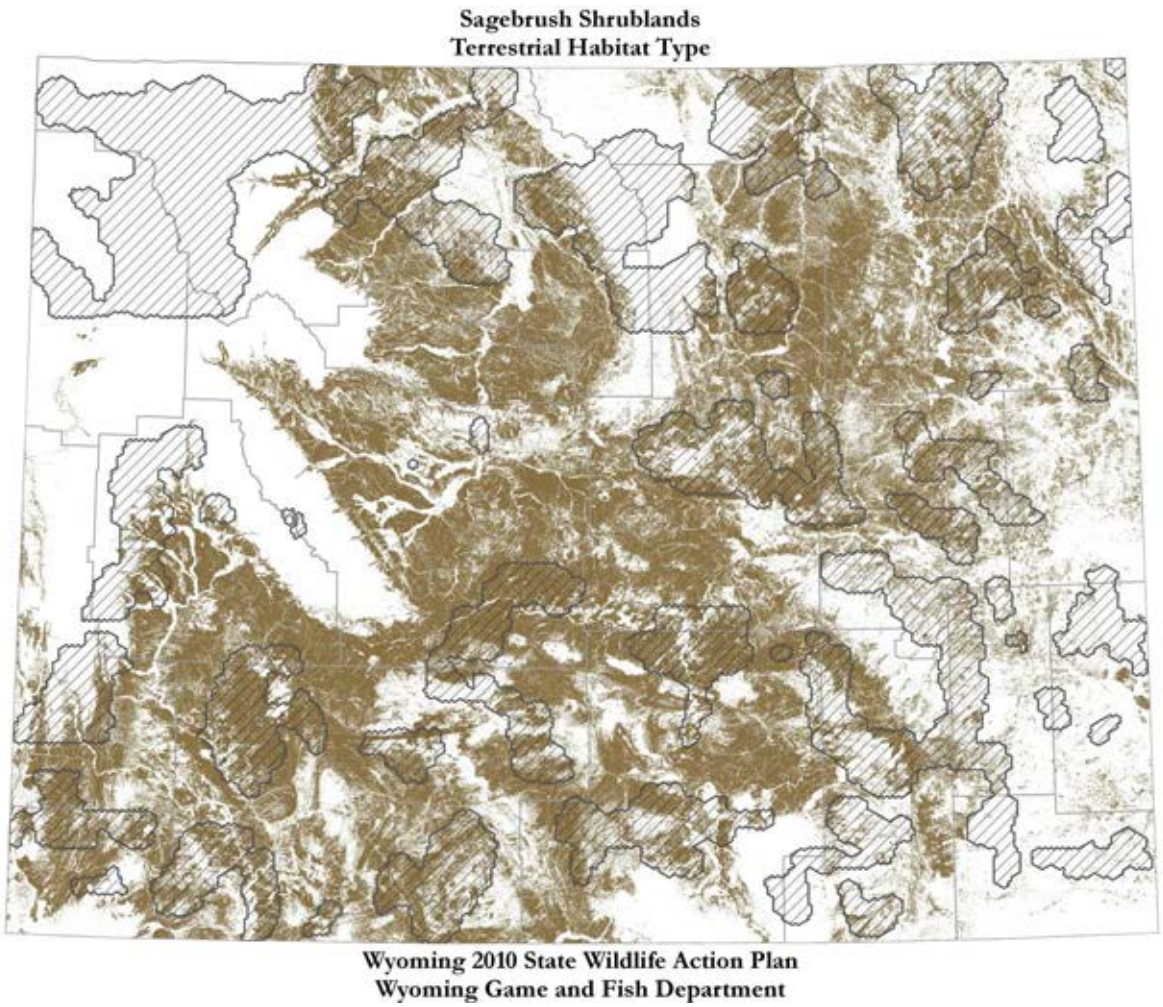

FIGURE 9. Wyoming Sagebrush Shrublands and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 17. Wyoming Sagebrush Shrublands NatureServe Ecological Systems[1]

1. Great Basin Xeric Mixed Sagebrush Shrubland
2. Inter-Mountain Basins Big Sagebrush Shrubland
3. Columbia Plateau Low Sagebrush Steppe
4. Inter-Mountain Basins Big Sagebrush Steppe
5. Inter-Mountain Basins Active and Stabilized Dune
6. Wyoming Basins Dwarf Sagebrush Shrubland and Steppe

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://www.natureserve.org/explorer.

TABLE 18. Wyoming Sagebrush Shrublands Species of Greatest Conservation Need

Mammals
Eastern Red Bat
Great Basin Pocket Mouse
Idaho Pocket Gopher
Olive-backed Pocket Mouse
Pallid Bat
Plains Pocket Gopher
Pygmy Rabbit
Spotted Bat
Spotted Ground Squirrel
Swift Fox

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

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

Amphibians
Plains Spadefoot
Great Basin Spadefoot

Sagebrush Shrublands Wildlife

Sagebrush-associated vegetation types provide habitat for approximately 87 species of mammals, 297 species of birds, and 63 species of fish, reptiles, and amphibians (Wyoming Interagency Vegetation Committee 2002). Sagebrush ecosystems in Wyoming not only support crucial habitats for some of the largest migratory populations of ungulates in North America, but also offer the best chance to sustain healthy populations of sage-grouse and other sagebrush dependent species (Wyoming Game and Fish Department 2010a). In Wyoming, sagebrush obligates include the sage sparrow, Brewer's sparrow, sage thrasher, sage-grouse, pygmy rabbit, sagebrush vole, and sagebrush lizard (Paige and Ritter 1999).

Sagebrush itself is a keystone plant. Sagebrush ecosystems provide important food and cover, especially winter habitat, for big game species and other wildlife. Elk, mule deer, and pronghorn are the primary wild ungulates that utilize sagebrush habitat. Pronghorn attain their highest population densities in these ecosystems. Wyoming big sagebrush is also regarded as a crucial food item for sage-grouse, black-tailed jackrabbits, and pygmy rabbits, and mature sagebrush cover is important for sage-grouse broods.

The protein level and digestibility of sagebrush are typically greater during winter than other shrub and herbaceous plants (Peterson 1995). During this time, sagebrush is commonly the only green vegetation that rises above the snow. Not only does this increase its forage value for wildlife, but sagebrush's comparatively tall stature and stiff twigs capture snow, which increases ground water content throughout the summer. The characteristic smell of sagebrush is the result of volatile oils such as terpenes, which serve as a chemical-defense mechanism to limit herbivory. Consequently, wildlife species such as pronghorn and sage-grouse that ingest large quantities of sagebrush have developed efficient digestion systems to cope with these defenses.

In addition to sagebrush dependent species, Wyoming sagebrush shrublands with lower shrub stature and density, such as Wyoming Basins Dwarf Sagebrush Shrubland and Steppe, are used by many grasslands wildlife species. Wyoming grasslands SGCN, including swift fox, mountain plovers, McCown's longspur, as well as other grasslands species often extend their ranges west into such sagebrush habitats. For many birds, the height, density, cover, and patchiness of sagebrush stands have been determined to be the best indicators of species composition and abundance (Paige and Ritter 1999).

Invertebrate communities in sagebrush are not well understood, but may be critical to its

effectiveness as wildlife habitat. Invertebrates represent high-protein forage, especially in spring and early summer, when plant protein is not yet available and vertebrates are generally protein-starved. Insect forage is known to be key to survival of sage-grouse chicks during the first few weeks after hatching, which in turn is key to increasing sage-grouse populations. Similar scenarios likely apply to other sagebrush-occupying wildlife. In addition to the numerous vertebrate and invertebrate animal species that depend on sagebrush for food and cover, there are several plant species primarily found only in association with sagebrush.

Sagebrush Shrublands Habitat Threats

Invasive plants – High

It has been estimated that nonnative invasive plants are overtaking many wildland areas at the rate of about 4,600 acres a day on BLM-administered public lands alone (Bureau of Land Management 2000a). In Wyoming, there is a gradient of nonnative plant species invasion. In the higher and cooler sagebrush habitats of southern and western Wyoming, invasive plants are primarily established on disturbed sites such as roadways and well pads (Bergquist et al. 2007), whereas in the lower and warmer elevations of northern Wyoming, invasive plants are widespread throughout the understory of Wyoming big sagebrush communities.

The establishment of invasive plants can lead to loss of water and soil nutrients, increased erosion, and reduced productivity of native vegetation (see Wyoming Leading Conservation Challenges – Invasive Species). These effects reduce habitat quality for sagebrush-associated species including antelope, mule deer, elk, greater sage-grouse, pygmy rabbits, and sagebrush passerines. Ecological function deteriorates as hydrological processes are impacted, litter accumulation and organic matter breakdown decreases, and soil surfaces become denuded of native plants. Once invasive plant species become established, a seed source is developed for invasive species to expand into adjacent habitats such as riparian areas.

Cheatgrass, in particular, is a growing threat for Wyoming sagebrush habitats. Cheatgrass invasion fundamentally alters fire and vegetation patterns in sagebrush habitats by creating a bed of continuous, fine fuel that readily carries fire. Where cheatgrass has invaded the Snake River Plains of Idaho, the natural fire cycle has shortened from 30–100 years to 3–5 years (Whisenant 1990). Because sagebrush may take several years to mature before producing seed, repeated fires can eliminate sagebrush entirely. Cheatgrass dominance eventually creates uniform annual grasslands, perpetuated by large, frequent fires and void of any patches of native plant communities (Paige and Ritter 1999). Among other impacts on wildlife, increased fire frequency can decrease spring insect availability for birds.

The Wyoming Cooperative Agricultural Pest Survey (2010) data housed on the University of Wyoming website showed cheatgrass increasing in 21 of 23 counties in the state between 2003 and 2007 (updated March 2009). The survey also reported that 11 of 23 counties have more than 20,000 acres of surface dominated by cheatgrass. Notable recent increases in cheatgrass have occurred in the Bighorn Basin, the Laramie Mountains of southeastern Wyoming, as well as the foothills of the southern Wind River Mountains. Cheatgrass has also been invading more undisturbed big sagebrush communities at higher elevations, especially on south-facing slopes, as well as in ponderosa pine communities. Increased temperatures and more variable precipitation predicted for Wyoming's climate by some climate models could favor cheatgrass expansion (Bradley 2009).

Leafy spurge, spotted knapweed, Russian knapweed, hound's-tongue, halogeton, Dalmatian toadflax, Canada thistle, and white-top are other invasive species that pose a threat to sagebrush communities. Weed invasions often originate in areas of disturbed or bare soil frequently associated with construction and overgrazing.

Incompatible energy development and mining practices – High

Wyoming is one of the top energy producing states in the country (see Wyoming's Leading Wildlife Challenges – Energy Development). It is the nation's leading producer of coal (National Mining Association 2008), ranked fifth in natural gas production, and ranked eighth in crude oil production (Lawrence 2007). Wyoming ranks seventh nationally for wind-power generating potential when factoring in land status and environmental constraints (Elliott et al. 1991). Uranium, bentonite, trona, and gypsum are also mined.

Energy development can result in direct and indirect impacts to wildlife species and their habitat. Direct impacts include the removal and fragmentation of sagebrush communities, introduction and spread of invasive species, and increased soil loss and erosion resulting from activities such as mine excavation and the building of roads, drill pads, fences, power lines, and pipelines. Soil disturbance from roads and other types of construction and increased vehicle traffic are significant contributors to the establishment and spread of invasive weed species in sagebrush communities.

Indirect impacts include increased human activity, noise, and predator intrusion into previously unbroken habitats (Bui 2009). These impacts can displace animals and decrease reproductive success if animals are forced to use less productive habitats or expend more energy avoiding people and predators. For example, the density of sagebrush-obligate birds within 328 feet of roads constructed for natural gas development in Wyoming was 50% lower than the density at greater distances (Ingelfinger 2001). The increase in the number of roads providing greater access into sagebrush habitat may also increase both the legal and illegal harvest of wildlife.

Direct mortality of wildlife from energy development can be associated with higher wildlife–vehicle collision rates from increased traffic. Sage-grouse have been known to drown in water evaporation ponds and production pits (Wyoming Sage-Grouse Working Group 2003).

An increase in the amount of standing water associated with some energy development techniques (Zou et al. 2006) may facilitate the breeding of mosquitoes that spread West Nile virus, which is lethal to many bird species including sage-grouse (Marra et al. 2004).

Produced water from oil and gas wells may be considered for enhancement of fish and wildlife habitats. For example, the creation of more mesic sites using produced waters may improve brood-rearing areas for species such as sage-grouse that tend to favor sites with abundant, succulent forbs (Aldridge and Boyce 2007). Utilization of produced waters can also increase forage and water reservoirs for other wildlife including ungulates. The WGFD has several programs that can provide funds for the development of water resources located by oil and gas drilling (Wyoming Game and Fish Department 2010c).

Some habitat impacts from energy development can be minimized by mitigation strategies, reclamation projects, and adequate planning efforts. Often these impacts are short-term and related to specific periods of activity which can be managed with timing stipulations to avoid conflicts with wildlife use of specific sites. Other impacts have yet to be thoroughly researched and associated rehabilitation and reclamation can be problematic and may take many years to achieve the complete recovery of a functioning sagebrush habitat (Monsen et al. 2004).

The accelerated pace of wind-energy development in Wyoming presents a new challenge for wildlife and habitat managers. Little research has been conducted to quantify the impacts of wind-energy development on sagebrush-dependent wildlife species. Bird strikes and bat mortality are commonly known to occur at wind energy facilities, but the effects on species that inhabit open landscapes, such as pronghorn and sage-grouse, are largely unknown. Some researchers have proposed similar impacts on wildlife from wind-energy development as those documented for oil and gas development (Becker et al. 2009).

Rural subdivision – High
Rural subdivision and development can reduce, degrade, and fragment sagebrush habitats (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). Houses, outbuildings, and lawns directly replace native wildlife habitat. Soil disturbance from construction, year-round grazing of horses and other hobby livestock, and the use of nonnative plants as ornamentals can facilitate the establishment of invasive species (Maestas et al. 2002).

Wildlife commonly abandons or alters use of habitats with greater human and pet activity. Increased energy expenditures in avoiding people or greater use of lower quality habitats can decrease animal health and reproductive capacity. Greater road densities and traffic volume can increase wildlife–vehicle collisions. Predation on wildlife can intensify with greater numbers of domestic dogs and cats, as well as increases in generalist predatory species such as ravens and human-commensal species such as raccoons (U.S. Department of Agriculture 2007).

Off-road vehicle use – Moderate
Off-road vehicle use, primarily by all-terrain vehicles (ATVs), is increasing in sagebrush habitats. Driving vehicles off established roads can enhance the spread of invasive species, especially spotted knapweed and cheatgrass (Rooney 2005). Tires can damage biological soil crusts leading to decreased organism diversity, soil nutrients, soil stability, and organic matter, as well as increased erosion, which may negatively impact water quality. Managing off-road vehicle use can be difficult and controversial in sagebrush ecosystems where new trails are relatively easy to create and where some off-road vehicle users have little value for what appears to be an unproductive and barren landscape. Wildlife frequently avoids areas of increased noise and disturbance from outdoor recreational vehicles, and this type of activity may impact sage-grouse use of leks, nesting sites, and brood-rearing habitat.

Varying management goals and conflicting views about sagebrush ecosystem ecology and wildlife habitat management – Moderate
An existing lack of knowledge and agreement among scientist and natural resource managers regarding sagebrush ecosystem ecology and wildlife habitat management is an obstacle to advancing coordinated sagebrush conservation actions.

Due to disruption of natural disturbance regimes, particularly fire, it is felt by many that sagebrush in Wyoming is in late successional stages dominated by plants of relatively even age classes and older than 50 years of age (Winward 1991, Miller et al.1994, Wyoming Interagency Vegetation Committee 2002). These stands are commonly believed to display reduced vigor, productivity, diversity, and nutritional quality (Wyoming Interagency Vegetation Committee 2002). It is also believed that a mosaic of sagebrush age classes are required to best meet wildlife forage and cover needs. As a consequence, sagebrush habitats have been subjected to a variety of treatments including burning, chemical control, and mechanical manipulation to improve wildlife habitat and livestock forage production. In addition to treatments, the widespread removal and conversion of sagebrush habitats to grasslands to increase livestock productionoccurred was common in the past. (Vale 1974).

However, there is no widespread agreement on what constitutes decadence and poor vigor, particularly among wildlife biologists and range managers. Prescribed fire programs and other sagebrush habitat treatments are often based on the assumption that fire suppression has substantially reduced the frequency of fire in sagebrush vegetation; however, this assumption is very hard to prove (Baker 2006). While fire suppression is most often associated with the perceived decadence of sagebrush systems, drought stress over the past decade has likely played a role. As a result of these uncertainties, it is difficult for natural resource managers to quantify the size and scope of the problem,

determine its cause, and apply appropriate management actions.

Furthermore, there is often little systematic monitoring following habitat treatments to document their extent and effectiveness. The Wyoming Governor's Sage-grouse Implementation Team identified the potential positive or negative effects of various habitat treatment practices (e.g., mowing/burning sagebrush, interseeding, grazing) and recommends that additional monitoring and research be conducted.

Incompatible grazing management practices – Moderate
Excessive grazing by domestic livestock during the late 1800s and early 1900s, coupled with severe drought, significantly impacted sagebrush ecosystems (Yensen 1981, Young and Sparks 2002). Since this time, livestock management has improved with the adaptation of practices to control the intensity, interval, and season of use for grazing. However, in some areas grazing techniques could still be improved to benefit wildlife. Grazing has an influence on sagebrush density, canopy cover, and re-establishment rates as well as herbaceous composition (Wyoming Interagency Vegetation Committee 2002). Grazing may also reduce fine fuels and alter fire regimes (Beck and Mitchell 2000). Spring developments, water pipelines, and fencing have distributed livestock and wildlife use over areas that were formerly only occasionally or lightly grazed by large herbivores. Grazing practices that do not promote cool season grasses, especially bunchgrasses, and lead to a loss or alteration of forbs and shrubs, can interfere with ecological process and reduce habitat quality for wildlife. Managing the timing and intensity of grazing is particularly important for retaining residual grass cover, which has a strong influence on nesting success for sage-grouse and ground-nesting birds by providing cover to hide nests and hatchlings from predators.

Valuable biological soil crust in ephemeral riparian areas can be damaged by livestock hoof action during wet periods and soil compaction is common during dry periods. This can limit seedling establishment for forbs and grasses in areas with little to no growing season rain. Excess browsing by wild ungulates can damage sagebrush plants, which can lead to mortality. Winter range in some areas has been damaged by drought and big game herd numbers that exceeded management objectives.

Conifer encroachment – Moderate
In certain areas of Wyoming, Wyoming big sagebrush communities and mountain big sagebrush communities have been impacted by encroachment from juniper, ponderosa pine, and limber pine. This expansion has been documented by repeat photography, discussions with long-time residents, and fossil packrat-midden studies (Jackson et al. 2005). Suppression of wildfire is thought to be a primary reason for coniferous species invading sagebrush habitats, but changes in grazing and climate may also play a role. Conifer encroachment into sagebrush communities reduces shrub density and cover and herbaceous species diversity and production, and it lowers water yield. Cheatgrass invasion can be greatly enhanced if juniper densities reach a point where crown fires can be sustained. Suitable habitat for sage-grouse, pronghorn, mule deer, and other species that depend upon sagebrush habitats may decline. Sage-grouse, in particular, are known to avoid juniper communities (Commons et al. 1999, Doherty et al. 2008, Freese 2009). While juniper thinning projects are common in the state, it is important to balance these projects with the need to provide locations of adequate habitat for juniper obligate species (see Habitat Terrestrial Type – Xeric Forest).

Drought and climate change – Moderate
Studies of age-class structure in sagebrush communities suggest that the establishment of new sagebrush plants is episodic and in many cases depends on above-average precipitation either during the first or second year of growth (Cawker 1980, Maier et al. 2001). Some climate models predict that Wyoming's climate will become drier (Christensen et al. 2007). More frequent and severe dry years could decrease the

establishment of new sagebrush plants and slow or prevent recovery of sagebrush stands following fire, habitat enhancement treatments, or other disturbances that kill adult shrubs.

Many sagebrush communities exist in areas of low annual precipitation, and some communities may be at the limit of their range due to water availability. Drought causes a decrease in the production of herbaceous cover and forb availability which may affect the abundance of many species of wildlife. The difference between sagebrush production in drought versus non-drought years can be as much as 900% (Wyoming Interagency Vegetation Committee 2002). Loss in production can lead to increased competition between livestock and wildlife for food and cover.

Current Sagebrush Shrublands Habitat Conservation Initiatives

Increasing levels of energy development and declines in sage-grouse and mule deer numbers have greatly increased attention toward conserving sagebrush habitats. Sagebrush habitat management and conservation have been a priority for the Wyoming Game and Fish Department (WGFD) since it embarked on the development of the statewide *Wyoming Greater Sage-grouse Conservation Plan* in 2000. Completed in 2003, this plan considers sagebrush conservation challenges and offers recommendations to address issues such as conflicting wildlife and wild horse management goals, invasive weeds, livestock grazing, energy development, recreation, residential development, vegetation management, and weather. The *Wyoming Greater Sage-grouse Conservation Plan* recommendations were also the genesis for the establishment of eight sage-grouse local working groups that direct on-the-ground habitat enhancement, population monitoring, and planning projects. Subsequently, each working group has developed a local sage-grouse conservation plan to guide these efforts.

A similar, more regional effort, the *Conservation Assessment of Greater Sage-grouse and Sagebrush Habitats* (Connelly et al. 2004), was completed by the Western Association of Fish and Wildlife Agencies (WAFWA) in 2004. As a follow-up document, WAFWA produced the *Greater Sage-grouse Comprehensive Conservation Strategy* in 2006 (Stiver et al. 2006).

In 2007, in response to the possibility of listing the greater sage-grouse under the Endangered Species Act, Governor Freudenthal formed two sage-grouse working teams: the Sage-grouse Implementation Team and the Science Technical Team. These teams were to develop recommendations for conserving greater sage-grouse across land ownership boundaries in Wyoming. First, the implementation team recommended extensive statewide mapping of sage-grouse habitat and habitat enhancement efforts. In April of 2008, Governor Freudenthal issued Executive Order 2008-2 which set forth Wyoming's Core Area Strategy. This strategy directs state agencies to focus sagebrush and sage-grouse conservation efforts within Core Population Areas developed by the Governor's Sage-grouse Implementation Team. New development within Core Population Areas would be authorized when it is demonstrated that the activity will not cause declines in greater sage-grouse populations. Incentives would be provided to encourage development outside Core Population Areas and to enhance reclamation in habitats adjacent to Core Population Areas.

In 2008, WAFWA, U.S. Forest Service, BLM, U.S. Fish and Wildlife Service, U.S. Geological Survey, Natural Resources Conservation Services (NRCS), and the Farm Service Agency entered into a memorandum of understanding to increase cooperation in the conservation and management of greater sage-grouse, sagebrush habitats, and sagebrush-dependent wildlife. This would be accomplished through the implementation of WAFWA's *Greater Sage-grouse Comprehensive Conservation Strategy* and conservation actions for other sagebrush-dependent species, adopting an adaptive management approach that recognized current

uncertainties, and establishing partnerships with agencies, organization, communities, and private landowners.

Sagebrush was also identified as one of eight priority habitats to enhance or maintain within the WGFD Strategic Habitat Plan (SHP). First created in 2001 and revised in 2009, the purpose of the SHP is to strategically guide WGFD habitat improvement and protection activities. Regional priority areas for conservation work were identified including crucial areas, necessary for maintaining terrestrial and aquatic wildlife populations and enhancement areas, where there is the potential to enhance or improve important wildlife habitats that have been degraded. Narratives for both crucial and enhancement areas describing the location, boundaries, values, issues, species, and solutions/actions were prepared (http://gf.state.wy.us/habitat/PriorityAreas/index.asp).

The WGFD Mule Deer Working Group (MDWG) was established in 1998 to explore solutions to the many challenges confronting mule deer conservation and management. Crucial areas for mule deer often encompass sagebrush habitat, particularly on mule deer winter range. In 2007, the MDWG drafted the *Wyoming Mule Deer Initiative* which was adopted by the Wyoming Game and Fish Commission. Among other topics, the initiative addresses habitat issues pertaining to crucial mule deer habitat improvement, the implementation of strategies to minimize negative impacts of energy development, and habitat monitoring to ensure that deer populations do not negatively impact plant species on which they browse.

There are several efforts in Wyoming focused on reducing the negative effects of energy development on sagebrush habitats through planning and mitigation. The Wyoming Landscape Conservation Initiative (WLCI) is a multi-stakeholder initiative in southwest Wyoming focused on data collection, monitoring, research, and facilitating land management actions to protect or enhance wildlife habitat and other resource values. The Jonah Interagency Office (JIO) is a $24-million mitigation fund that has been established to support projects to maintain important biological areas in the vicinity of natural resource development near Pinedale. Similar mitigation activities are underway for other oil and gas fields, including the Continental Divide-Creston, Hiawatha, and Pinedale Anticline.

Since 1975, Coordinated Resource Management (CRM) teams have used a collaborative, stakeholder-based approach to address land management issues in Wyoming. Currently, there are approximately 40 CRM teams composed of ranchers, land and wildlife management agency personnel, conservation organizations, and sportsmen in Wyoming, many of whom are focused on improving management techniques to benefit wildlife and livestock in sagebrush habitats. In partnership with the BLM and U.S. Forest Service, some federal grazing permittees are incorporating private sagebrush monitoring and best management practices into their ranching operations.

Prescribed burning and mechanical treatments are commonly used in sagebrush habitats to improve forage, increase age and structural diversity, and reduce encroachment by conifers. Treatments include targeting individual junipers or treating large patches with prescribed fire, mastication with heavy equipment, and hand cutting administered by seasonal fire crews. Aerial spraying to control cheatgrass has been initiated in many areas following guidance from the State Weed and Pest Plan, Wyoming Cheatgrass Task Force, and more recently by the Wyoming Cheatgrass Task Force. Public land and wildlife agencies including the BLM, U.S. Forest Service, WGFD, and Wyoming State Land Board have worked on initiating road closures in sensitive sagebrush habitats. Conservation easements held by a variety of land conservation organizations and the Wyoming Game and Fish Commission are being negotiated with willing landowners in sagebrush habitats.

Recommended Sagebrush Shrublands Conservation Actions

Increase research and develop plans to address the establishment and spread of cheatgrass and other invasive species in sagebrush habitats.
A literature review and discussions with researchers and land managers should occur to develop a comprehensive understanding of recent changes in cheatgrass abundance and density in Wyoming, and to determine the likely causes of this increase. Climatologists should be included in these discussions to develop a better understanding of how potential changes in future temperature and precipitation patterns in Wyoming may influence the spread of cheatgrass. This information could be used to identify regions of Wyoming which will likely be susceptible to significant increases in cheatgrass abundance. Results of this analysis could then be communicated to landowners and natural resource professionals to help guide cheatgrass control efforts. Efforts to minimize the spread of other invasive species, including black henbane, should continue. County Weed and Pest District invasive species control efforts should be supported and enhanced. Education and partnership opportunities for invasive species control exist with the energy industry.

Increase research on the sagebrush habitat ecology and the effects of habitat treatments.
Research should focus on determining the influence of management practices on multiple wildlife species and ecological functions. Investigations relative to the type of management practice (e.g., seeding, thinning, removal, and no treatment), the method of treatment (e.g., mechanical, herbicide, fire, or a combination of these), and associated grazing strategies (e.g., prior, during, and post treatment) are needed. The size of treatment, species composition, and site condition should be among the parameters investigated. Until more information is available, prescribed fire should not be used where sagebrush cover is a limiting factor for sage-grouse, where the understory lacks perennial forbs and grasses, or where invasive species or high amounts of less palatable shrubs such as rabbitbrush, horsebrush, or snakeweed are present (Miller and Eddleman 2001).

A variety of entities have been successful in mediating conflicting perceptions about sagebrush management into integrated habitat plans. These include the University of Wyoming Cooperative Extension Service, local conservation districts, and local Coordinated Resource Management teams. Efforts should be made to increase general public awareness about sagebrush conservation issues and the value of sagebrush habitats to wildlife.

Enhance planning and mitigation efforts to minimize the negative impacts of energy development on sagebrush habitats.
The development and implementation of energy-development plans, particularly for oil, gas, and wind, is crucial to the success of accommodating growth in these industries while minimizing negative impacts to sagebrush ecosystems, wildlife habitats, and wildlife species. Mitigation plans should stress avoiding biologically sensitive areas within project sites and directing off-site mitigation funds to nearby high-value wildlife locations. Energy development planning and mitigation efforts could be specifically benefited by:

- Continued research about the effects of energy development on sagebrush wildlife species and ecosystems. The Wyoming Natural Diversity Database and Wyoming Cooperative Research Unit are currently conducting research to evaluate the vulnerability of Wyoming terrestrial SGCN to oil, gas, and wind development. Vulnerability is being determined by evaluating each species' potential exposure and sensitivity to energy development. Exposure is being evaluated through a GIS analysis that overlays distribution maps of SGCN with areas of known and projected energy development. Sensitivity is being determined by examining habitat and behavioral attributes of SGCN as well as

reviewing existing impact studies. Research results will not only give an indication of which species and taxonomic groups are potentially vulnerable to development, but also help direct future research to address information gaps. The project is being funded jointly by the U.S. Geological Survey, WLCI, and WGFD.

- Review management actions proposed by state and federal agencies involving sagebrush ecosystems and associated wildlife habitats, and work closely with the Wyoming Governor's office, industry, private land owners, and agency staff during early stages of energy development project planning. The SWAP, SHP, and Sage-grouse core population areas should be consulted during development and mitigation planning. Maintaining connectivity between core areas will be important for the long-term conservation of sage-grouse and other sagebrush associated species.
- Where appropriate, encourage the implementation of mitigation measures and/or best management practices detailed within the Wyoming Game and Fish Commission documents: *Recommendations for Development of Oil and Gas Resources within Crucial and Important Wildlife Habitats* (Wyoming Game and Fish Department 2010a), *Recommendations for Wind Energy Development in Crucial and Important Wildlife Habitat* (Wyoming Game and Fish Department 2010b). Sage-grouse habitat protection recommendations for uranium and bentonite mining as well as other significant surface disturbing activities are addressed in the Sage-grouse core area implementation recommendations available on the WGFD website. Development of stipulations for Sage-grouse core population areas and noncore areas and the *BLM Instructional Memorandum on Sage-grouse* should be reviewed.

Develop long-term grazing and habitat management plans for sagebrush ecosystems within identified priority sage-grouse habitats and big game winter range. Long-term, interagency management plans should be developed in key wildlife areas including those identified within Wyoming's SWAP, WGFD SHP, and Sage-grouse Core Population Areas. The publication *Grazing Influence, Management and Objective Development in Wyoming's Greater Sage-grouse Habitat – With Emphasis on Nesting and Early Brood Rearing* (University of Wyoming 2009) provides an excellent overview and discussion relative to the influences of livestock grazing on sagebrush ecosystems and sage-grouse habitat. Wet meadows within sagebrush systems deserve particular attention. Livestock prefer these sites as the summer progresses and uplands become desiccated, which increases the tendency for over utilization. Many wildlife species use these sites during critical periods, such as pronghorn and mule deer fawning and sage-grouse late brood-rearing. However, meadows excluded from livestock grazing by fences may need to be periodically grazed to reduce dense grassy cover that may inhibit forb availability for wildlife.

While fences are effective for livestock management, they can also be barriers to wildlife movement and cause direct mortality. Fences should be designed to readily allow the passage of big game including pronghorn. Fencing design and instructions can be found in the WGFD Habitat Extension Service Bulletin No. 53 *Fencing Guidelines for Wildlife* (WGFD 2004). Fences also can be a source of mortality to sage-grouse from strikes by flying birds (Wyoming Game and Fish Department 2009a). Strikes have been documented in winter sage-grouse foraging areas, near leks, and fences around riparian areas used by grouse broods in the summer. Problem fences should be modified, removed or fitted with marking devices so grouse can see the wires while in flight in low visibility situations.

Efforts should be made to maintain big game herd numbers at ecologically sustainable levels that account for the carrying capacities of the herd unit's summer and winter ranges.

Develop incentives for landowners and land operators to adopt actions identified in the SWAP.
Many ranching operations own and use sagebrush dominated systems for various activities including livestock grazing. Additional incentives need to be developed before management strategies focused on increasing wildlife habitat values in sagebrush systems can be widely adopted. Examples of successful incentives include grassbanks, management agreements encouraging prescribed livestock grazing, and conservation easements. NRCS Farm Bill programs, the NRCS 2010 Sage-grouse Initiative, the USFWS Candidate Conservation Agreement with Assurances, and Wyoming Local Sage-grouse Working Groups all provide opportunities for the establishment of cooperative habitat improvement projects. Additional funding sources include the WGFD Trust Fund Program and Sage-grouse Programs, Tom Thorne Sage-grouse Fund, and Wyoming Wildlife and Natural Resource Trust.

Manage off-road vehicle use in environmentally sensitive areas or during seasons where wildlife is particularly sensitive to disturbance.
More efforts should be made on public lands to identify areas that are appropriate and inappropriate for off-road vehicle use including using Carsonite markers. Locations may vary seasonally to minimize disturbance to wildlife during critical periods such as when animals are on winter range or during nesting or fawning seasons. Public education should include increasing awareness of the ecological role of maintaining unbroken biological soil crust and the value of all types of vegetation.

Conduct more research about the potential effects of climate change on sagebrush ecosystems.
Reduced establishment of new sagebrush plants resulting from changes in climate, while currently hypothetical, could have serious consequences for the future of sagebrush ecosystems and wildlife in Wyoming. Additional research and modeling are needed to better understand the influence of temperature and precipitation on the establishment of sagebrush plants and potential future changes to Wyoming's climate patterns. This information could be used to make predictions on how climate change may influence sagebrush system health and distribution and where in the state these changes are likely to occur. This information should be communicated to wildlife biologists, natural resource managers, and landowners throughout the state to assist in sagebrush ecosystem and wildlife conservation planning.

Sagebrush Shrublands Monitoring Activities

Continue monitoring population trends or changes in distribution of sagebrush SGCN and other obligates in order to infer changes in habitat quality or other threats.
Monitoring should be used to determine distribution and seasonal habitat use to refine priority habitat maps. The U.S. Geological Survey habitat modeling effort to map potential sage-grouse habitat will provide landscape scale seasonal habitat maps for sage-grouse species which may have potential application for other sagebrush species (T. Christiansen, personal communication, 31 March 2010).

Monitor the size and landscape distribution of sagebrush shrublands through remote sensing.
Remote sensing is useful in tracking the size and distribution of this habitat type in Wyoming. Information gathered would be helpful in determining the cumulative impacts of activities and events such as energy development, rural subdivision, road construction, conifer encroachment, and the spread of invasive species. Special attention should be given to monitoring sagebrush ecosystems in SWAP SGCN priority areas (Figure 9). Monitoring should also be conducted in relation to the possible effects of climate change.

Establish sites and protocols for long-term monitoring to evaluate the effects of habitat

management activities on individual plants, vegetation communities, wildlife species, and ecological processes.

Inventory and monitor sagebrush systems and habitats in federal grazing allotments as part of annual inspections and during the 10-year allotment reviews.
Monitoring should include evaluation of livestock and wildlife browsing levels, invasive species, conifer encroachment, and plant understory composition.

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Wetlands

Photo courtesy of WGFD

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Information included in this section was adapted from the Wyoming Wetlands Conservation Strategy (WJVSC 2010). Those desiring additional information on Wyoming wetlands and wetland conservation not covered in this section should consult this document.

Habitat Description

Wetlands are habitats where the soil is annually saturated with water or covered by water at some time during the growing season of each year. For the purposes of this document, wetlands include wet meadows, potholes, playas, oxbows, beaver ponds, marshes, bogs, seeps, the vegetated shorelines of lakes and ponds, and other types of open water. Wetlands have been segregated from riparian areas (page III-8-1) which are designated as habitats associated with riverine systems. This differentiation has been made for SWAP planning and implementation purposes. Conservation and ecological issues for wetlands and riparian habitat types have considerable overlap. A list of the NatureServe Ecological Systems included in the wetlands habitat type can be found in Table 19. Much of Wyoming lacks the precipitation needed to support expansive wetland complexes such as those found in wetter regions of the country (Hubert 2004). Wyoming is the fifth driest state in the United States based on a statewide average rainfall of 16.8 inches (Wyoming State Geological Survey undated).

Wyoming wetlands can be divided into several morphological groups depending on their location and origin. The plains and intermountain basins are typified by low densities of shallow, playa-type wetlands that formed either in blowouts or, in some cases, as a result of tectonic activity. Kettle, cirque, and moraine type wetlands and lakes are present in higher elevations once covered by montane glaciers; however, the Pleistocene glacial sheets that left dense wetland complexes throughout the U.S. and Canadian prairie pothole region, did not reach Wyoming. Springs, bogs, and seeps are scattered throughout the state, but are most common in the montane areas.

Prior to settlement, natural wetlands covered about 3.2% of Wyoming (Dahl 1990) and were predominantly associated with riparian corridors and glaciated montane regions. By the mid-1980s, the total area of wetlands had been reduced to approximately 2% (Dahl 1990). Both the number and area of natural wetlands continue to decline, though this is offset to some extent by an increase in ponds and other human-created wetlands and water bodies.

Since the late 1800s, manmade wetlands have been created, both deliberately and coincidentally, as a result of human activities. Created wetlands vary in quality and can be associated with livestock impoundments; spring developments; windmill basins; irrigation seepage or runoff; sediment retention basins; reclaimed and abandoned mine impoundments; produced water from oil and gas operations; highway ditches and borrow pits; reservoir backwaters; mitigation sites; habitat areas on private, state, and federally-managed lands; and other miscellaneous activities (Tessmann 2004).

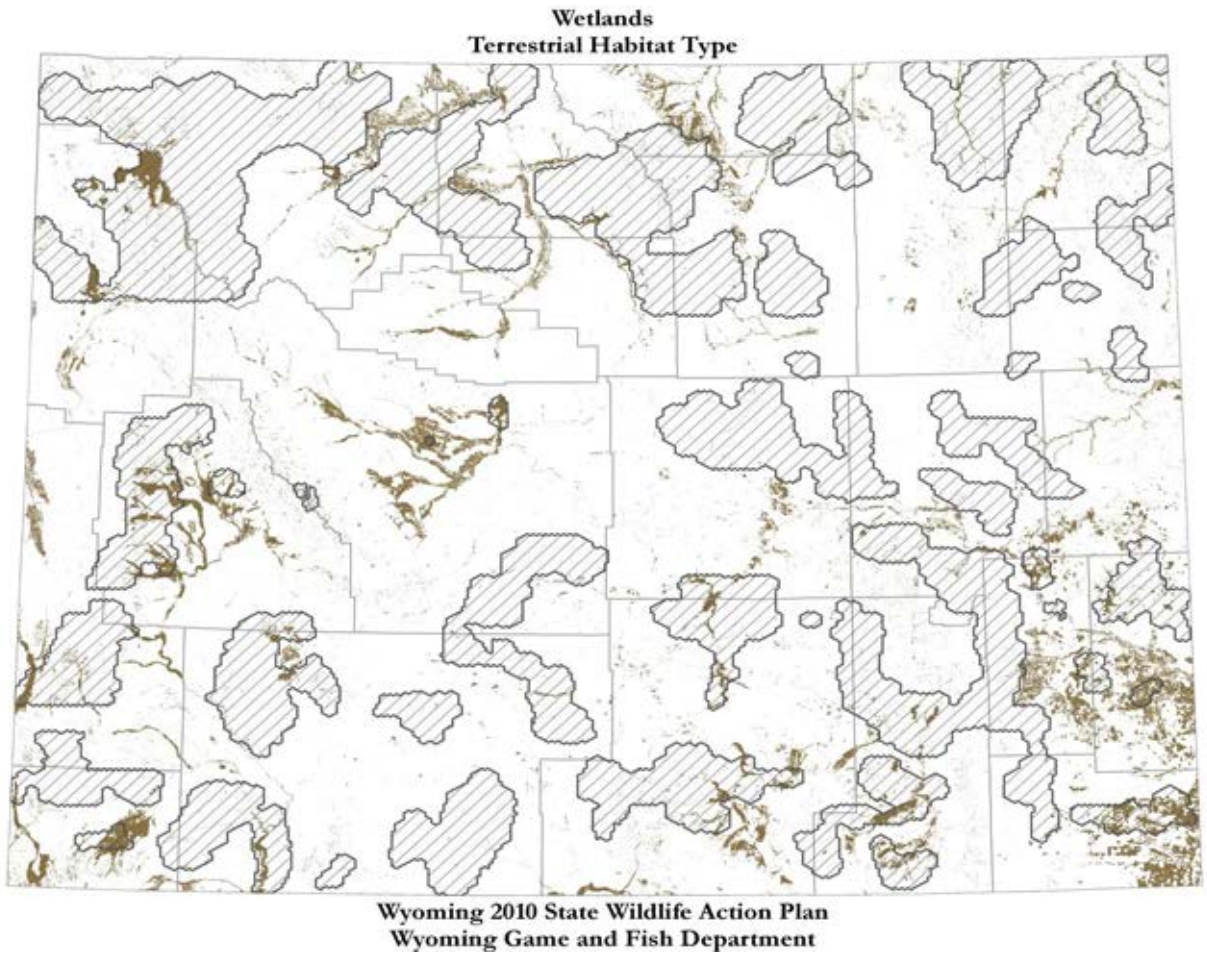

FIGURE 10. Wyoming Wetlands and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 19. Wyoming Wetlands NatureServe Ecological Systems[1]

1. Open Water
2. Pasture/Hay
3. Inter-Mountain Basins Playa
4. Introduced Riparian and Wetland Vegetation
5. Great Plains Prairie Pothole
6. Rocky Mountain Alpine-Montane Wet Meadow
7. Western Great Plains Open Freshwater Depression Wetland
8. North American Arid West Emergent Marsh
9. Columbia Plateau Vernal Pool
10. Rocky Mountain Subalpine-Montane Fen
11. Western Great Plains Closed Depression Wetland
12. Western Great Plains Saline Depression Wetland
13. Inter-Mountain Basins Alkaline Closed Depression
14. Inter-Mountain Basins Interdunal Swale Wetland

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. http://www.natureserve.org/explorer.

TABLE 20. Wyoming Wetlands Species of Greatest Conservation Need

Birds
American Bittern
Black-crowned Night-Heron
Barrow's Goldeneye
Black Tern
Canvasback
Caspian Tern
Clark's Grebe
Common Loon
Forster's Tern
Franklin's Gull
Greater Sandhill Crane
Lesser Scaup
Redhead
Snowy Egret
Trumpeter Swan
Virginia Rail
White-faced Ibis

Mammals
Big Brown Bat
Fringed Myotis
Hayden's Shrew
Little Brown Myotis
Long-eared Myotis
Long-legged Myotis
Moose
Northern Myotis
Pallid Bat
Preble's Shrew
Pygmy Shrew
Spotted Bat
Townsend's Big-eared Bat
Vagrant Shrew
Water Vole

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

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

Wetlands Wildlife

Wetlands are an extremely important wildlife habitat, disproportionately contributing to the diversity of Wyoming wildlife relative to the land base which they occupy. About 90% of wildlife species in Wyoming use wetlands and riparian habitats daily or seasonally during their life cycle, and about 70% of Wyoming bird species are wetland or riparian obligates (Nicholoff 2003). The high wildlife value of wetlands is derived largely from the presence of water which supports a large diversity of plants and animals, including invertebrates, which provide a forage base. Along altitudinal gradients, wetlands at mid and lower elevations tend to support greater diversity and density of wildlife because the growing season is longer, enabling those wetlands to be more productive. High elevation wetlands (over 8,000 ft) can be important for specific life stages of several species, but are not as productive.

Wetlands serve a valuable role in storing water. Marshes, fens, wet meadows, and similar cover types act as sponges that absorb and retain snowmelt and runoff, then slowly release it through the growing season. This increases the amount and reliability of downstream flows, especially in late summer, which in turn increases the quality of downstream riparian habitats. In addition, most wetlands improve the quality of water that is discharged. This is accomplished by removing sediments and some pollutants from water, thus acting as filtration systems for downstream communities, both human and ecological.

Clusters of wetlands in close proximity (wetland complexes), especially wetlands of differing size, chemistry, vegetation cover, and hydrology tend to sustain greater use by wildlife (WJVSC 2010). In addition, species richness and abundance tend to increase with wetland size (Mack and Flake 1980, Belanger and Couture 1988, Brown and Dinsmore 1986, McKinstry and Anderson 2002). Accordingly, diversity of size and water permanence are important attributes of wetland systems. Isolated wetlands in arid environments are also extremely valuable for wildlife. Wetlands in these areas often provide a crucial water source and enhanced cover and forage production, making

them a hub of activity for terrestrial wildlife that inhabit the surrounding area.

Wetlands provide irreplaceable habitat for waterfowl. Notable waterfowl species in Wyoming include the mallard, pintail, American widgeon, gadwall, green-winged teal, blue-winged teal, cinnamon teal, redhead, ring-necked duck, goldeneye, snow goose, and Canada goose.

Migrating shore birds also depend on wetlands. Shorebirds are known to have the longest migrations of any animal species, migrating as far as from the Arctic to the tip of South America, with non-stop flights, exceeding a thousand miles per leg (Brown et al. 2001). Wetlands provide food rich environments for shorebirds to build up fuel reserves needed to complete these long flights. Shorebirds frequently seen in Wyoming wetlands include American avocet, black-necked stilt, Wilson's phalarope, greater and lesser yellowlegs, long-billed dowitcher, killdeer, common snipe, spotted sandpiper, solitary sandpiper, western sandpiper, semipalmated sandpiper, willet, long-billed curlew, and white-faced ibis.

Wetlands are also very important for bats. Physical characteristics that influence how bats use water resources include size of the water body, extent of open water, surrounding and emergent vegetation, turbulence of the water, proximity to roosts, and water quality. In general, water features increase in value to bats if they are large, calm, and uncluttered; are in close proximity to roosts; have a diverse and productive riparian zone; support a diverse insect community; and are free of pesticides and other contaminants. Bats drink while in flight, accordingly they require water sources that are large and uncluttered for them to approach and skim the surface. Although tall vegetation and other features surrounding small bodies of water may reduce accessibility for some bats, the presence of some vegetation around water is nevertheless an important component of bat habitat. The vegetation provides abundant insect prey and protection from predators, and improves foraging conditions by blocking wind.

Alpine and sub-alpine wetlands and wet meadows are especially important for shrews and the water vole. These semi-aquatic species, rely heavily on leaves, roots, and stems of forbs, and invertebrates.

Wetlands are an important feature for amphibians. All of Wyoming's amphibian species are reliant on water to complete their life cycle. Eggs are laid aquatically, where they hatch into larvae (some are referred to as tadpoles). The larvae then undergo metamorphosis to become terrestrial adults. However, the barred tiger salamander may remain aquatic as an adult while retaining larval characteristics (termed *paedomorphism*). Many wetlands provide ephemeral fishless pools that amphibians prefer for breeding. In addition to utilizing wetlands for breeding and larval development, many frogs, toads, and salamanders are tied to aquatic environments as adults. Many amphibians, primarily frogs and salamanders, require wet environments to prevent desiccation and to provide cover from predators. Barred tiger salamanders may live their entire lives in an aquatic environment, exhibiting paedomorphism.

Many reptile species also prefer wetland habitats. Gartersnakes are particularly reliant on this habitat type. Gartersnakes are found in the subfamily Natricinae and closely related to the genus Nerodia (watersnakes). They are typically found in the moist environments found in wetlands and other riparian corridors. Gartersnakes feed on a variety of aquatic species including fish, invertebrates, and amphibians.

Wetland Habitat Threats

For a more additional detail and more complete listing of threats facing Wyoming wetlands, please refer to *Wyoming Wetland Conservation Strategy* (WJVSC 2010) and *Wyoming Partners In Flight Bird Conservation Plan - Wetlands Section (*Nicholoff 2003). For consistency, habitat threats ranked *extreme* in the Wyoming Wetland Conservation Strategy were ranked *high* in the SWAP which does not use an *extreme* threat category.

Climate Change and Drought - High
Variable weather patterns and periodic drought cycles are common occurrences in the West and an important driver of wetland ecology. However, the frequency and duration of droughts have increased markedly since the 1980s, producing undesirable

changes in wetland hydrology and the long-term loss of functional wetlands in some areas. Wetlands associated with irrigation may be insulated from drought if water continues to be available. Alternatively, wetlands dependent upon irrigation, particularly created wetlands with junior water rights, can remain dry for extended periods. In addition, natural wetlands can be severely impacted by long-term climatic changes leading to desertification and depleted stream flows (see Wyoming Leading Wildlife Challenges - Climate Change).

Rural Subdivisions – High
Houses, outbuildings, and lawns directly eliminate native wildlife habitat. Additional infrastructure such as roads, buildings, power lines, and fences, along with disturbances including traffic, human activity, and increased predator densities, can lessen the suitability of wetland habitats for sensitive wildlife. Loose pets, especially cats, are very problematic for wildlife near subdivisions. Pesticides, herbicides, and nutrients may enter aquatic environments, and their concentrations increase as a result of runoff from nearby lawns and landscaping use. Soil disturbance from construction and the year-round grazing of horses and other hobby livestock can facilitate the establishment of invasive plant species. Wildlife attempting to avoid human-related disturbances expend greater energy and displace to lower quality habitats, resulting in lower survival and reproductive capacity (See Wyoming Leading Conservation Challenges – Rural Subdivision and Development).

Conversion of agricultural operations to rural residential development can also lead to a loss of flood irrigated meadows which are important to many wildlife species. The establishment of water wells for domestic use can deplete groundwater and negatively impact springs and wetlands.

Invasive Plant Species - High
Invasive plants impair habitat functions of wetlands and riparian communities in many regions of the Wyoming. Tamarisk (also known as *saltcedar*) and Russian olive are causing the most significant impact on Wyoming's wetland habitats. Although tamarisk and Russian olive provide cover and forage benefiting some species of wildlife, they often dominate native vegetation, adversely affect wetland hydrology, and attract abnormally high densities of predators (see Wyoming Leading Wildlife Challenges – Invasive Species). Other invasive species also impact wetlands including leafy spurge, Dalmatian toadflax, whitetop, Canada thistles, black henbane, and spotted knapweeds.

Water Development Projects – High
The Wyoming Game and Fish Department's Stream/Lake Database includes 666 manmade reservoirs covering a surface area of slightly over 248,000 acres or 388 mi^2 (these figures do not include most livestock impoundments or waters on the Wind River Indian Reservation). At least 30 Wyoming reservoirs exceed 10,000 acre-ft in capacity, and 15 exceed 100,000 acre-ft. Although dams create large deepwater habitats, significant areas of wetlands and riparian habitats are often inundated. The potential for wetland margins to develop around shores of large reservoirs is limited by wave action and unstable water levels, which generally preclude the establishment of wetland vegetation. In addition, large reservoirs stabilize flows and cause several downstream impacts including loss of braided channels, eventual loss of oxbow wetlands, and channel constriction by riparian vegetation. Flood control also allows residential and commercial development to take place within floodplains. Finally, reservoirs trap silt loads, and the clear water that is discharged from dams causes additional channel downcutting and erosion (see Wyoming Leading Wyoming Wildlife Challenges – Disruption of Historic Disturbance Regimes *and* Riparian Habitat Type).

Energy Development and Mining Practices - High
Gas, oil, coal, uranium, coal-bed methane, and wind development are taking place on a landscape scale throughout many regions of Wyoming (see Wyoming Leading Conservation Challenges – Energy Development). Bentonite, trona, and gypsum are also mined on a large scale. Impacts from energy development vary depending on the type of development, location, regulatory requirements, and mitigation efforts.

Vegetation clearing, road construction, noise, and increased human and equipment activity associated with energy development and mining are known to adversely impact several species of wildlife (see Transportation Infrastructure). Ponds and wetlands have been created on some gas fields by discharging oil- and gas-produced water onto the surface in specific locations. Such ponds are often beneficial to wildlife. However in inappropriate locations, they may enhance breeding conditions for mosquitoes and increase spread of West Nile virus, which is detrimental to sage-grouse and several other avian species. New water sources on big game winter ranges can also change animal distribution, potentially resulting in less forage available during winter. Wind turbines sited within or too close to lakes and wetlands can potentially cause waterfowl, waterbirds, and shorebirds to displace from or avoid areas of otherwise suitable habitat. Turbines and associated power lines also increase mortality due to collisions if they are located too near migration corridors, refuges, and feeding and resting sites (WJVSC 2010). Sand and gravel mining operations sited on floodplains have likely produced a net gain of wetlands and open water habitats in Wyoming because it was historically common to convert abandoned or reclaimed gravel quarries into ponds and small lakes with wetland margins. The net effect of this practice has been an increase in pond-type habitats and some loss of riverine, shrubland, and other types of habitats.

Incompatible Agricultural Practices - High
Agricultural operations have created wetlands in conjunction with irrigation projects, livestock watering ponds, and federal cost share programs for wetland restoration in several areas of Wyoming. However, in the absence of adequate financial incentives or alternative conservation options, some agricultural practices adversely affect wetlands. Sediment runoff from tilled fields, heavily grazed pastures, or poorly managed watersheds can decrease the lifespan of ponds and wetlands. Some agrichemical runoff, including fertilizers, pesticides, herbicides, and animal waste, also impairs water quality and is harmful to plant life, and wildlife. Livestock grazing within wetland basins can remove vegetation cover,- and destroy nests of ground-nesting birds. It is important to manage the timing of grazing so nests are not trampled and paths through wetland vegetation are not created, which allows predators to access vulnerable nests, eggs, and young. Most agricultural impacts are minimized or avoided by following appropriate best management practices (Dressing et al. 2003).

Transportation Infrastructure - High
Road improvements can affect wetlands through vegetation removal, alteration of hydrology, and increased human activity including vehicle traffic. Hydrology is affected by drainage ditches, borrow pits, gravel quarries, culvert installation, and instances of construction of the original roadbed blocking surface drainage. Additional impacts associated with roads include disturbances caused by traffic, which can displace sensitive species from nearby wetlands. Roads also become barriers to less mobile wildlife such as salamanders and turtles, and heavy traffic increases mortality of all wildlife attracted to nearby wetlands.

Management and Maintenance of Existing Wetland Projects - High
It can be a challenge for agencies to obtain ongoing funding needed to maintain wetlands in a productive, properly functioning condition. This is particularly the case at created wetlands where water levels need to be manipulated, dikes maintained, vegetation treated, and the appropriate grazing and erosion control practices administered.

Alternation of Irrigation Delivery Systems - Moderate
Wetlands have become established in many locations by seepage along irrigation canals and lateral ditches, and runoff from irrigated fields. Improvement projects intended to reduce seepage losses, such as installing canal linings or pipes, can potentially eliminate some of these wetlands. On the other hand, more efficient water delivery can increase appropriated water supplies to some wetlands, and may also increase irrigation runoff into others. Ongoing conversions from flood irrigation to center pivot sprinkler systems is adversely impacting wetlands in several regions of Wyoming because this water conservation measure yields substantially less runoff or waste water into watersheds and wetland basins.

Current Wetlands Conservation Initiatives

Wetlands conservation is receiving a great deal of attention in Wyoming. Prominent organizations engaged in these efforts include Ducks Unlimited, US Fish and Wildlife Service's Partners for Fish and Wildlife Program, Intermountain West and Northern Great Plains Joint Ventures, Natural Resource Conservation Service, Conservation Districts, The Nature Conservancy, and regional land trusts.

Ducks Unlimited (DU) is a nonprofit organization focused on wetland and waterfowl conservation. To accomplish its goals, DU frequently works with private landowners to build, restore, and conserve wetlands through conservation easements, fee title acquisitions, management agreements, and technical assistance. Two of DU's efforts that benefit Wyoming are the Platte River Initiative and Rainwater Basin Initiative in DU's Southern Great Plains region and the High Country Wetlands Initiative in DU's Northern and Southern Rockies region. DU was recently awarded two North American Wetlands Conservation Act (NAWCA) standard U.S. grants to fund wetland and grassland conservation within the Platte River and Rainwater Basin Initiative areas, including the lower North Platte River in Wyoming.

The mission of the Intermountain West Joint Venture (IWJV) is to facilitate the long-term conservation of key avian habitat including planning, funding, and developing habitat projects that benefit all biological components of Intermountain ecosystems. The IWJV Management Board reviews and ranks various habitat protection, restoration and enhancement projects for funding through NAWCA and other programs. The IWJV Implementation Plan identifies priority bird species and lists statewide conservation goals for priority habitats such as total acreage protected, maintained, enhanced, or restored (Intermountain West Joint Venture 2005). The Northern Great Plains Joint Venture (NGPJV), a similar initiative, has been engaged primarily in planning efforts and is a cooperator in the development of a NE Wyoming regional component of the Wyoming Wetlands Conservation Strategy. The NGPJV administrative boundary includes seven counties in NE Wyoming: Campbell, Converse, Crook, Johnson, Niobrara, Sheridan, and Weston (Pool and Austin 2006).

The U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program promotes on-the-ground wetland restoration projects on private lands. Focal areas targeted for wetland projects include the Laramie Plains, Goshen Hole, Wind River Indian Reservation, Great Divide Basin, and the New Fork Pothole Region of the Upper Green River Basin. Statewide goals are to: restore 15,000 acres of wetlands; restore or enhance 5 million acres of upland habitat; restore 1,000 miles of riparian habitat; and restore 1,000 miles of instream habitat. Much of the wetland work accomplished to date has been in the upper Wind River Basin and the Goshen Hole wetland complexes.

The Natural Resource Conservation Service (NRCS) and Farm Service Agency administer four Farm Bill programs that provide funding and technical assistance for the conservation and restoration of wetlands, watersheds, and wildlife habitat on private lands. They include the Wetland Reserve Program (WRP), Environmental Quality Incentives Program (EQIP), Wildlife Habitat Incentives Program (WHIP), and Grassland Reserve Program (GRP).

The Wyoming Game and Fish Department (WGFD) has worked on several small projects to provide nesting and summer habitat for a population of trumpeter swans established in the Upper Green River basin through a captive breeding program. A State Wildlife Grant was obtained in 2003 to identify several trumpeter swan projects on private lands. Plans were developed for over 20 projects; 4 have been completed to date.

Local Conservation Districts in Wyoming have been involved in numerous projects to improve wetlands habitat through land management and restoration techniques on private lands. Conservation easements held by Wyoming land trusts, including the Jackson Hole Land Trust, Green River Valley Land Trust, and Wyoming Stock Growers Agricultural Land Trust, also help to protect wetlands from potentially detrimental land uses and development.

The Wyoming Wetlands Conservation Strategy (WWCS) was developed through a collaboration between several agencies and organizations represented on the Wyoming Joint Ventures Steering Committee (WJVSC) in 2010 (WJVSC 2010). The WWCS presents a thorough review and analysis of important wetland and riparian habitats, major threats, conservation goals and strategies, regulatory framework, partnership opportunities, and links to resources that can assist efforts to conserve and enhance wetlands and riparian habitats in Wyoming. Another purpose of the WWCS is to provide a technical foundation for the wetlands habitat section of the revised 2010 State Wildlife Action Plan.

Conservation focus areas identified in the WWCS were based upon results of two studies. The first was a semi-qualitative assessment completed by the WGFD and U.S. Fish and Wildlife Service (USFWS) for inclusion in the 1995 Statewide Comprehensive Outdoor Recreation Plan (WGFD 1995). The 1995 study identified 49 wetland complexes including 8 priority complexes throughout Wyoming. A more recent geospatial analysis by The Nature Conservancy (TNC) has identified 222 wetland complexes (Copeland et al. 2010). The Copeland et al. study also produced several sets of condition indices that can be applied in a variety of ways to prioritize wetlands.

For purposes of the WWCS, 28 priority complexes were identified based on highest species diversity scores (Copeland et al. 2010), and the WJVSC selected three additional complexes based on unique ecological considerations (Appendix A, Table 21). From the 31 priority wetland complexes, the WJVSC identified 9 primary focus areas (wetland complexes) in which partners will be encouraged to plan and implement projects over the next 10-year horizon (shown as green-shaded rows in Appendix A, Table 21, and as dark blue shaded complexes in Figure 11). The criteria for selecting 6 focus areas included a normalized Shannon diversity score of at least 93 (on a scale of 100), combined with a *high* project opportunity rating. The 3 complexes with unique ecological values were added to these. All 8 priority complexes identified in the 1995 study are included in the 9 focus areas identified by the WJVSC.

A thorough review of the regulatory and statutory framework influencing wetland conservation, mitigation, and restoration in Wyoming is provided in the WWCS (WJVSC 2010).

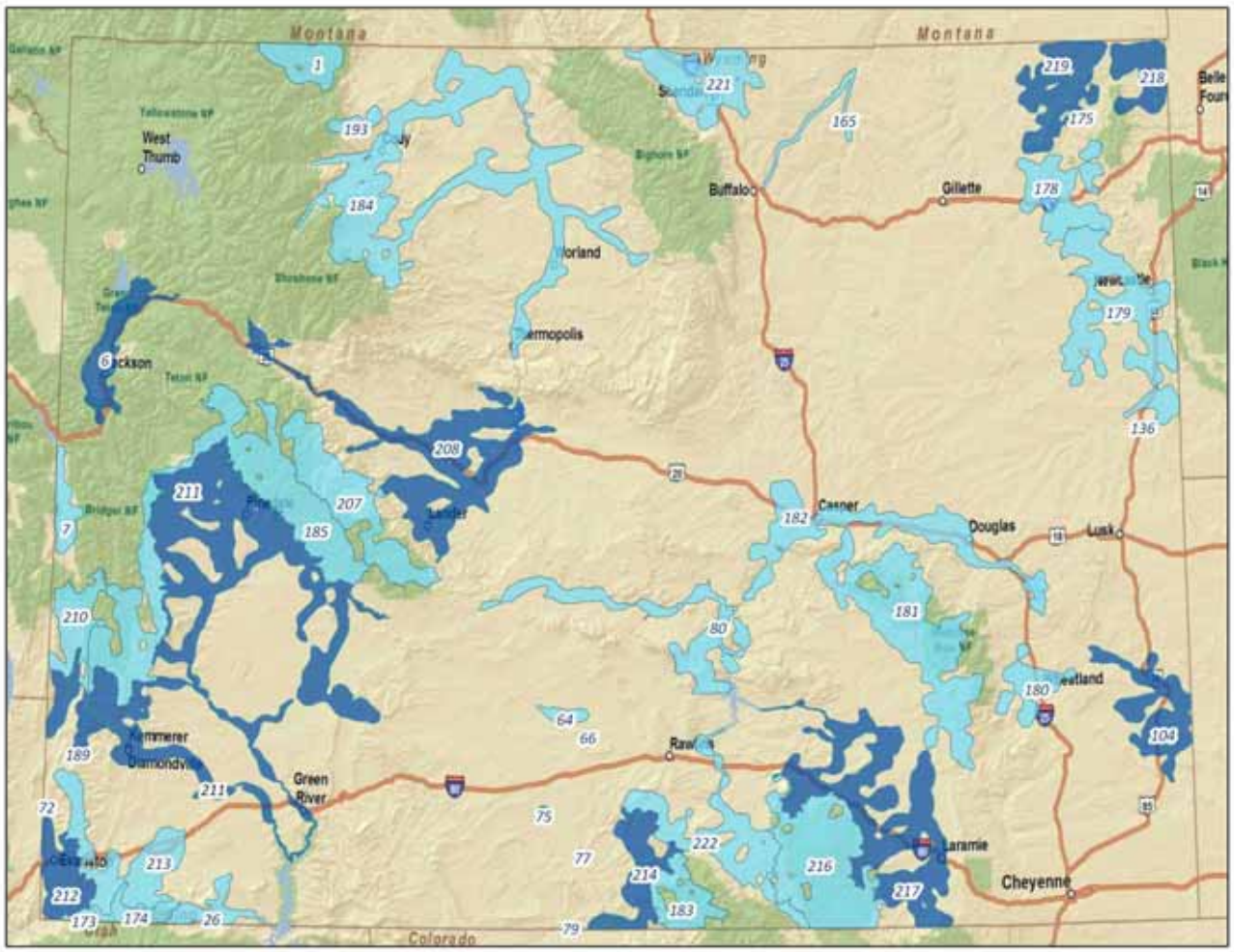

Figure 11. Thirty-one priority wetland complexes including nine primary focus areas (dark blue) identified by the Wyoming Joint Ventures Steering Committee. The nine primary focus areas are: Bear River, Goshen Hole, Laramie Plains, Little Snake R./Muddy Cr., NE Wyoming (Little Missouri R./Belle Fourche R./Beaver Cr.), Red Desert/Great Divide Basin, Snake River Valley (Jackson), Upper Green River, and Wind River Basin. Based on data provided by Copeland et al. (2010).

Recommended Wetlands Conservation Actions

A more comprehensive description of wetland conservation recommendations can be found in the WWCS (WJVSC 2010).

Secure additional human resources to plan and implement wetland conservation projects.
The WJVSC has identified the limited availability of agency specialists and other human resources as the leading constraint to making full use of available wetlands conservation programs and funding sources in Wyoming. Wetlands conservation projects can be complex and time consuming and frequently call for persistent attention to ensure all requirements are met. Specific knowledge is needed to identify and develop project proposals, assemble grant applications, complete certified engineering designs, conduct land surveys, secure permits and clearances including water rights, and administer projects. Currently, a lack of dedicated personnel with specific expertise in these areas is a significant limitation to the level of wetlands conservation work in Wyoming, despite available funding.

The WWCS (WJVSC 2010) has recommended creation of statewide or regional wetlands coordinator positions to connect conservation organizations with partners and available funding sources and to help develop project proposals in order to increase the amount of wetland conservation work done in Wyoming. Funding to support such positions could be assembled from several sources, and the positions could be designed to advance the work of multiple wetland conservation groups operating within the state. The current state hiring freeze may limit the ability to house these positions within the WGFD.

Enhance use of existing wetland conservation and funding programs.
Wetland conservation programs and funding sources available in Wyoming are not being used to their full potential. For example, at the end of the 2009 federal fiscal year, the Wyoming Natural Resources Conservation Service (NRCS) turned back approximately $3.24 million of unobligated U.S. Department of Agriculture Wetland Reserve Program funds from Wyoming's $5.24 million total allocation. Because future state allocations are partially based on previous years' program use, this could negatively impact the amount of funding made available to Wyoming for this program in the future. Capitalizing on existing wetland conservation programs may become increasingly important in an era of budget reductions where the establishment of new funding sources may be limited.

Methods to enhance the use of existing funding sources include increasing coordination and partnerships to leverage dollars in order to meet matching fund requirements for WWNRT, Joint Ventures, and other grant programs. The establishment of watershed/basin scale projects can also improve the ability to access large funding sources such as NAWCA. Organizing projects on a larger watershed or wetlands complex scale can help create lists of eligible shovel-ready projects which are often necessary to take full advantage of funding sources that operate on annual granting cycles. Additionally, increasing dialogue with the Wyoming State Engineers Office, Board of Control, and the NRCS could help identify opportunities to streamline permitting processes and better align permitting with grant funding cycles.

The capability to fully utilize existing wetlands programs is often dependent on availability of personnel to deliver projects. Efforts to fully fund the Wyoming Wildlife and Natural Resource Trust Fund at $200 million should continue in order to meet the state match requirement for most federal conservation programs.

In addition to pursuing voluntary conservation agreements, wetlands protection efforts should include monitoring compliance with state and federal wetlands protection laws, notifying appropriate regulatory authorities of potential violations, and working collaboratively with landowners, industry, and agencies to recommend avoidance or effective mitigation for projects that may potentially impact wetlands.

Rely on the WWCS statewide prioritized list of high wildlife value wetlands to focus conservation efforts.
The 31 priority wetland complexes and 9 focus areas that have been identified in the WWCS (WJVSC 2010) should be used to guide wetlands enhancement and conservation actions in Wyoming (Appendix A, Table 21). However, projects for

which there is high interest, partnership potential, and funding availability should not be excluded even if they are not located within one of the priority or focus areas. The WJVSC recently produced a report highlighting the nine focus areas and strategies for conservation in each area. This report could help catalyze wetlands projects in the nine focus areas, and help make the case for grant funding.

Distribute a statewide list of potential wetlands projects and restoration sites to agencies, industry, and nongovernmental organizations involved with wetlands conservation and mitigation.

Appendix B of the WWCS (WJVSC 2010) contains a statewide list of potential wetlands and riparian conservation and restoration projects and project concepts. The list will be made available to government agencies, industry, and conservation organizations administering wetlands programs. As well, efforts will be made to increase awareness and training for entities required to mitigate wetlands as part of the construction permitting process. The WWCS contains links to several credible sources in the wetlands design arts and other resources that can assist with planning and implementing wetlands projects throughout the state. Advancing wetland creation and enhancement through the Wyoming Wetlands Act [W.S. §§ 35-11-308 through 35-11-311] mitigation banks will also be investigated (WJVSC 2010).

Increase availability and dependability of water supplies.

Water supplies can be a limiting factor for creating and maintaining wetlands in several areas of Wyoming. Excellent water quality at all nesting and foraging sites is critical. Water level management is also vital to ensure that emergent vegetation used for nesting and cover has adequate water for growth, and that nests are neither flooded nor left high and dry, both of which contribute to nest failure. Recurring drought and increasing agricultural, industrial, and residential demands for water will likely be a part of Wyoming's future. New options should be explored to provide adequate water for wetlands creation and enhancement projects. Possibilities include investigating new and existing funding sources to enhance water delivery, developing groundwater wells to augment surface water supplies into constructed wetlands, and leasing or acquiring property on which water rights can be managed to enhance wildlife habitats. Other options to obtain water should be explored with the Wyoming State Engineers Office. Additionally, numerous opportunities exist throughout Wyoming to establish small palustrine wetlands by reintroducing beaver into suitable vacant habitat.

Continue to support wetland-based recreational opportunities.

Access to wetlands outdoor recreation and educational opportunities is important to maintain public support for wetlands conservation. Federal Duck Stamps, required for migratory waterfowl hunting, have generated more than $750 million which has been used to help purchase or lease over 5.3 million acres of waterfowl habitat in the U.S. (USFWS website). Nonprofit organizations founded by outdoor recreationists have contributed even more to wetlands conservation. For example, Ducks Unlimited has directly conserved 12,248,956 acres of wetlands in North America and influenced an additional 47,656,894 through policy measures (DU website). In addition to hunting, wetlands sustain other outdoor activities such as fishing, wildlife viewing, and nature photography. In 2006, close to 35 million people visited national wildlife refuges in the lower 48 states, generating almost $1.7 billion of sales in regional economies (Carver and Caudill 2007). About 82 % of these expenditures were generated by activities other than hunting and fishing. While encouraging this interest and support, special attention should be given to minimizing human disturbance, especially during the breeding season, because many species are extremely sensitive and, if disturbed, will abandon nests, eggs, or young.

Create Wyoming wetlands conservation website.

The WJVSC recommends developing and hosting a statewide website to increase awareness about wetlands in order to foster wetland conservation throughout Wyoming. The website would identify wetland habitat protection, mitigation, and enhancement opportunities in priority regions of the state. The overriding purpose is to facilitate cooperation and collaboration among wetlands conservation groups operating in Wyoming and to connect project proponents with available

funding and other resources to accomplish additional projects. Projects lists will also present opportunities for companies, individuals, and agencies to fulfill mitigation obligations, as required under various federal laws and programs. Finally, the website would contain basic information about the ecological values of wetlands, laws and programs pertaining to wetland conservation in Wyoming, as well as mitigation guidelines and management practices. The website could also host a downloadable version of the aforementioned focus areas report.

Wetlands Monitoring Activities

Continue monitoring wetlands SGCN in order to detect population trends or changes in distribution that may reflect habitat problems. This information should be used to guide future monitoring and research, as well as habitat conservation needs.

Continue to monitor the distribution and condition of wetlands through remote sensing and ground surveys.
Remote sensing is a useful tool for tracking the size and distribution of wetlands and changes in their hydrologic condition. Such information would be useful in determining the cumulative impacts through time of activities and events such as drought, energy development, rural subdivision, agricultural conversions, and wetlands creation projects. Special attention should be given to monitoring these parameters within the 31 priority wetland complexes and 9 primary focus areas identified by WJVSC (2010) (Figure 11). This technique will require the further development of monitoring protocols. In addition, periodic ground surveys will be needed to monitor the physical, chemical, and biological condition of wetlands throughout Wyoming, and to identify those that exist in an impaired condition.

Track wetlands conservation, mitigation, and restoration projects on the 31 priority wetland complexes and 9 primary focus areas identified by WJVSC (2010) to assess their success and guide future actions.
Monitoring records should include acreages under various conservation strategies, conservation mechanism (easement, fee title acquisition, management agreement, wetland creation or enhancement project, etc.,), issues addressed (development restrictions, grazing plan, water or watershed management, habitat creation, etc.,) and partners involved. The use of state, federal, and private funds and in-kind match should also be tracked.

In cooperation with research entities and the Wyoming State Climatologist, monitor the effects of climate change including extended drought or wet cycles.

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Appendix A

The Nature Conservancy Wetlands Assessment Study

The Wyoming Wetlands Conservation Strategy (WJVSC 2010) identifies focus areas for wetlands conservation based upon two wetland complex prioritization efforts. The first assessment was completed by the WGFD and U.S. Fish and Wildlife Service (USFWS) for inclusion in the 1995 Statewide Comprehensive Outdoor Recreation Plan (SCORP). The SCORP prioritization relied upon qualitative ranking criteria adapted from National Wetlands Priority Conservation Plan (NWPCP). Priority rankings were based on the following NWPCP criteria and weights: wetland functions and values (33%), historic trends of wetland losses (33%), and relative threat of future loss or degradation (33%).

The Nature Conservancy (Copeland et al. 2010) led a study to define 222 wetland complexes through Wyoming and examine the landscape scale characteristics and conditions of each. Descriptors included wetland density (average number of wetlands per hectare within each complex perimeter), wetland

condition or integrity (based on proximity of land uses or activities known to impair wetland functions, Figure 12), wildlife species richness (number of SGCN present), species diversity (Shannon index based on SGCN, Figure 13), number of rare species (based on state and internationally-recognized species), and future vulnerability (based on models projecting future residential and oil and gas development and climatic conditions, Figure 14). Identification of priority complexes was based on SGCN diversity. Primary focus areas included those priority complexes with a normalized diversity score of at least 93 and high project potential. Three additional complexes identified by the WJVSC were included in the list of nine focus areas based on unique ecological considerations and/or high project interest.

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Table 21. Wyoming Wetlands Conservation Strategy (WJVSC 2010) 31 priority wetland complexes and 9 focus areas. *

									Normalized Scores = [(raw score) ÷ (max score)] X 100				
	TNC ID No.	WGFD ID No.	Shannon Diversity Rank	WGFD Rank	Complex Name	Complex Area (mi²)	Wetland Density (No/mi²)	Wetland Area (acres)	No. SGCN	Shannon Diversity	Rare Species Presence	Integrity	Vulnerability	Project Opportunity
	1	49	11		Beartooth Plateau	255.9	10.7	3,433	27	86	83	81	22	Unk.
	6	41	3	6,7	Snake R.Valley – Jackson	239.6	8.0	8,554	32	96	67	70	44	High
	7	39	7	2	Salt River	155.2	10.8	10,064	27	91	67	70	36	Medium
	26	36	11		Henrys Fork	168.4	6.7	10,377	28	86	67	75	31	Low
**	64,66	28,29			Red Desert/Great Divide Basin **	59.9	8.0	2,997	8	59	0	85	34	Medium
	72,189 212	38	4	3	Bear River (3 segments)	587.6	8.0	40,060	32	94	67	71	24	High
**	75,77, 79, 214	27			Little Snake R./ Muddy Creek **	429.5	6.0	11,654	14	69	17	75	62	High
	80	11	9		Pathfinder – Sweetwater River	573.9	6.0	12,527	33	89	67	79	19	Medium
	104	1,2,3,6	4	4	Goshen Hole	491.0	5.7	7,149	32	94	50	56	29	High
	136	17	10		Old Woman Creek	2.0	2.5	5	21	88	33	72	0	Low
	165	21	7		Clear Creek – Powder River	92.2	0.8	109	30	91	33	66	56	Medium
	173	37	12		Sulphur Creek	26.3	16.7	1,012	25	85	67	63	13	Medium
	174	36	9		Wasatch Front	135.6	14.7	2,473	29	89	83	77	10	Unk.
**	175, 218-19	25			NE WY (L Missouri/ Belle F/Beaver Cr)**	877.9	5.0	5,371	23	83	33	76	42	High
	178	25	9		Inyan Kara	477.3	4.6	3,497	27	89	33	71	21	Medium
	179	25	10		Beaver Cr. – Upton	933.5	4.5	4,878	27	88	33	68	16	High

Table 21. (continued)

									Normalized Scores = [(raw score) ÷ (max score)] X 100				
TNC ID No.	WGFD ID No.	Shannon Diversity Rank	WGFD Rank	Complex Name	Complex Area (mi²)	Wetland Density (No/mi²)	Wetland Area (acres)	No. SGCN	Shannon Diversity	Rare Species Presence	Integrity	Vulnerability	Project Opportunity
180	4 & 5	6		Wheatland	236.6	5.6	4,819	30	92	50	52	8	Medium
181	N/A	9		Laramie Range	1,214.4	5.4	8,295	32	89	50	78	4	Low
182	8	3	8	Middle N. Platte R.	753.3	5.1	9,802	34	96	67	57	75	Low
184	44	1		Bighorn River/ Greybull River	1,859.4	5.7	29,825	41	100	100	53	90	Medium
185	N/A	10		West Wind R. Range	1,603.9	11.3	29,782	36	88	83	86	24	Low
193	Out	10		Skull Creek/Pat O'Hara Creek	80.2	5.4	147	30	88	67	64	37	Unk
207	Out	12		East Wind R. Range	709.7	8.1	9,783	35	85	67	93	6	Low
208	43	3		Wind River Basin	1,246.8	7.1	37,706	40	96	100	65	97	High
210	38	10		Smiths Fork/ Lower Bear River	317.7	5.7	4,860	32	88	67	82	10	High
211	34	2		Green River Basin	2,594.6	8.2	174,193	36	97	100	69	81	High
213	35	4		Blacks Fork/Little Muddy Creek	590.2	8.3	38,006	32	94	83	70	7	Unk.
216	Out	13		Snowy Range	1,021.1	10.1	22,461	30	81	67	73	13	Low
217	15	5	5	Laramie Plains	1,401.9	6.4	83,094	32	93	67	70	34	High
221	22	8		Tongue R. – Sheridan	564.6	4.8	3,625	29	90	33	54	81	High
222	26	6		Upper N. Platte R.	655.6	7.0	27,969	32	92	50	70	8	High

* Data from Copeland et al. (2010) and WGFD (1995, 2008). Areas highlighted in green are priority wetland complexes identified by the Wyoming Joint Ventures Steering Committee (WJVSC). Except as noted below, these areas have TNC diversity ranks in the top 5 *and* high project potential.

** Additional wetland complexes were included at the discretion of the WJVSC because they have unique ecological values that are not reflected by their TNC diversity scores *and* exceptionally high potential for conservation projects.

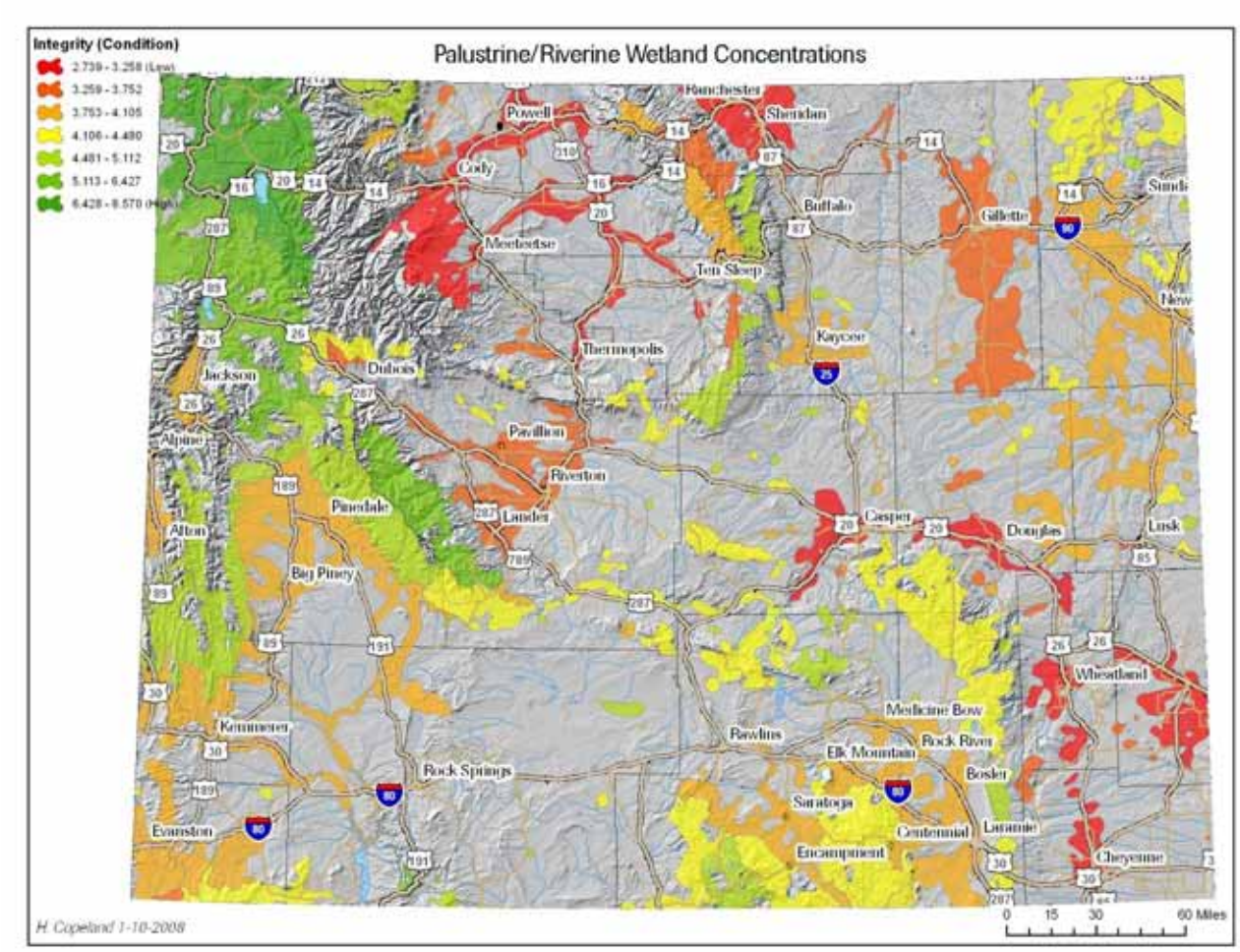

Figure 12. Integrity scores of Wyoming wetland complexes (Copeland et al. 2010).

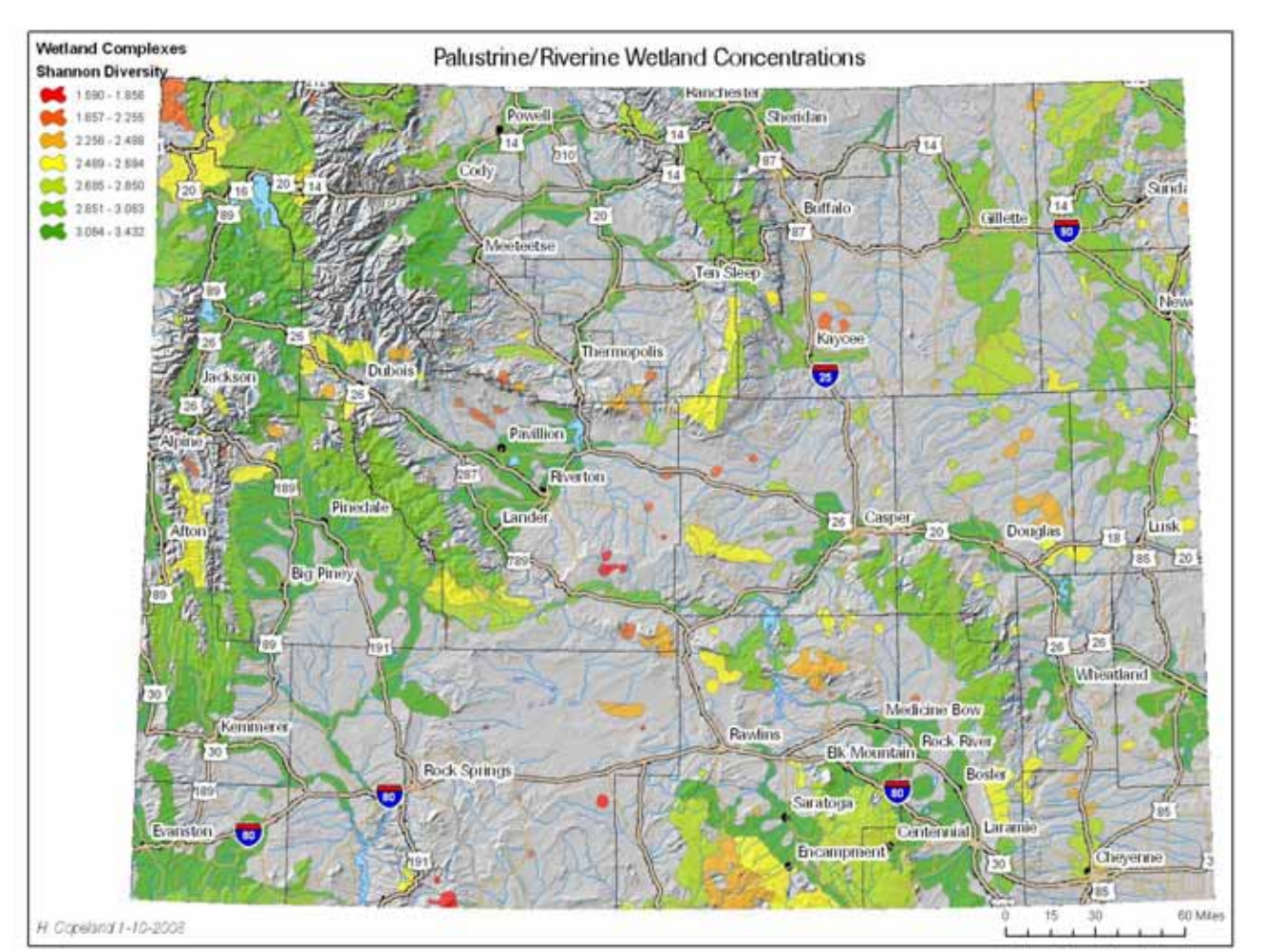

Figure 13. Species diversity (Shannon Diversity Index) of Wyoming wetland complexes based on wetland-associated SGCN (Copeland et al. 2010).

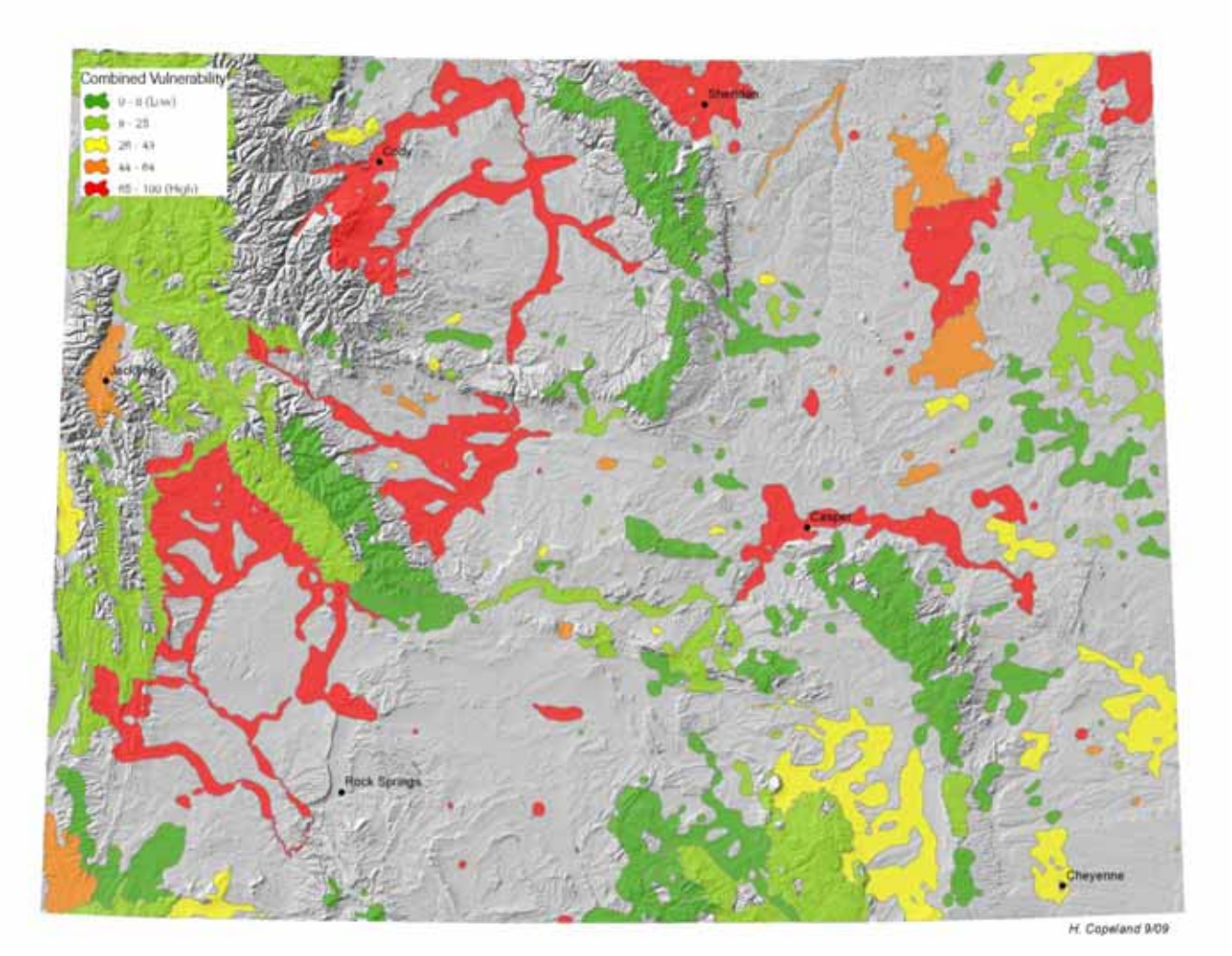

Figure 14. Vulnerability of Wyoming wetland complexes to ongoing and future development (Copeland et al. 2010).

Xeric and Lower Montane Forest

Photo courtesy of WGFD

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Habitat Description

Xeric and lower montane forests exist in a variety of areas in the western United States and Wyoming ranging from lower elevations to high elevations (Arno 1980, Bock et al. 1993, Green and Conner 1989, Idaho Partners In Flight 2000, Knight 1994, NatureServe 2009). NatureServe (2009) lists eight ecological systems in Wyoming (Table 22). Within the three ponderosa pine systems they list over 50 associations, and within the five limber pine/juniper systems they list over 40 associations in the western United States. Historically, before about 1890, frequent fires often confined these conifer woodlands to rocky sites or the leeward sides of slopes. Typically, this fire pattern created open savannahs and patchy, park-like woodlands. Present conditions have changed the appearance and distribution of these ecosystems across the landscape. Mature forest landscapes are more fragmented and denser with younger trees dominating stands. At many sites, tree densities and fuel loads would support high intensity crown fires rather than the low intensity understory fires typically associated with these sites. In some areas stands are expanding into adjacent grassland and shrublands. Common uses of these forests include wildlife habitat, livestock grazing, commercial timber harvesting and firewood gathering, recreation, residential development, and mineral development. The lower elevation and openness of this habitat type often leads to more intensive human activity.

Juniper

Junipers are conifers with leaves of overlapping scales and seed-bearing cones that resemble small berries. Juniper sometimes forms pure stands, but is often mixed with other gymnosperms (Elias 1980). It commonly grows on bluffs, ridges, cliffs, and dry, rocky hillsides, and it does best on slightly alkaline/calcium-based soils (Elias, 1980). Only 2.2% of the land area in Wyoming supports juniper woodlands. Juniper can be found from 4,000 to 10,000 feet in elevation, but it generally occurs below 6,000 feet (Nicholoff 2003). In these areas, annual precipitation averages 8 to 20 inches (West et al. 1975), and typically comes in the form of snow, spring rain, and infrequent summer thunderstorms.

Rocky Mountain and Utah juniper are widespread, ranging from British Columbia to Arizona and New Mexico, and from Nevada and Washington east to the Dakotas and Nebraska. They are the most common juniper species in Wyoming. Utah juniper is found along escarpments in western Wyoming and in arid basins throughout the state. Rocky Mountain juniper is found in eastern Wyoming along ravines that receive greater summer precipitation and is often found in association with ponderosa pine, mountain-mahogany, or limber pine.

Today, in Wyoming, tree densities in juniper communities vary from open savannahs to closed canopies. Prior to European settlement, juniper woodlands ranged from savannah-like conditions to more closed canopy stands on rocky ridges and rocky low sagebrush flats. Fire return intervals and severities were mixed in juniper communities and were very site specific. Low intensity fires may have occurred every few decades, while high intensity crown fires occurred less frequently, often in terms of centuries (Baker and Shinneman 2004). This mix of fire severity created a mosaic of different tree densities and associated grass and shrub species.

Since 1860, the distribution of juniper woodlands has increased 125–625% across the West (Miller et al. 2008), although juniper expansion has not been as dramatic in most areas of Wyoming as it has been in other areas of the West (Nicholoff 2003). Juniper expansion has most frequently occurred northward, as well as downward in elevation into grasslands and shrublands with deeper soils, more fine fuels, and previously higher fire frequencies (Gillihan 2006). The cause of this expansion is debated. Some researchers contend that expansion is part of a natural cycle in response to changes in climate, citing documented evidence that juniper has been on

this landscape since 10,000 years before present (BP) (Jackson, et al. 2005). Since this period, the range of juniper has probably varied in response to the documented climatic variations such as the Medieval Climate Anomaly and the Little Ice Age. In addition to climate fluctuations, it is widely agreed that in some areas the recent expansion of juniper has been aided by a combination of fire suppression and overgrazing.

Unlike in the southwestern United States, mature piñon (or pinyon) pine is uncommon in juniper woodlands in Wyoming. Exceptions can be found in southwestern Wyoming near Flaming Gorge Reservoir and in the foothills of the Uinta Mountains. Shrub species associated with juniper woodlands include big sagebrush, black sagebrush, true and curl-leaf mountain-mahogany, rabbitbrush, antelope bitterbrush, yucca, and skunkbush sumac (Knight 1994).

Juniper expansion can alter the local plant communities by reducing the abundance of grasses, forbs, and shrubs through competition for water, light, and nutrients, as well as by producing plant-growth inhibiting chemicals. Dense stands of juniper can also change the hydrology of a site by increasing erosion. The reduction of the herbaceous understory increases water runoff and decreases water infiltration. This reduction in understory plants creates an extended period of self-perpetuating conditions favorable for juniper expansion by reducing the amount of fuel available for fire. Thinning juniper and increasing shrubs and herbaceous cover may create a more historic fire return interval by improving fuel availability.

Juniper wood is resistant to decay, is durable and clean-burning, and it is often harvested for fence posts, poles, firewood, and furniture making. In Wyoming, approximately 572,000 acres (231,000 ha) of juniper habitat are in public ownership; the remaining 282,000 acres (114,000 ha) are privately owned (Thompson et al. 2005).

Limber Pine

Limber pine comprises about 4% of Wyoming forested lands (Wyoming State Forestry Division 2009). Limber pine is a generalist and pioneer species, and it is cold- and drought-tolerant, allowing it to grow under a wide variety of environmental and physiological circumstances (Schoettle 2004). It grows across the widest elevational range of any conifer in the Rocky Mountains, ranging from approximately 5,250 feet to almost 11,000 feet (Schoettle and Rochelle 2000). At low elevations it often occurs with ponderosa pine, juniper, and Douglas fir, and at treeline it is frequently located in association with whitebark pine. Limber pine has been documented as having moved both upslope and downslope throughout the Holocene (approximately 11,500 years BP to present day), driven by factors such as drought, changing climate, and management techniques (Means 2010).

In some circumstances, changing fire regimes combined with low competitiveness with other species, poor regeneration due to blister rust, and spreading infestations of mountain pine beetle are altering distribution and lowering survival for limber pine. Where many of these woodlands serve as climax communities, limber pine can reach ages of up to 1,500 to 2,000 years (Tomback 2009). It often has irregular or multi-stem growth formation on harsh exposed sites and may even have Krummholz formation at higher elevations, rarely reaching over 50 feet in height. Typically limber pine has been restricted to rocky soils and ridges because the seedlings do not compete well with other species (Knight 1994). Choke cherry, ground juniper, king spike fescue, mountain big sagebrush, Oregon-grape, and western snowberry are commonly found with limber pine (Knight 1994). Although limber pine has received little attention, it fills a similar ecological role to whitebark and piñon pine. As a pioneer species, it regenerates well after fire or canopy-opening disturbances. It acts as a nurse tree, facilitating the establishment of later successional species at both low and high elevations (Baumeister and Callaway 2006, Rebertus et al. 1991, and Tomback 2009).

Ponderosa Pine

Ponderosa pine can grow to over 130 feet tall and occurs on a wide variety of soils, usually in

open areas because this species is intolerant of shade. Trees can grow in pure stands, especially at lower elevations where they are subject to frequent forest fires. Ponderosa pine and limber pine are commonly found in Wyoming foothills and on escarpments in warmer areas with higher summer precipitation. Areas with notable concentrations of ponderosa pine include the Black Hills, at lower elevations in the Bighorn Mountains, on the east slope of the Laramie Mountain range, and in a few localities around the Medicine Bow, Split Rock, and Seminoe Mountains (Knight 1994). Associated tree species in the Black Hills include the southernmost outliers of white spruce and paper birch in the U.S. and in the more northern parts of the Black Hills there is a significant component of bur oak and green ash. Aspen is also present but typically not in pure stands. Other tree species associated with ponderosa pine in other parts of the state include Douglas fir, limber pine, lodgepole pine and Rocky Mountain juniper. Other woody and herbaceous plant species frequently found with ponderosa pine include skunkbush sumac, sideoats grama, and little bluestem (Knight 1994).

Ponderosa pine is a fire adapted tree. Adaptations to survive surface fires include open crowns; self-pruning branches; thick, insulative, relatively inflammable bark; thick bud scales; tight needle bunches that enclose and protect meristems, then open into a loose arrangement that does not favor combustion; high foliar moisture; and a deep rooting habit (Howard 2003). Where fires are common, ponderosa pine often exists in savannah-like landscapes. Mean Fire Historic Interval (MFI) varies between ponderosa pine sites. Prior to the 1900s, ponderosa pine was perpetuated by surface fires that recurred every 5 to 30 years. (Howard 2003). Unlike in the southwestern U.S., ponderosa pine in Wyoming has a historical record of a mixed severity fire regime with crown fire being a component (Hunter et al. 2007) as well as low severity surface fires.

Pine leaves can be toxic to cattle, and trees reduce the rate of herbaceous forage production in the understory (Knight 1994).

Ponderosa pine is an important tree species for the forest industry in Wyoming. Sixty-six percent of the saw log harvest was composed of ponderosa pine in 2000 (Wyoming State Forestry Division 2009). Equally significantly, 73% of those materials came from privately owned forests (Wyoming Division of Forestry 2009). In particular, private lands in the northeast corner of the State are producing 78% of the harvest volume (The Conservation Fund 2009).

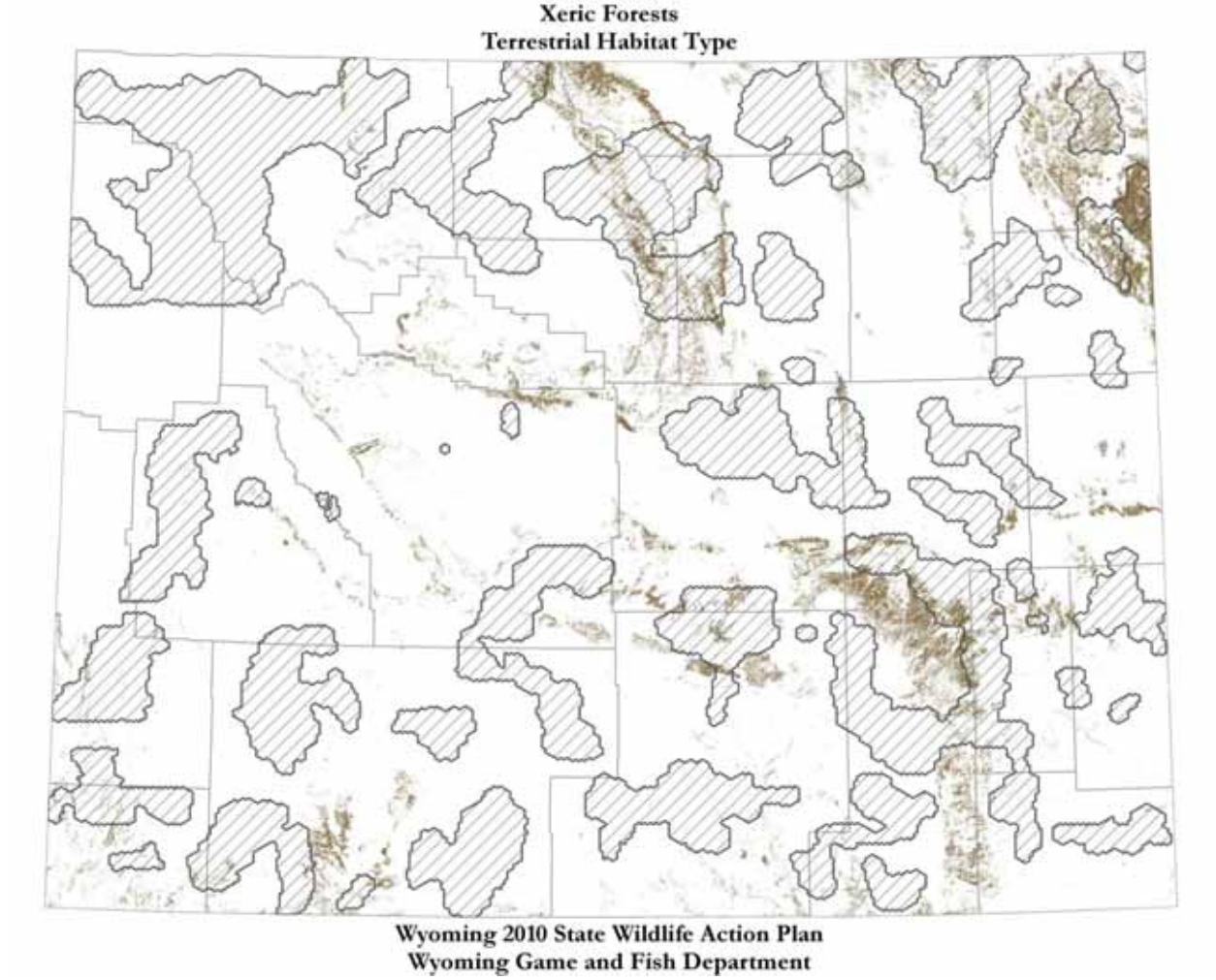

FIGURE 15. Wyoming Xeric and Lower Montane Forests and SWAP SGCN Priority Areas (cross-hatched areas)

TABLE 22. Wyoming Xeric and Lower Montane Forests NatureServe Ecological Systems[1]

1. Colorado Plateau Pinyon-Juniper Woodland
2. Northern Rocky Mountain Foothill Conifer Wooded Steppe
3. Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
4. Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna
5. Rocky Mountain Foothill Limber Pine-Juniper Woodland
6. Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland
7. Southern Rocky Mountain Ponderosa Pine Woodland
8. Northern Rocky Mountain Subalpine Woodland and Parkland

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://www.natureserve.org/explorer.

TABLE 23. Wyoming Xeric and Lower Montane Forests Species of Greatest Conservation Need

Birds
Ash-throated Flycatcher
Bushtit
Juniper Titmouse
Lewis's Woodpecker
Merlin
Pygmy Nuthatch
Western Scrub-Jay

Mammals
Big Brown Bat
Canyon Mouse
Cliff Chipmunk
Fringed Myotis
Long-eared Myotis
Long-legged Myotis
Little Brown Myotis
Northern Myotis
Pallid Bat
Piñon Mouse
Silky Pocket Mouse
Spotted Bat
Townsend's Big-eared Bat
Western Small-footed Myotis
Yellow-pine Chipmunk

Reptiles
Black Hills Red-bellied Snake
Northern Tree Lizard
Pale Milksnake
Smooth Greensnake

Xeric and Lower Montane Forests Wildlife

Juniper woodlands often have a higher abundance and diversity of birds than other habitats including big sagebrush, ponderosa pine, and lodgepole pine (Nicholoff 2003). In fact, piñon-juniper woodlands support one of the highest proportions of obligates or semi-obligate bird species (Paulin et al. 1999). Over 100 species of birds have been documented in the juniper woodlands of southwestern Wyoming and approximately 40 species nest there routinely (Nicholoff 2003). Higher bird concentrations in juniper stands are related to their structural diversity which provides numerous sites for perching, singing, and nesting. Most of the juniper obligates favor mature trees (older than 100 years) along with a shrub understory for nesting and foraging. Older trees with dead or dying limbs provide nesting sites for cavity nesters. Species richness is highest in early and mid-succession juniper communities because these provide both food and cover from the junipers as well as from their associated shrubs and grasses. Wildlife food from junipers comes in the form of plentiful berries and diverse insects. Species richness of all wildlife declines once juniper canopies close because there is less variety and quantity of food.

Many species of wildlife also use junipers for thermal cover. The shape of juniper trees is effective at blocking wind and trapping ground heat in winter and providing shade in the summer. Juniper is an important wintering habitat for mule deer and elk, and mule deer, in particular, also browse on juniper.

Sparse juniper and lower elevation limber pine habitats are often utilized by many reptile species. One notable example is the northern sagebrush lizard. Trees are often used as basking sites and thermal refugia. Yellow-bellied racers may also be found in this habitat at lower elevations.

Many ponderosa pine communities occur on south-facing slopes at elevations that lie between big game summer and wintering grounds. Due to these topographic features, ponderosa pine communities can provide quality early-green forage for mule deer. If fall moisture occurs, which is common, these slopes also provide green re-growth. Many of these communities support crucial winter range for mule deer and elk. Ponderosa pine forests also provide habitat for white-tailed deer, black bear, wild turkey, blue and ruff grouse, migratory songbirds, black-backed and American three-toed woodpeckers, olive-sided flycatcher, mountain bluebird, flying squirrels, and red squirrels, as well as various other rodent and squirrel species (Tomback 2009). Ponderosa pine is an important tree species for cavity-nesting birds such as mountain bluebirds,

American kestrel, chickadees, wrens, and a variety of woodpeckers. In Wyoming, ponderosa pine savannas contain over 60% of Wyoming's known merlin nesting sites and a significant but not quantified portion of nesting Lewis's woodpeckers. Abert's squirrel is a ponderosa pine obligate species whose range just barely extends into Wyoming in the southern part of the Snowy Range. Clark's nutcracker is an important distributer of limber pine seeds across the landscape.

In southern Sweetwater County, rock outcrops in proximity to juniper habitats are particularly valuable to several SGCN mammals. The distribution of the cliff chipmunk, canyon mouse, and piñon mouse is restricted to this portion of the state. Important habitat components include high diversity of invertebrates, as well as vegetative seeds and berries. Also, the steep cliffs and canyons that are common in juniper woodlands provide many opportunities for rock and crevice-roosting bats. The structural diversity, shrub understory, and other vegetation in most juniper woodlands provide high insect diversity and important foraging habitat for several species of bats (Hester and Grenier 2005).

Xeric and Lower Montane Forests Habitat Threats

Fire suppression - High
Prior to European settlement, fire was a frequent occurrence in ponderosa, limber pine, and juniper forests and produced savanna-like landscapes. Fire suppression has resulted in range expansions, increased tree densities, buildup of dead downed material, and reduced understory plant species diversity in these woodlands. Increased densities in ponderosa pine stands have led to hotter crown fires occurring more frequently and over larger acreage when compared to historic fire patterns. In the Laramie Range, this has resulted in many ponderosa pine forests changing to grasslands during the last 10–15 years. The loss of old growth has resulted in few snags (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes).

Diseases and insects – High
Bark beetles (*Ips* spp), including mountain pine beetles (*Dendroctonus* ssp.; MPB), are serious pests to ponderosa pine, piñon, and limber pine with regular infestations occurring over centuries. There have been significant outbreaks of MPB in the Black Hills every 11–20 years. MPB tends to most seriously impact second-growth stands that have been undisturbed for many years. However, beetle epidemics combined with environmental conditions such as prolonged drought has resulted in increased pine mortality in many regions (Howard 2003). The spread of MPB has been aided by the general warming climate, by the persistent drought of the early 2000s, as well as by management practices which have excluded fire and reduced tree thinning and harvest.

White pine blister rust (WPBR), an exotic disease, is currently infecting all age classes of limber pine at all elevations (Means 2010). This disease, in conjunction with MPB, will likely reduce the future abundance of this species throughout its range in Wyoming. Greenhouse trials have shown limber pine has infection levels as high as 98–100 % and mortality rates of 75% (Hoff and McDonald 1993). The low resistance of limber pine to WPBR reduces the number of potentially resistant trees. When limber pine stands are lost due to WPBR infections, the limber pine becomes functionally extinct in the local area for hundreds of years until rust-resistant types emerge (Kendall 1997).

Dwarf mistletoe (*Arceuthobium* spp.) is a serious disease for limber pine (Koski et al. 2009) and ponderosa pine, with ponderosa pine infection rates up to 33% in some areas (Howard 2003). Dwarf mistletoe alters tree form, suppresses growth, and reduces volume and the overall wood quality of its host (Epp and Tardif 2004).

Invasive species – High to Moderate

Cheatgrass and other annual grasses such as Japanese brome are invading juniper, limber pine, and ponderosa pine forests. Invasions often originate from disturbed sites at lower elevations. These fire-adapted, nonnative species have the potential to increase the frequency of fire and reduce native grasses and forbs, which supply wildlife forage and support insect diversity (see Wyoming Leading Wildlife Conservation Challenges – Invasive Species).

Varied perceptions on the location and extent of removal and thinning treatments - Moderate

While their ranges have varied over the centuries, juniper and limber pine are believed to have expanded their range in Wyoming within historic times (Jackson et al. 2005). Because their establishment can result in decreased plant diversity and productivity, including reductions in forage for livestock and big game, removal and thinning programs are common. If not adequately considered, the value of this habitat type to obligate species can be unknowingly eliminated or reduced through the inclusion of prescribed treatment projects or the exclusion of fire suppression plans.

Drought and climate change - Moderate

In the Black Hills, some climate change modeling (Rehfeldt 2006) shows that climate has supported ponderosa pine transitioning into a new extramural climate that has not previously existed. If this continues to occur, spruce/paper birch habitat will become a decreasing component of the ecosystem, and ponderosa pine seedling establishment may become more sporadic. Observed lack of seedling and sapling establishment in at least one stand in the Bighorn Basin indicates stress from climatic change; however, some climate change models show a potential for ponderosa pine to expand in this and other areas (Joyce et al. 2001), which will be contingent upon temperature extremes, precipitation conditions, soil suitability, and a host of other factors.

Limber pine position on the lower treeline and foothills in semi-arid climate systems is predicted to be particularly vulnerable to climate change (Means 2010). Vegetation redistribution is likely to be most rapid and obvious at semi-arid ecotones (Allen and Breshears 1998). A multifactor combination of climate stress, dwarf mistletoe, WPBR, and bark beetles have created complex situations in limber pine forests, which has caused high population mortality in many areas (Schoettle 2004, Millar et al. 2007). A major drought event from 1985 to 1995 caused a widespread mortality wave, whereas a subsequent drought event from 1999 to 2004 did not affect as many populations, with healthy regeneration currently occurring in some areas (Miller et al. 2007). However, high potential still exists for an extensive, rapid drought-induced die-off at a sub-continental scale (Breshears et al. 2005, Coop and Schoettle 2009), particularly when trees have the physiological stress of fighting off pathogens, which can divert energy resources from other plant functions or make the plant more sensitive to environmental stresses (Schoettle 2004). Some research predicts that vegetation redistribution resulting from climate change is more likely to be driven by mass mortality as opposed to the establishment of new populations (Allen and Breshears 1998). Some preliminary research indicates that limber pine may be shifting its range downslope in response to changing climatic conditions (Means 2010). It is unknown how juniper species will be affected by climate change, but Rehfeldt (2006) predicted a significant decrease in Utah juniper in Wyoming by the year 2090. Finally, some studies have shown the infilling of sub-alpine coniferous forests at treeline and into alpine landscapes as a result of changing climate conditions (Joyce et al. 2007). (See Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Habitat fragmentation – Moderate

Rural subdivision and development can reduce, degrade, and fragment foothill shrublands habitats (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). Houses, outbuildings, and lawns directly replace native wildlife habitat. Soil disturbance from construction, year-round grazing of horses and other hobby livestock,

and the use of nonnative plants as ornamentals can facilitate the establishment of invasive species (Maestas et al. 2002).

Wildlife commonly abandons or alters use of habitats with greater human and pet activity. Increased energy expenditures in avoiding people or greater use of lower quality habitat can decrease animal health and reproductive capacity. Greater road densities and traffic volume can increase wildlife–vehicle collisions. Predation on wildlife can intensify with greater numbers of domestic dogs and cats, as well as increases in generalist predatory species such as ravens and human-commensal species such as raccoons (U.S. Department of Agriculture 2007).

Fragmentation of land ownership can adversely affect natural resource management in ponderosa pine forest. As large blocks of private land are subdivided, habitat management may become more difficult. There is economy of scale in forest management, and management of small parcels can become economically unfeasible (Wyoming State Division of Forestry 2009). Easements for the use of roads across multiple landowners for habitat improvement projects can be expensive and difficult to obtain. Greater human safety and property loss concerns increase the need for fire suppression.

Off-road recreational vehicle use – Moderate

Vehicle use off established roads can enhance the spread of invasive species—especially spotted knapweed and cheatgrass—damage native vegetation, and destroy nests. Soil disturbance can increase erosion and impact water quality. Wildlife often avoids areas of increased noise and disturbance from outdoor recreational vehicles. These impacts can also lead to conflicts with hunting, wildlife viewing, and other forms of nature-based recreation.

Xeric and Lower Montane Forests Conservation Initiatives

The Wyoming Game and Fish Department, Bureau of Land Management (BLM), and The Nature Conservancy have been involved in thinning projects in the Lander, Platte County, Flaming Gorge, Baggs, Lovell, and Ten Sleep areas through both fire and mechanical means. The size and type of treatments typically vary depending upon the density of the stand, location in relation to other stands, existing understory vegetation, and threat of invasive species, primarily cheatgrass. Treating early and mid-successional stands is cheaper than treating dense, closed stands and often does not require post-treatment seeding. Removing juniper may lead to an invasion of weeds if the understory is missing or in poor condition.

A regional effort has brought together the US Forest Service, BLM, National Park Service, Colorado State University, and the Rocky Mountain Research Station to identify and grow WPBR-resistant limber pine through seed collection and breeding. It is expected that this project will initially take five or six years to develop seedlings for planting.

The Black Hills National Forest, the State of Wyoming, and BLM, along with private landowners, have undertaken aggressive forest health treatments to reduce ponderosa pine stand densities in order to lessen the impact of mountain pine beetle and crown fires. There have also been a number of efforts to reduce ponderosa pine tree densities on the west slope of the Big Horns, primarily on BLM lands. A National Science Foundation grant has been awarded to conduct workshops regarding climate change influence on ponderosa pine expansion in the Bighorn Basin. Other ponderosa pine management projects have been completed in the Ferris, Laramie, and other mountain ranges in the south central part of the state; however, most of this work has been localized.

Wyoming State Forestry Division (2010) has highlighted the need to maintain whitebark and

limber pine stands in the Wyoming Statewide Forest Resource Strategy. The BLM in Wyoming has listed both whitebark and limber pine on their sensitive species list (Bureau of Land Management 2010a).

Recommended Xeric and Lower Montane Forests Conservation Actions

Identify juniper habitat within the state that should be managed for the long-term conservation of juniper obligate species. Breeding populations for four avian and three mammalian SGCN (ash-throated flycatcher, bushtit, juniper titmouse, western scrub-jay, canyon mouse, cliff chipmunk, and piñon mouse) are limited to juniper habitats in a relatively small area in southwestern Wyoming. Resource managers should be informed of the location and value of these habitats so that they are not unknowingly included in prescribed treatment projects or automatically excluded from fire suppression plans without adequate consideration. In these areas, the Wyoming Bird Conservation Plan, Version 2.0. (Nicholoff 2003) should be consulted for appropriate management actions.

Outside of identified juniper obligate conservation areas, habitat management goals should be designed to maintain site ecological function with consideration to the historic climax plant community. The USGS Pinyon and Juniper Field Guide, Circular 1335 (Tausch et al. 2009) contains a good overview of site considerations and habitat treatment options.

Increase coordination among state and federal agencies, private landowners, and conservation groups for developing and implementing habitat management plans. Mixed landownership and associated differences in mandates and management goals increase the need for inter-agency coordination in developing management strategies for xeric and lower montane forests. Coordination should extend to federal and state agencies in Colorado and Utah for juniper due to the peripheral nature of much of this habitat in Wyoming.

Manage ponderosa pine forests to mimic natural disturbance regimes to promote a diverse, fire-adapted forest mosaic. Manage forest stands to improve vigor, age and species diversity; reduce fuel loads and wildfire intensity; and reduce competition between species to avoid future stand conditions that would again lead to landscape-level beetle mortality. Fire is not a precise tool and should not be utilized in stands where there is a significant departure from natural fire regimes. Better results can be obtained in these areas from mechanical treatments that allow managers to determine residual stand complexity and density, species and age selection and retain valued stand components such as snags. In these locations fire is better used as a maintenance tool following other treatments.

Develop methods to advance timber management practices that benefit wildlife on private lands. Ponderosa pine forests comprise a large proportion of forest products despite being a small portion of Wyoming's commercially productive forest lands. These lands also provide critical habitat for many wildlife species. The adoption of wildlife-sensitive timber management practices should be encouraged through:

- Promoting the development and implementation of stewardship plans with participation in cost share programs.
- Increase the amount and accessibility of information and education to private landowners on the best management practices including reaching out to absentee landowners, developing assessment tools for landowners, training landowners on basic data collection techniques and basic forest management, and using local media to reach out to landowners.
- Encourage implementation of Forest Inventory and Analysis (FIA) in Wyoming

to capture information about private forest lands. (See above.)

- Provide financial incentives for management through the use of cost-share programs.
- Develop and implement certification programs for landowners including American Tree Farm System and Stewardship Forest Wyoming (Wyoming State Forestry Division 2010).

Work to mitigate the effects of land fragmentation.

- Encourage landowners to work together, rather than as individual entities, when developing subdivision-level habitat and timber management plans as part of subdivision development.
- Provide incentives to conserve working forest lands including conservation easements. The Forest Legacy Program can be a source of funding for these easements.
- Keep private forestry practices financially viable by developing and maintain a forest products industry infrastructure to provide consistent markets for forest products (Wyoming State Forestry Division 2010).

Habitat management and treatments should be followed by long-term monitoring where appropriate.

Tree removal and thinning can result in unintended consequences such as increases in invasive species. If an increase in weeds or erosion will likely occur after a burn, using mechanical removal may be the best option. To minimize the establishment of invasive species following fires, sterilized soils from intensely burned areas, including brush pile locations, should be inoculated by adding soil from unburned patches, and native seed mixes should be planted. The creation of maps that include data on treatment sites should be a component of post-treatment monitoring protocols. Special attention should be directed toward mechanical removal for problems such as heavy equipment damage to other plants and unseen changes in soil water retention. On large-scale treatment areas there is also a need to monitor the results to the ecological system. Depending on the size of the treatment, funding availability, land manager goals, and regulations, monitoring may range from merely photo points to multiple established transects both within and adjacent to the treatments.

Work with State Forestry to identify forest health conditions of low-elevation (below 8,500 feet) limber pine woodlands within priority wildlife areas to facilitation statewide management strategies.

The BLM is in the process of issuing direction on the *Whitebark and Limber Pine Management Strategies for Wyoming BLM* that includes the silvicultural prescriptions for limber as well as whitebark pine (Bureau of Land Management 2010b).

Work with State Forestry to develop silvicultural prescriptions that can be used to maintain limber pine woodlands on the landscape within priority wildlife habitat areas.

Thin limber pine stands to appropriate stocking levels to improve individual tree and stand vigor and to reduce interspecies competition in order to provide some stand resistance to mountain pine beetle attacks. Where feasible, plant WPBR-resistant limber pine seedlings to increase stand resistance to the disease**.**

Consult wildlife habitat priority areas and best management practices to improve energy development planning and mitigation design.

Energy development mitigation plans should stress avoiding biologically sensitive areas within project sites and directing off-site mitigation funds to nearby high-value wildlife locations. SWAP SGCN priority areas identified in Figure 15 , WGFD Strategic Habitat Plan Crucial areas, and Wyoming Sage-grouse Core Areas can help guide these efforts. The implementation of mitigation measures and/or best management practices detailed within the Wyoming Game and Fish Commission's *Recommendations for*

Development of Oil and Gas Resources within Important Wildlife Habitats (Wyoming Game and Fish Department 2010) and *Recommendations for Wind Energy Development in Crucial and Important Wildlife Habitat* (Wyoming Game and Fish Department 2010) should be encouraged. Mitigation plans should consider the need to reduce fragmentation of important habitats by using practices such as acquiring conservation easements and implementing associated stewardship plans in areas of high biological value.

Xeric and Lower Montane Forests Monitoring Activities

Continue monitoring xeric and lower montane forests SGCN in order to detect population trends or changes in distribution that may reflect habitat problems. This information should be used to guide future monitoring and research.

Monitor the landscape distribution and habitat intactness of xeric and lower montane forests through remote sensing. Remote sensing is useful in tracking the size, distribution, and fragmentation level of this habitat in Wyoming. Information gathered would be helpful in determining the cumulative impacts of activities and events such as energy development, rural subdivision, wildfire, and presence of invasive species. Special attention should be given to monitoring the level and location of these activities in relation to SWAP SGCN priority areas with a high proportion of xeric and lower montane forests habitat type (Figure 15). This technique may require the further development of monitoring protocols and identification of sample sites.

Whenever possible, establish vegetation monitoring transects to determine the vegetation and community responses to habitat treatments. Transects should include photo points, with special notes on invasive plant species.

Monitor the establishment and spread of invasive plant species in cooperation with Weed and Pest Districts and other federal and state agencies.

In cooperation with research entities, monitor the effects of climate change including extended periods of drought or pluvial cycles. Special attention should be given to the effects of climate on outbreaks of insects and disease.

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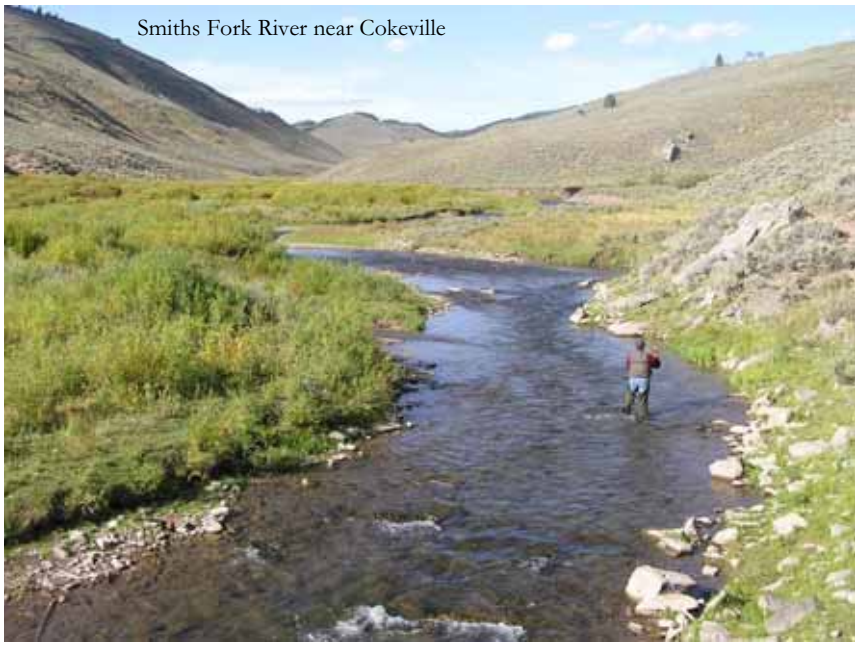
Bear River Basin


Smiths Fork River near Cokeville

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Watershed Description

Three of the nation's major river systems have their headwaters in Wyoming: the Missouri, Colorado, and Columbia Rivers. In addition, the inland Great Basin has Wyoming headwaters from the Bear River. These watersheds provide a natural basis for delineating aquatic conservation areas. Six major watersheds were identified for conservation planning purposes under this State Wildlife Action Plan (SWAP) using hydrographic boundaries and fisheries assemblage and management considerations (Figure 1). These areas are consistent with the aquatic ecosystems identified for freshwater biodiversity conservation worldwide by Abell et al. (2008). The watershed areas are also synonymous with aquatic zoogeographical units and ecological drainage units identified under The Nature Conservancy's (TNC) hierarchical classification framework (Higgins et al. 2005). The watersheds each include one to four sub-regions (4-digit hydrologic unit code [HUC] watersheds). This approach allows the nesting of multiple spatial and temporal scales for planning and prioritizing conservation actions.

The Bear River basin is based on, and exactly corresponds with, the Bear River hydrologic unit (HUC 1601). It includes two 6-digit HUCs: Upper Bear and Weber (Figure 1). Three 8-digit HUCs and twelve 10-digit HUCs occur partly or wholly within this area. These watersheds span about 1,500 square miles in southwestern Wyoming's Lincoln and Uinta counties. Land ownership is predominantly public, but substantial private land (38%) occurs. The public land is managed primarily by the Bureau of Land Management (40%) and U.S. Forest Service (12%).

The 7,500–sq mi Bear River basin includes portions of northeast Utah, southeast Idaho, and southwest Wyoming. In Wyoming, the basin is simply the Bear River and its tributaries. The Bear River originates in Utah's Uinta Mountains and flows north into Wyoming, crosses back into Utah and then to Wyoming again before exiting into Idaho and its ultimate destination—the Great Salt Lake in Utah. Two major tributaries are the Smiths Fork River and the Thomas Fork River. Other direct tributaries include Yellow Creek, Sulphur Creek, Cottonwood Creek, Twin Creek, and Sublette Creek (Figure 1). From an analysis of the 2010 Version 2.0 National Hydrological Database (NHD) at 1:100,000, there are approximately 1,800 miles of streams in the Bear River basin in Wyoming. This equates to a drainage density of about 1.2 stream miles per square mile land area. About 79% of these stream miles are first or second order streams.

The Wyoming Basins terrestrial-based ecoregion, defined originally by Bailey (1995) and adapted by The Nature Conservancy, occupies most of the Great Basin watershed, but the higher elevations along the periphery coincide with the Utah-Wyoming Rocky Mountain ecoregion. Elevations range from over 10,600 feet in the Wyoming Range in the northeast to 6,050 feet where the Bear River exits the state to flow into Idaho. Except for the Uinta Mountain Range, these landscapes largely do not reflect a glacial history but rather consist of sagebrush plains, floodplain terraces, fertile high elevation valleys along the Bear River and Smiths Fork and Thomas Fork Rivers, sub-irrigated wet meadows (man-made and natural) in those valleys, and the moderately steep slopes of the Wyoming Range and Uinta Mountain Range. The moderate to steep slopes of the Uinta Range contain moraine features and U-shaped valleys (Chapman et al. 2004).

The geology of the region is marked by the uplifted sedimentary overthrust belt of the southern Wyoming Range (Lageson and Spearing 1988). The remaining ridges and valleys are a product of erosion of the folded and faulted sedimentary bedrock. The sedimentary formations are easily eroded and provide surface waters with large volumes of sediments. Furthermore, fine-grained soils and moderate foothill slopes result in streams that are sensitive to disturbance and highly dependent on riparian vegetation for

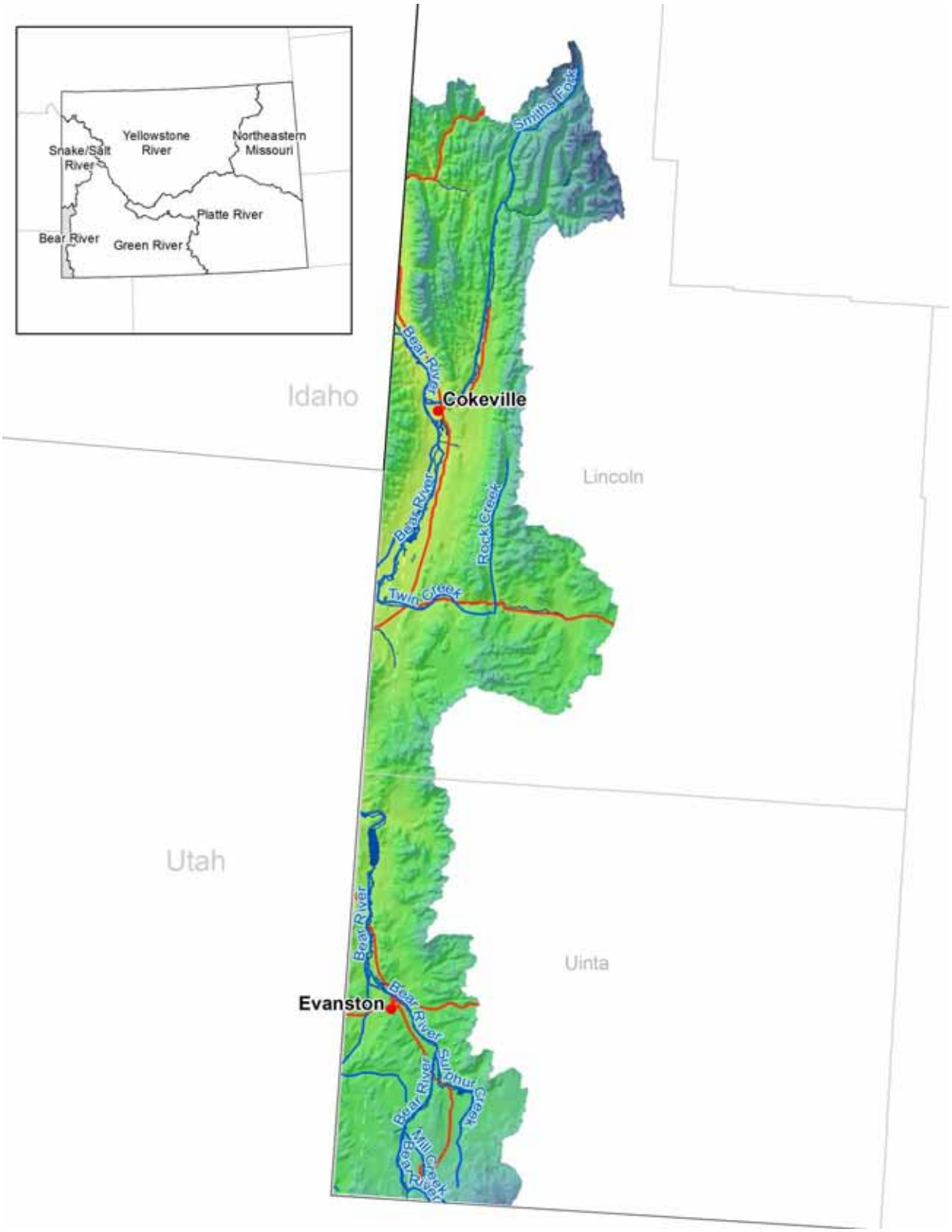

Figure 1. Bear River Basin.

stabilizing stream banks (Wyoming Department of Environmental Quality 2010).

Over geologic history, several large lakes existed here and throughout the Great Basin in Utah, Idaho, Nevada, and Oregon to the west. Lake Bonneville was the largest of these ancient lakes at a size similar to Lake Michigan (Behnke 1992). Limestone deposits of the Green River formation and associated fossils from an early inland water body are visible today at Fossil Butte National Monument west of Kemmerer. Through periods of glaciation largely to the north, a connection to the Columbia River system periodically occurred and influenced today's aquatic fauna. For example, Bonneville cutthroat trout are believed to have derived from Yellowstone cutthroat trout immigrants to the Bonneville basin (Behnke 1992).

The Bear River basin occurs on the west side of Wyoming's climate division 3 (Curtis and Grimes 2004). This climate division is the third coolest climate division of the ten climate divisions in Wyoming, warmer only than divisions 1 and 2 to the north. Monthly temperatures range from an average of about 15º F in January to about 63º F in July. The climate is one of the driest in the state, with annual precipitation of only about 10 inches. Peak precipitation occurs in May, while winters are cold and dry, with the exception of snow at bordering mountain high elevations (Curtis and Grimes 2004).

All 11 habitat types defined in this SWAP (e.g., sagebrush shrublands, riparian, etc.,) occur in the watershed and are based on combinations of Ecological Systems (ES) developed by NatureServe (Comer et al. 2003, NatureServe Explorer 2009). The determination and delineation of ES is based on land cover maps produced by the Northwest Gap Analysis Project (NWGAP 2010). Land cover mapping under NWGAP for the Bear River basin in Wyoming is in USGS mapping zone 22 (Wyoming Basins). Of the 173 ES identified under NWGAP, 52 occur in the Bear River basin (excluding developed and open water classes). The most prevalent classes are associated with the sagebrush shrublands (35%), foothills shrublands (28%), and the wetlands (12%) habitat types. The Inter-Mountain Basins Big Sagebrush Steppe is the most common ES in the sagebrush shrublands of the Bear River basin. Associated species assemblages, threats, and conservation actions of this and other habitats in this watershed are addressed in separate SWAP chapters.

Land use includes livestock grazing, timber production, irrigated cropland, energy development (oil, potentially oil shale, natural gas, and wind), trona mining, and recreation (Chapman et al. 2004, Department of Interior 2010). The Kemmerer District of the BLM largely overlaps this basin, and a Resource Management Plan (RMP) was approved in May 2010 to guide management. Livestock grazing is one of the most obvious and long-term land uses in the basin. Crop production includes largely irrigated meadow grass for grazing or hay. Irrigation is almost exclusively via flood irrigation application with relatively small water use via sprinklers (Bear River Basin Water Plan 2001). Development along the Bear River occurs within the municipality of Evanston which relies on treated water from Sulphur Creek Reservoir. The other municipality in the watershed, Cokeville, is near the confluence of the Smiths Fork River and the Bear River, and it derives water from groundwater sources (Bear River Basin Water Plan 2001).

Major reservoirs in the basin upstream of the lowest point on Bear Creek in Wyoming are Sulphur Creek Reservoir and Woodruff Narrows Reservoir with storage of 19,775 acre feet (af) and 57,300 af, respectively. In addition to the large reservoirs, hundreds of stock ponds and many miles of irrigation ditches have been constructed. The total annual runoff in the watershed is about 427,000 af at the Wyoming-Idaho gage (Bear River Basin Water Plan 2001). Runoff patterns are typical of snow-melt dominated systems with high peak flows in late May or early June and lowest annual flows occurring in January or February. The majority of the water produced in the watershed is allocated among users in Wyoming, Idaho, and Utah with little surplus (Bear River Basin Water

Plan 2001). Flows are commonly perennial in the headwaters, particularly those at higher elevations, and low or intermittent flows are common in downstream stream reaches (Waddell et al. 2003).

The Bear River below Sulphur Creek and down to Woodruff Narrows Reservoir, a distance of 36 miles, is threatened by sediment and is on the 303(d) List (Wyoming Department of Environmental Quality 2010). The other impaired water in the basin is a 14.5-mile reach of Bridger Creek, which was identified as a significant contributor of sediment and phosphates to the Bear River above the Twin Creek confluence. Incised channels in erodible soils, due to a variety of land uses (intensive historic grazing practices, road construction, agricultural crop production, phosphate mining, and riparian willow removal by chemical spraying), have created stream bank erosion and sediment challenges in several streams.

Aquatic Wildlife

Fish

Twenty-one fish species, including two subspecies of cutthroat trout and twelve native species, are now found in the Bear River basin (Table 1). The nonnative fish community consists of nine game species, the most common of which are introduced salmonids.

Table 1. Fishes present in the Bear River Basin. Species of Greatest Conservation Need (SGCN) are followed by an asterisk (*).

Native game	Native nongame	Nonnative game	Nonnative nongame
Bonneville cutthroat trout*	Bluehead sucker*	Brook trout	Common carp
Mountain whitefish*	Longnose dace	Brown trout	
	Mottled sculpin	Green sunfish	
	Mountain sucker	Largemouth bass	
	Northern leatherside chub*	Rainbow trout	
	Paiute sculpin	Smallmouth bass	
	Redside shiner	Snake River cutthroat trout	
	Speckled dace	Walleye	
	Utah chub	Yellow perch	
	Utah sucker		

Simon (1951) surveyed only three sites in the Bear River basin: two on the mainstem Bear River and one on the Smiths Fork. However, combining his sampling with previous work, he documented the presence of 10 of the 12 species now known to be native to the drainage. The taxonomy of the genus Cottus (sculpins) is confusing and has been repeatedly revised. Simon indicated that the species *C. semiscaber* which he called the Rocky Mountain sculpin was present in the Bear River drainage. Today, two species of sculpin, *C. bairdi* and *C. beldingi,* are considered native to the Bear River basin, but it is not clear which of the two was collected by Simon. Simon (1951) also failed to collect bluehead sucker *Catostomus discobolus*.

The historic distribution of native suckers is confounded by changes in taxonomic nomenclature and problems distinguishing the bluehead sucker and mountain sucker *Catostomus platyrhynchus,* both of which were once considered to be members of the genus *Pantosteus* (Gelwicks et al. 2009). The first likely record of bluehead sucker in the basin in Wyoming was reported from the Bear River by Sigler and Miller (1963). Baxter and Simon (1970) documented the presence of bluehead

sucker in the Smiths Fork River, and Wheeler (1997) found a single bluehead sucker in the mainstem Bear River, one of 17 sites that he surveyed in the basin in 1995 and 1996. Bluehead sucker were sampled in several sections of the Smith's Fork River and in the mainstem Bear River as recently 2005 (Craig Amadio and Pete Cavalli, personal communications).

During early surveys by the Wyoming Game and Fish Department (WGFD), some of the native subspecies of cutthroat trout had not yet been described. As a result, Simon (1951) reported sampling Yellowstone cutthroat trout *O. clarkii bouvieri* from the Smiths Fork and concluded that the subspecies may also be native to the Bear River basin. However, it is now accepted that the Bonneville cutthroat trout *O. clarkii Utah* is the only trout native to the Bear River basin. Historic abundance of native cutthroat in the basin was reduced by competition and hybridization with nonnative salmonids, habitat deterioration, and overfishing, to the point that it was believed to be extinct (Sigler and Miller 1963, Baxter and Simon 1970). However, in the 1960s, WGFD biologists began to document observations of a potentially unique cutthroat strain in the basin, and cutthroat trout investigations began in earnest. By the late 1970s, it was widely accepted that the native cutthroat in the Bear River basin was a unique subspecies *Salmo clarki Utah*. Common names for the newly recognized subspecies included Bonneville, Bear River, Utah, and Snake Valley cutthroat trout. Binns (1981) and Duff (1988) provide excellent summaries of the history and status of the newly described subspecies of native cutthroat. Bonneville cutthroat investigations intensified in 2000, and during the next six years, six graduate research projects were completed (Johnstone 2000, Colyer 2002, Schrank 2002, White 2003, Roberts 2004, and Carlson 2006). These theses and subsequent publications (Carlson and Rahel 2007, Colyer et al. 2005, Johnstone and Rahel 2003, Schrank et al. 2003, Roberts and Rahel 2008, White and Rahel 2008) contributed significantly to our current understanding of the status, distribution, and life history of this unique subspecies of native cutthroat. The Bonneville cutthroat has been petitioned for listing under the Endangered Species Act (ESA) on multiple occasions. The most recent finding was issued in September 2008. The U.S. Fish and Wildlife Service concluded that listing was not warranted because "viable, self-sustaining Bonneville cutthroat trout populations are well distributed throughout its historic range and are being restored or protected in all currently occupied watersheds (Federal Register: Sepetember 9, 2008, Vol. 73, Number 175, pp. 52235-52265).

The Bear River basin also constitutes the core of the native range of northern leatherside chub *Lepidomeda copei* (LSC) in Wyoming. The known distribution of native populations of management significance in Wyoming currently consists of a single population in Pacific Creek in the Pacific Northwest watershed and three relatively widespread populations within the Bear River basin. The Bear River populations include 1) the Smiths Fork drainage near Cokeville, 2) the Rock Creek drainage near Fossil Butte National Monument, and 3) the upper Bear River tributary streams south of Evanston. Status is summarized in Zafft et al. (2009), Miller et al. (2009), and Amadio et al. (2009). In 2007, this species was also petitioned for listing under the ESA. As of July 2010, the U.S. Fish and Wildlife Service had not issued a finding.

No native species are known to have been extirpated from the Bear River basin, but introduced brook, brown, and rainbow trout are common. Introduced Snake River cutthroat trout, largemouth bass, smallmouth bass, green sunfish, and yellow perch are rare. Walleye and smallmouth bass were illegally introduced into Sulphur Creek Reservoir where they are successfully reproducing. Green sunfish have been found in a single, private trout pond, Quealy Reservoir. Common carp are abundant in the mainstem Bear River. Largemouth bass and yellow perch have also been found in the mainstem Bear River, but population sizes are unknown.

Aquatic Reptiles
No turtles are native to the Bear River Basin watershed, and none have been introduced.

Freshwater Mollusks and Crayfishes
Few published accounts exist (Beetle 1989, Henderson 1924, Hoke 1979, Hovingh 2004), but native mussel populations are currently present in every major drainage of Wyoming except the Green River and Great Divide basins. Wyoming is still in the discovery phase in terms of its freshwater mussels and gastropods, but the WGFD has intensified sampling efforts in recent years. One biologist on the Aquatic Assessment Crew has been assigned to coordinate mollusk sampling and collect observations. Field personnel have been trained and instructed to record mussel observations during other routine fieldwork and submit specimens. A voucher specimen collection was established at the University of Colorado Natural History Museum in Boulder, Colorado, in 2007.

As of late 2010, seven species of native mussels were known to inhabit Wyoming waters, all of which are considered SGCN. Two of these species, the western pearlshell *Margaritifera falcata* and the California floater *Anodonta californiensis* have been documented in the Bear River watershed (Beetle 1989). The western pearlshell was collected as recently as 2008 from the Bear River (live specimens) and the Smiths Fork (empty shell) immediately north of Cokeville. This species was also collected in 2010 from the upper Bear River near the Utah state line. One shell had tissue attached, documenting recent occurrence (C. Amadio, personal communication). Numerous live California floater, a federal species of concern, were collected in 2010 from the Bear River approximately 10 mi south of Cokeville, Wyoming (G. Edwards, personal communication).

Little is known about the current distribution of Wyoming gastropods. Beetle (1989) contains some of the only published observations in Wyoming, listing species occurrences by county. In 2009, the WGFD funded a project at the University of Wyoming (UW) to conduct a literature review, identifying the current and historical information on freshwater gastropod distributions in Wyoming and to develop gastropod collection methods for WGFD, and assess the distribution of freshwater gastropods in the Bighorn and North Platte river drainages in Wyoming. This project did not include any sampling in the Bear River basin. The UW research project will provide gastropod sampling protocols. Baseline survey data are needed for all gastropods in the Bear River watershed.

The only crayfish species known to be native to the Bear River basin in Wyoming is *Pacifasticus gambelii*. This was the only species found during a 1985-–1987 crayfish survey (Hubert 1988). *Orconectes virilis*, a nonnative species, was the only species found in the Bear River drainage during the 2007-2009 survey and appeared to have displaced *P. gambelii* (Hubert 2010).

Table 2. Species of Greatest Conservation Need present in the Bear River Basin

Fish
Bluehead sucker
Bonneville cutthroat
Northern leatherside chub
Mountain whitefish

Crustaceans
Pilose crayfish

Mollusks
California floater mussel
Western pearlshell mussel

Identification of Conservation Areas

The 7,500 sq mi Bear River basin includes portions of northeast Utah, southeast Idaho, and southwest Wyoming. Approximately 20% of the basin lies in Wyoming, The Wyoming Game and Fish Department Strategic Habitat Plan (WGFC 2009) references multiple goals, two of which are to conserve and manage wildlife habitats that are crucial for maintaining

terrestrial and aquatic wildlife populations for the present and future, and to enhance, improve and manage priority wildlife habitats that have been degraded. Crucial habitat areas were identified to accomplish the first, and enhancement areas were identified to accomplish the second. While only 20% of the Bear River basin lies in Wyoming, the entire Wyoming portion of the basin is considered an important conservation area for aquatic SGCN (Figure 2).

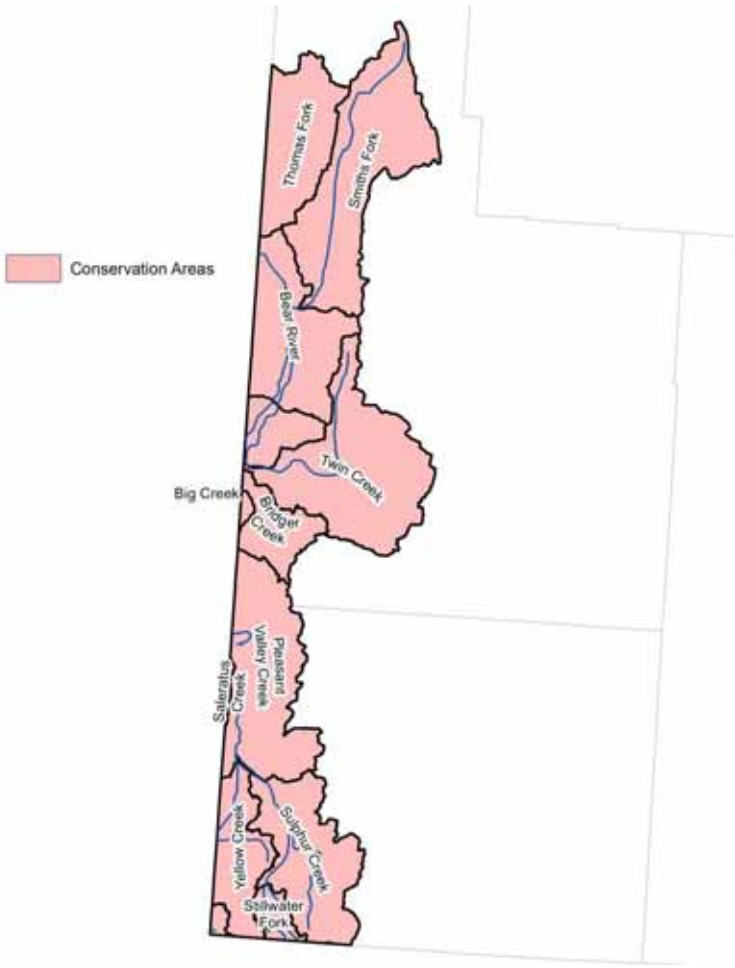

Figure 2. Aquatic Wildlife Conservation Areas in the Bear River Basin

The mainstem Bear River is an important migration corridor for spawning Bonneville cutthroat trout and bluehead suckers have been documented in the river. Major tributaries Twin Creek, Smiths Fork, and Thomas Fork are critical to the conservation of northern leatherside chub, Bonneville cutthroat trout or both. The headwater tributaries of Mill, LaChapelle, and Sulphur creeks draining the north slope of the Uinta Mountains are critical for northern leatherside chub. Wyoming's efforts to conserve Bonneville cutthroat trout and northern leatherside chub in the basin have contributed significantly to keeping these two species from listing under the ESA. Conservation areas are likely to be further refined upon completion of the northern leatherside chub project described below.

Threats

Ungulate grazing and browsing – High
On a landscape scale, livestock grazing is the primary factor currently and historically influencing habitats in the Bear River basin.

Stream habitat conditions are below potential because of eroded stream banks and high sediment levels contributed by degraded plant communities. Herbicide spraying in the 1960s and long-term heavy grazing have severely impacted willow communities. Proper stocking levels and grazing regimes can be effective habitat management tools and are compatible with stream channel, riparian, and upland area maintenance and improvement. However, improper grazing can eliminate vegetation and associated wildlife, widen stream channels, cause soil erosion, increase water sediment loads, raise water temperature, encourage the spread of invasive plan species, change bank configuration, and lower surrounding water tables (Chaney et al. 1991, Nicholoff 2003). Overbrowsing by wildlife, particularly elk and moose, can also have similar negative effects. As with livestock grazing, impacts tend to be site specific, where herd numbers exceed management objectives, or where animals congregate to escape hunting and other forms of predation, or as a result of other causes.

Water development/altered flow regimes – Moderate

Natural flow regimes in stream segments around the state have been altered by human activities including irrigation diversions and water developments for more reliable water supply, hydropower, and flood control. These altered flow regimes are also a consequence of broad-scale changes in land use and management associated with agriculture, grazing, timber harvest, and housing development (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes). The majority of the Bear River basin is publically owned. Because it is such an arid region the limited amount of irrigated cropland has a significant impact on aquatic wildlife. In addition, the direct effects of dewatering the irrigation diversions impede movement, and some fish are lost to entrainment into the irrigation ditches. Lateral and longitudinal hydrologic connectivity and physical access by fish populations to all habitats necessary to complete their life history is limited throughout the drainage. In-channel obstructions and dewatering have reduced some populations of native fishes.

The need for additional water for human use will intensify in the immediate future, and that trend will be especially evident in the western U.S. This trend has multi-faceted consequences for fish and wildlife and the habitats upon which they depend. In Wyoming, trans-basin water diversions are not uncommon and are likely to be further proposed and pursued. Energy diversification, including hydropower development, may increase as the nation's energy demands rise. Warmer conditions with more erratic precipitation— which some predict for Wyoming's future climate—may heighten the need for additional water development (water storage) for municipal and agricultural purposes. The likely trend will be water development projects closer to the delivery point and conveyance via pipelines instead of stream channels. Additional emphasis will likely be placed on lining irrigation ditches and other practices to more efficiently use water for consumptive purposes. The net effect of all such water management practices will be to alter the timing, magnitude and duration of natural hydrographs and reduce intra- and inter-annual variability in Wyoming's streams and associated riparian corridors (see Wyoming Leading Wildlife Conservation Challenges – Climate Change, and the Riparian habitat chapter).

Two assessments of additional water storage have been conducted recently in this basin. The Cokeville Reservoir Study includes the construction of a dam in the Smiths Fork River (RJH Geotechnical and Water Resources Engineering 2010). The Sublette Creek Reservoir Mau / Covey Canal Rehabilitation Project proposes additional water development options in the Smiths Fork drainage (Sunrise Engineering, Inc. 2004). Projects under both studies would impede upstream migration of native fish and reduce stream flow.

Drought and climate change – Moderate

Climate change may increase air and surface water temperatures, alter the magnitude and seasonality of precipitation and runoff, and shift the reproductive phenology and distribution of

plants and animals (Seavy et al. 2009) (see Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Changes in precipitation patterns under various climate change scenarios are predicted to produce peak flows earlier in the yearly cycle and to lower base flows (Barnett et al. 2004, Gray and Anderson 2009). Drought lowers water tables, leading to reduced plant growth and reproduction. Riparian vegetation declines lead to lower bank stability, higher siltation and altered stream habitat quality and quantity. Lower water levels increase water temperatures and reduce the living space available to fish and other aquatic wildlife. All these conditions can be detrimental to the health and reproductive success of all aquatic wildlife species.

Invasive species – Moderate
Competition, predation, and hybridization with nonnative trout is a concern within the Bear River watershed but these threats have not eliminated any native species. Piscivorous fish, including brown trout, yellow perch and walleye prey upon native nongame fish. Populations of walleye, smallmouth bass, brook trout and rainbow trout located in the Wyoming portions of this watershed threaten native fish.

Aquatic invasive species (AIS) including fish, pathogens, plants, and mollusks are currently present in Wyoming, most notably the New Zealand mudsnail and the parasite that causes whirling disease. These AIS can alter the native species in a watershed through competition, disease, shifts in food availability, and direct mortality. While AIS currently in Wyoming can cause problems and need to be controlled, the most significant known threat to Wyoming's native species is from zebra and quagga mussels, based on their proximity to Wyoming and demonstrated negative impacts in other areas. Zebra and quagga mussels can out-compete native mussels for space and resources and will attach to and smother native mussels causing mortality (Cummings and Mayer 1992, Strayer 2008). They filter plankton out of the water column at high rates (up to a liter per day per individual) so that little plankton remains available for fish populations, resulting in their decline (Benson 2009). In addition, invasive mussels produce pseudofeces which can lead to harmful algal blooms affecting numerous aquatic species.

The Wyoming Aquatic Invasive Species Act of 2010 allowed the WGFD to implement the Wyoming AIS Program with the goal of executing a coordinated strategy to prevent, control, contain, monitor, and whenever possible, eradicate aquatic invasive species from the waters of the state. The Wyoming AIS Management Plan of 2010 is the framework for this three-part strategy which includes 1) outreach and education, 2) inspection of watercraft to increase boater awareness of AIS threats and prevention and to intercept high risk watercraft that may be transporting AIS, and 3) monitoring of waters to allow for early detection and rapid response to any new AIS populations in the state.

Conservation Initiatives

Since 2005, numerous conservation planning efforts have been conducted by the WGFD, federal agencies, and conservation groups to benefit SGCN in the Bear River basin. Partners continue to work together to follow management activities specified in Conservation Agreement and Strategy plans for Bonneville cutthroat trout (May and Albeke 2005), bluehead sucker (Utah Division of Wildlife Resources 2006), and the northern leatherside chub (Utah Division of Wildlife Resources 2009). The Nature Conservancy, working with numerous cooperators, recently completed a Conservation Action Plan for the Bear River drainage, and the U.S. Fish and Wildlife Service is currently drafting a management plan for the Cokeville Meadows National Wildlife Refuge.

Fish passage has been a priority in the watershed, and research and planning efforts have led to a number of projects to address passage issues. The U.S. Bureau of Land Management recently completed a survey of road culverts that are acting as fish barriers in western Wyoming and eastern Utah. Several

irrigation diversions have been modified to allow fish passage and eliminate entrainment into canals. These projects include diversions on Coal Creek, Grade Creek, and several diversions on Rock Creek. In addition, the amount of water diverted on Grade Creek has been reduced, allowing water to flow once more through a section of stream that had been dry for several decades. Diversions on Twin Creek and the Smiths Fork River are currently being evaluated for future modification. Cooperators on various passage projects include Trout Unlimited, the WGFD, the U.S. Forest Service, and private land owners.

WGFD studies of relationships between flow and habitat for Bonneville cutthroat trout have been extensive in parts of the Bear River basin. From these studies, 17 instream flow water rights have been filed by the WGFD and Wyoming Water Development Office and permits approved by the State Engineer. These instream flow water rights permits protect 41 miles of streams in the Smiths Fork and Thomas Fork drainages (Paul Dey, personal communication).

Riparian habitat improvement has also been a priority. The WGFD and other organizations are currently pursuing conservation easements on several important tracts of private land in the Smiths Fork and Bear River drainages. Recent habitat improvement projects in the Thomas Fork drainage have included willow plantings, grazing exclosures and head cut stabilization. Plans are currently being developed to improve roads to reduce sediment loading to streams.

WGFD aquatic habitat personnel work closely with the BLM to improve watershed health with an emphasis on riparian and aquatic habitats. Cooperative efforts include assisting the BLM and permittees with maintenance of pasture fences and riparian exclosures and extensive coordination with BLM range and wildlife personnel to monitor annual use and distribution of livestock. Furthermore, to provide additional information to support the BLM's 2001 allotment evaluation, a range suitability analysis was performed using a GIS based rangeland suitability tool (Oberlie and Bishop 2009). A settlement agreement between the BLM and other parties on an appeal of the 2005 Allotment Management Plan has the BLM consulting with WGFD to develop Bonneville cutthroat trout habitat objectives. Finally, riparian greenline data are being cooperatively collected with the BLM.

Cooperative grazing management with the Kemmerer Ranger District of the Bridger-Teton National Forest is likewise an area of ongoing effort by the WGFD. The WGFD has provided assistance and input into allotment management plan development, implementation, and monitoring.

Two large-scale status assessment projects funded by the State Wildlife Grants (SWG) are being initiated to address SGCN in the Bear River basin. The first project was initiated in 2010 to determine the current distribution of northern leatherside chub (LSC) in Wyoming. The distribution of this species is primarily within the Bear River drainage in Wyoming. The objectives of this project are to 1) determine baseline abundances for major populations of LSC in Wyoming, 2) identify species of fish sympatric with LSC in Wyoming, 3) identify relationships between LSC distributions and habitat characteristics, and 4) collect tissue samples from major LSC populations in Wyoming for genetic analyses. Brigham Young University (BYU) and Idaho State University (ISU) researchers are also conducting LSC research in the basin and are coordinating efforts with WGFD biologists. A BYU project will address objective 3 above. The genetic analysis (objective 4 above) will be completed as part of a master's degree project through ISU, which was funded by the Wyoming Governor's office.

The second project will be initiated in spring 2011 to determine baseline distributions and status of freshwater mussel species in the Bear and Snake/Salt River basins in Wyoming. The specific objectives of this project are to 1) establish mussel distribution and habitat survey methods appropriate for use throughout Wyoming, 2) establish species distributions and identify core populations of mussels, 3)

contribute to a comprehensive collection of mussel voucher specimens at the University of Colorado Museum, and 4) evaluate the need for population monitoring and propose management recommendations.

The states of Utah, Nevada, Wyoming, and Idaho, and the U.S. Forest Service, Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, Confederated Tribes of the Goshute Reservation, and Utah Reclamation Mitigation and Conservation Commission are signatories to a range-wide conservation agreement and strategy for Bonneville cutthroat trout. This agreement was implemented to ensure the long-term survival of the subspecies through coordination of conservation efforts among the signatory agencies (BRC Conservation Team 2000). Under the auspices of this plan, numerous conservation actions have been planned and implemented through state and federal conservation and management plans. A Bonneville Cutthroat Trout Conservation Team was formed as part of that plan. The team includes biologists from the Wyoming Game and Fish Department, Utah Division of Wildlife Resources, Nevada Division of Wildlife, Idaho Department of Fish and Game, Bureau of Land Management, U.S. Forest Service, the National Park Service, and the U.S. Fish and Wildlife Service. The team completed a status report (May and Albeke 2005) that describes the range-wide status of Bonneville cutthroat trout in the United States.

An active conservation and management program for northern leatherside chub has developed in the last several years. One of the most important recent accomplishments is that the states of Idaho, Nevada, Utah, and Wyoming along with the U.S. Forest Service, Bureau of Land Management, Bureau of Reclamation, National Park Service, Fish and Wildlife Service, Trout Unlimited and The Nature Conservancy, signed a conservation agreement to jointly conserve, protect, and restore northern leatherside populations within their historic range (BRC Conservation Team 2009). This agreement has already begun advancing range-wide conservation and management efforts.

The WGFD's Fish Division has developed basin management plans to guide management across the state. These plans provide background and history of aquatic wildlife management as well as management direction for sportfish, SGCN, and aquatic habitat. The management direction includes reference to the SWAP and the Strategic Habitat Plan, attempting to incorporate management direction from those two plans that is relevant to each basin into each basin management plan.

The WGFD has the opportunity to comment on most environmentally sensitive construction or management actions submitted through the National Environmental Policy Act (NEPA) review process. Projects include state and federal lands and private ventures that require action by state or federal agencies. The WGFD regularly provides recommendations to protect habitat and populations of aquatic wildlife at the project level. Department efforts are guided by the Wyoming Game and Fish Commission mitigation policy (WGFC 2008).

The WGFD has a rigorous collection permitting system that restricts commercial, scientific, and educational activities (WGFC 2005) and provides protection to aquatic wildlife. The regional fisheries supervisor reviews all requests for permits and recommends either approval or rejection of the request based on merit and impacts to the resource in question.

The movement of fish by WGFD employees is critical to address many of the aspects, thus the intent, of our mission. However, the act of moving or importing fish also presents risks that could potentially jeopardize that mission. To address this conflict, a method to determine the relative level of risk associated with any proposed fish importation and/or transplant was developed. The WGFD utilizes Hazard Analysis and Critical Control Point (HACCP) procedures (Gunderson and Kinnunen 2001) and has developed a risk assessment matrix from these procedures to manage transplants, thereby protecting the aquatic resources within

the state. Using the procedures and matrix, WGFD fisheries managers develop documentation that explains whether a transplant is nearly free of risk. The documentation must address all aspects of the transplant, including but not limited to verifying that the fish being transplanted are disease free, the water source is disease free, and non-target species are excluded from transplant. Source populations of salmonids are verified disease free by collecting a standardized number of fish, having them inspected by an American Fisheries Society-certified Fish Health Inspector for all known pathogens, and receiving disease-free certification. The resulting documentation is reviewed and either approved or denied by the WGFD Chief of Fisheries. Whirling disease-infected trout, native or nonnative, are not stocked by the WGFD, and they are not allowed to be stocked by others (WGFC 2003).

In Wyoming, Game and Fish Commission policy precludes the stocking of fish into waters that are capable of maintaining satisfactory, self-sustaining fisheries (WGFC 1998). A commonsense, biologically based protocol for fish rearing and stocking has historically been followed in Wyoming, with emphasis on management for native fish and wild fish wherever possible (Wiley 1995). Only 3% of the streams listed in the Wyoming Game and Fish Department database inventory are stocked annually. Maintenance of native cutthroat trout subspecies has been a management priority for more than 40 years (Stone 1995), and protection from stocked predators of native nongame fishes has been an important consideration for at least the last decade.

Wyoming has regulations prohibiting unauthorized stocking of fish or fish eggs. Private citizens can only stock waters in Wyoming following a WGFD permitting system that includes review by the responsible regional fisheries supervisor (WGFC 2005). WGFD has increased public education efforts regarding problems associated with illegal introductions of fish. The Wyoming Legislature increased the penalties for illegal fish stocking in 2010, and the Wyoming Wildlife Protectors Association has offered $2,500 rewards for information leading to the conviction of individuals found illegally moving or stocking fish.

Habitat management efforts are guided by the Strategic Habitat Plan (SHP) that was adopted by the Wyoming Game and Fish Commission in January 2009. The SHP includes five goals: 1) Conserve and manage wildlife habitats that are crucial for maintaining terrestrial and aquatic wildlife populations for the present and future, 2) Enhance, improve, and manage priority wildlife habitats that have been degraded, 3) Increase wildlife-based recreation through habitat enhancements that maintain or increase productivity of wildlife, 4) Increase public awareness of wildlife habitat issues and the critical connection between healthy habitat and abundant wildlife populations, and 5) Promote collaborative habitat management efforts with the general public, conservation partners, private landowners, and land management agencies. Efforts are focused in priority areas in each of the management regions and include crucial areas essential for conservation of important species and communities, and enhancement areas, which represent places where work should be conducted to manage or improve wildlife habitat.

The Wyoming Legislature created the Wyoming Wildlife and Natural Resource Trust (WWNRT) in 2005. Funded by donations, legislative appropriation, and interest earned on a permanent account, the purpose of the program is to enhance and conserve wildlife habitat and natural resource values throughout the state. Any project designed to improve wildlife habitat or natural resource values is eligible for funding. The WWNRT is an independent state agency governed by a nine-member citizen board appointed by the Governor. The WGFD has partnered with the WWNRT to successfully implement a wide range of projects to benefit a broad array of Wyoming's wildlife.

Landscape Conservation Cooperatives (LCCs) are a new program of the U.S. Fish and Wildlife Service. The vision is that they serve as applied conservation science partnerships focused on a defined geographic area that inform on-the-

ground strategic conservation efforts at landscape scales. LCC partners include U.S. Department of Interior agencies, other federal agencies, states, tribes, non-governmental organizations, universities, and other stakeholders. It is hoped that LCCs will enable resource management agencies and organizations to collaborate in an integrated fashion within and across landscapes. LCCs are intended to provide scientific and technical support to inform landscape-scale conservation using adaptive management principles. They are proposed to engage in biological planning, conservation design, inventory and monitoring program design, and other types of conservation-based scientific research, planning, and coordination. It is hoped that LCCs will play an important role in helping partners establish common goals and priorities, so they can be more efficient and effective in targeting the right science in the right places. Products developed by LCCs should inform the actions of partners and other interested parties in their delivery of on-the-ground conservation. The WGFD will continue to participate in the LCC process as appropriate.

The National Fish Habitat Action Plan (NFHAP) was developed by a coalition of fisheries professionals, state and federal agencies, tribes, foundations, conservation and angling groups, businesses, and industries, all determined to reverse the declines of America's fish habitats. In its design, the plan encompasses five important lessons that emerge from America's past efforts to protect and restore fish habitat: 1) Be strategic rather than merely opportunistic, 2) Address the causes of and processes behind fish habitat decline, rather than the symptoms, 3) Provide increased and sustained investment to allow for long-term success, 4) Monitor and be accountable for scientifically sound and measurable results, and 5) Share information and knowledge at all levels from local communities to Congress. The Wyoming Game and Fish Department has been heavily involved with the development and implementation of the NFHAP. WGFD is involved with three NFHAP partnerships, Great Plains Fish Habitat Partnership, the Western Native Trout Initiative, and the Desert Fishes Habitat Partnership. The latter two cover the Bear River basin.

The mission of the Western Native Trout Initiative (WNTI) is: "To serve as a key catalyst for the implementation of conservation or management actions, through partnerships and cooperative efforts, resulting in improved species status, improved aquatic habitats, and improved recreational opportunities for native trout anglers across western states." Their vision is: "An increase in healthy, fishable western native trout populations resulting from sharper focus and commitment to action on common conservation needs of western native trout; enhanced public benefit resulting from multiple partners working together, sharing resources, and speaking with a united voice about the conservation and value of western native trout; and increased funding to accomplish strategic actions as a result of greater community and financial support from initiative partners and collaborators." By working together, the partners in WNTI are striving to implement the most strategic actions needed to benefit these trout. And by working together to establish secure populations, WNTI will also benefit anglers by enhancing recreational fishing opportunities for unique trout species across the West.

The Desert Fish Habitat Partnership's purpose is to conserve aquatic habitat in the arid west for desert fishes for the American people by protecting, restoring, and enhancing these unique habitats in cooperation with, and in support of, state fish and wildlife agencies, federal agencies, tribes, conservation organizations, local partners, and other stakeholders. The Desert Fish Habitat Partnership seeks to address fish and habitat issues over a broad geographic area that encompasses the entirety of the Great Basin and Mohave deserts, and those portions of the Sonoran and Chihuahuan deserts that lie within the United States. The benefits of aquatic habitat conservation extend beyond desert fishes to include humans and other animal and plant species. Riparian habitats that depend on

surface water not only support a significant number of terrestrial and avian species identified as priority conservation species in SWAPs, but also function to store water that supplements groundwater recharge. The declining status of so many desert fishes highlights the importance of preserving these aquatic habitats so that water is available not only for the native fish, but also for future generations of humans. The Partnership can play an important role in conserving water in the West for future generations.

Recommended Conservation Actions

Secure and enhance populations and habitats in SGCN priority areas.
Evaluate the feasibility of reducing populations of or removing nonnative fishes from priority conservation areas in the basin.

Monitor the status and distribution of native aquatic wildlife assemblages with emphasis on Bonneville cutthroat trout, bluehead sucker, and northern leatherside chub.
Continue basin-wide surveys to identify fish distribution, relative abundance, and habitat preferences.

Beginning in 2010, assist the SWG LSC biologist with project development and data collection.

Assist Mark Belk (BYU) and John Henderson (BLM) with BYU LSC research project development and data collection.

Further explore the status of bluehead sucker in the basin.

Represent the WGFD on the interagency northern leatherside chub conservation team and help implement the Range-wide Conservation Agreement and Strategy for Northern Leatherside.

Represent the WGFD on the interagency Bonneville cutthroat trout conservation team and help implement the Range-wide Conservation Agreement and Strategy for Bonneville cutthroat trout.

Assess the genetic purity of Bonneville cutthroat trout, bluehead sucker, and northern leatherside chub populations.
Collect and store tissue samples from individual populations for future genetic analysis.

Provide funding from BLM sensitive species grant to develop micro-satellite genetic markers for LSC.

Identify and reduce threats to native fish populations from nonnative species.
Monitor walleye, yellow perch and smallmouth bass distribution within the drainage.

Conduct annual monitoring of the Sulphur Creek Reservoir fish populations with trout and walleye gillnetting efforts in June to assess stocking strategies and walleye predation effects on trout abundance.

Continue to investigate opportunities to chemically remove the walleye and smallmouth bass populations from Sulphur Creek Reservoir.

Increase educational efforts about the ecological, economic, and social values of aquatic SGCN.
The importance and role of aquatic SGCN is poorly understood by the general public. Efforts should be enhanced to increase public education in this area.

Continue building voucher collections for all aquatic wildlife.
Continue to fill voids in voucher inventory for fish per WGFD protocol (Zafft and Bear 2009).

Mussel specimens have been donated to the University of Colorado Museum, and new specimens will be added as needed. A database containing freshwater mussel occurrences will be maintained and enhanced with specimen photos.

Determine if there is a museum interested in voucher specimens of gastropods. If so, expand the voucher program to include those organisms.

Complete the comprehensive survey for freshwater mussels.
Future efforts will focus on filling gaps in distribution information, initiating comprehensive drainage surveys, maintaining WGFD records, and expanding specimen collections.

Continue aquatic habitat work in the basin.
Supply flow or other information to the State Engineer's Office and Water Development Office to facilitate adjudication of instream flow water rights.

Monitor instream flow segments for compliance with approved instream flow levels. Pursue compliance as needed when water is available and in priority.

Identify, prioritize, and pursue fish passage solutions on Twin Creek, Smiths Fork, Thomas Fork, Bear River and their tributaries to improve adult trout access to headwater spawning areas and downriver connection to overwintering habitat.

Prioritize and screen irrigation diversions on Twin Creek, Smiths Fork, and Thomas Fork and their tributaries to reduce fish loss.

Identify whether and where passage or screening issues are relevant for northern leatherside chub conservation. Where appropriate, take action to resolve identified problems.

Assist the BLM with monitoring riparian greenline transects and tracking progress toward attainment of Smiths Fork Allotment Management Plan goals.

Continue protecting and enhancing riparian willow communities in the Twin Creek, Smiths Fork, and Thomas Fork watersheds.

Explore water management approaches that enhance fish habitat.
Identify opportunities to work with private water right holders to manage water diversions and uses with the goal of restoring natural flow regimes. Where opportunities exist, develop cooperative strategies with landowners and other partners to implement strategies that are beneficial to aquatic resources.

Identify stream segments where habitat and available flow regimes indicate a need to file instream flow water rights for SGCN. As opportunities are identified, conduct needed studies and file for state-held instream flow water rights.

Identify fish and wildlife mitigation for new reservoirs as they are built including instream flow regimes and minimum fishery pools. Ensure that mitigation recommendations are included as conditions in applicable permits and licenses.

Follow up on recommendations from the graduate research project on gastropods.
The WGFD-funded graduate project at the University of Wyoming will provide direction for sampling methods. Those recommendations should be followed, and baseline gastropods surveys should be conducted in the Bear River basin.

Monitoring

Establish standardized monitoring protocols and locations for native SGCN.
Establish a standardized fish sampling program at multiple sites in the Bear River drainage to follow up on the northern leatherside chub project.

Monitor seasonal flow regimes and temperature in areas containing important native SGCN populations and lacking active USGS or other recording stations.

Use flow and water quality monitoring data to further define the specific life stage needs of leatherside chub for further use in instream flow water right studies.

Monitor the establishment and spread of invasive species. Take action to avoid their introduction and minimize their spread if and when they are documented.

Continue to monitor populations of Bonneville cutthroat trout and northern leatherside chub.

Monitor populations of walleye and smallmouth bass in Sulphur Creek Reservoir in case circumstances change and allow removal efforts to be completed.

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Green River Basin

North Cottonwood Creek near Big Piney

Green River above Warren Bridge

Savery Creek on McMillan Ranch below High Savery Dam

South Cottonwood near Big Piney

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Watershed Description

Three of the nation's major river systems have their headwaters in Wyoming: the Missouri, Colorado, and Columbia Rivers. These watersheds provide a natural basis for delineating aquatic conservation areas. Six major watersheds were identified for conservation planning purposes under this State Wildlife Action Plan (SWAP) using hydrographic boundaries and fisheries assemblage and management considerations (Figure 3). These areas are consistent with the aquatic ecosystems identified for freshwater biodiversity conservation worldwide by Abell et al. (2008). The watershed areas are also synonymous with aquatic zoogeographical units and ecological drainage units identified under The Nature Conservancy's (TNC) hierarchical classification framework (Higgins et al. 2005). The watersheds each include one to four sub-regions (4-digit hydrologic unit code [HUC] watersheds). This approach allows the nesting of multiple spatial and temporal scales for planning and prioritizing conservation actions.

The Green River basin is based on, and exactly corresponds with, the Upper Colorado hydrologic unit in Wyoming (2-digit HUC 14). Major drainages corresponding to 8-digit HUCs include Upper Green, New Fork, Upper Green-Slate, Big Sandy, Bitter, Upper Green-Flaming Gorge, Blacks Fork, Muddy, Vermillion, Great Divide Closed Basin, Little Snake, and Muddy (in Little Snake drainage). The Great Divide Basin is a closed basin and is included. These watersheds span about 21,000 square miles in southwestern Wyoming's Carbon, Lincoln, Sublette, Sweetwater, and Uinta counties. Very small portions of Fremont and Teton counties occur in the basin as well. Land ownership is predominantly public (72%). Much of the 28% of privately-held lands occur in the "checkerboard" band of ownership along the Union Pacific railroad. Green River basin public land is managed primarily by the Bureau of Land Management (managing 56%) and U.S. Forest Service (managing 10%).

The Green River originates at over 10,500 feet in the Bridger Wilderness in the Wind River Mountains of Wyoming and flows for about 250 miles before leaving the state at Flaming Gorge Reservoir. Major tributaries include the New Fork, East Fork, Big and Little Sandy Rivers, LaBarge, Cottonwood, and Horse Creeks in the northern part of the basin, and the Little Snake, Hams Fork, Blacks Fork, and Henry's Fork Rivers in the south (Figure 3). From an analysis of the 2010 Version 2.0 National Hydrological Database (NHD) at 1:100,000, there are approximately 23,000 miles of streams in the Green River basin in Wyoming. This equates to a drainage density of about 1.1 stream miles per square mile land area. About 80% of these stream miles are first or second order streams.

The Wyoming Basins terrestrial-based ecoregion, as defined originally by Bailey (1995) and adapted by The Nature Conservancy, occupies most of the Green River basin, but the higher elevations along the periphery coincide with the Utah-Wyoming Rocky Mountain ecoregion. Elevations range from over 13,800 feet atop Gannett Peak, the highest point in Wyoming, to 6,040 feet where the Green River passes into Utah at Flaming Gorge Reservoir. Landforms are very diverse in this basin: much of the high desert basin is marked by mesas, buttes, and badlands with the higher peaks of the Wind River Range, Wyoming Range, Gros Ventre Range, Sierra Madre Range, and Uinta Range surrounding the basin. Sand dunes and playas of the Great Divide Basin contrast with the steep granitic and metamorphic slopes of the Wind River Range. The interior of the basin consists of sagebrush plains, floodplain terraces, and moderate to low gradient streams with finer gravel or sand substrates derived from shale (Chapman et al. 2004). Mountain glacial activity created cirques and shaped many of the valleys and streams at higher elevations, particularly in the Wind River Range (Knight 1994).

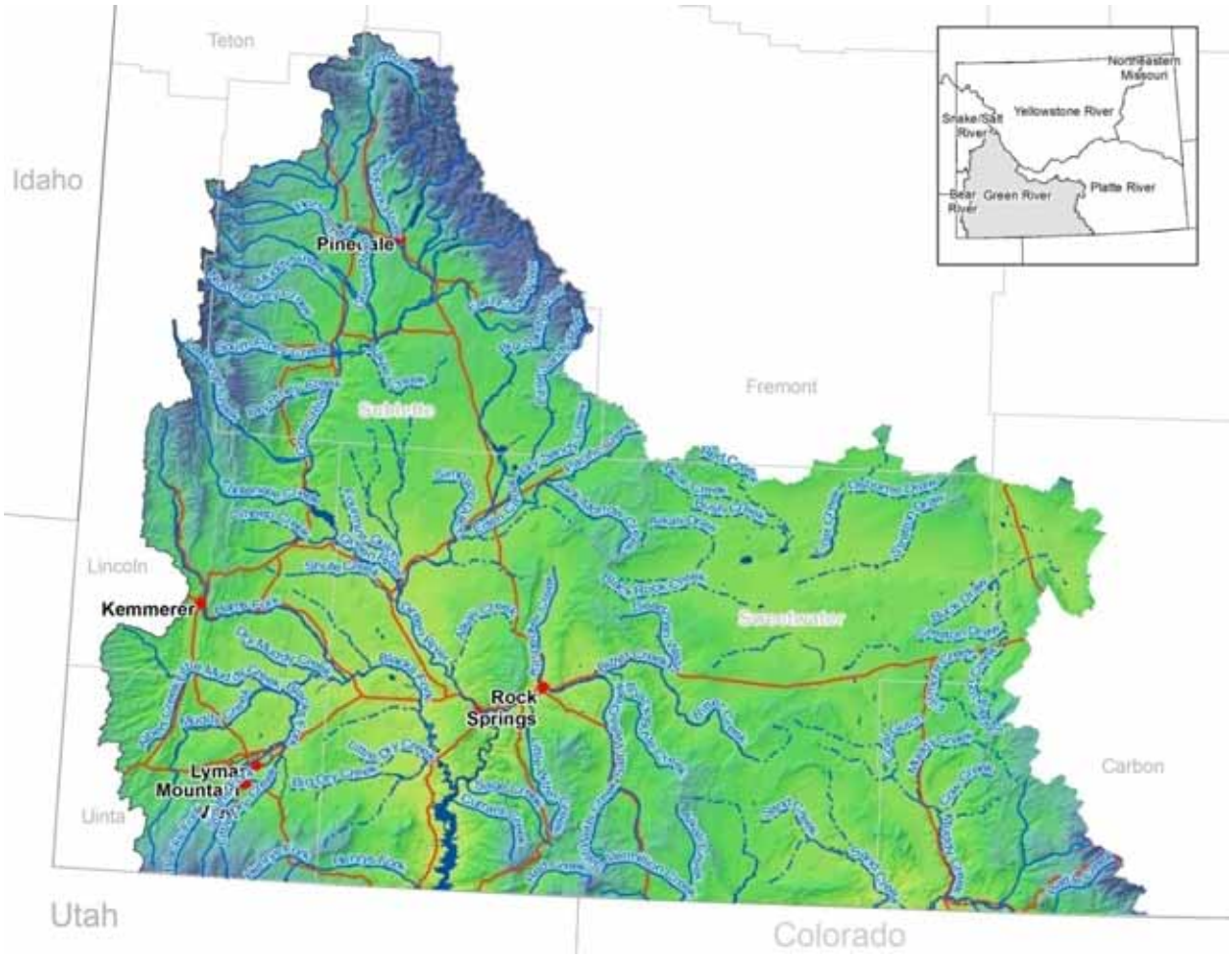

Figure 3. Green River Basin

The Green River Formation is a distinguishing geologic feature of the region (Lageson and Spearing 1988). This sedimentary rock is a remnant from the large Eocene Lake Gosiute and is associated with coal, uranium, saline minerals such as trona, and oil shale (Mason and Miller 2004). The folded strata of the Pinedale Anticline in the northern basin produce world-class quantities of natural gas, and extensive energy development fields are ongoing. Significant deposits of coal and oil exist in the basin. The Laney Member of the Green River Formation underlies central and eastern parts of the basin and contains oil shale (Clark and Davidson 2009). Other bedrock geology units of the southern watershed include the sedimentary Fort Union and Wasatch which have sandstone, shale, and thin coal beds. Coal bed and conventional natural gas development are also extensive in the Muddy Creek area in the southeast portion of the basin (Clark and Davidson 2009).

The Green River basin largely overlaps Wyoming's climate division 3 (Curtis and Grimes 2004). This climate division is the third coolest climate division of the ten climate divisions in Wyoming, warmer only than divisions 1 and 2 to the north. Monthly temperatures range from an average of about 15° F in January to about 63° F in July. The climate is one of the driest in the state, with annual precipitation of only about 10 inches. Peak precipitation occurs in May, while winters are cold and dry with the exception of snow at bordering mountain high elevations (Curtis and Grimes 2004). Annual precipitation ranges

from less than 8 inches at low elevations to more than 40 inches in mountainous areas; much of the basin receives less than 11 inches annually (Mason and Miller 2004).

Larger water bodies in the Green River basin include the Flaming Gorge Reservoir, which has 3,789,000 acre feet storage capacity (Jacobs and Brosz 2000), the Green River Lakes, New Fork Lake, Willow Lake, Fremont Lake, Halfmoon Lake, Burnt Lake, Boulder Lake, Big Sandy Reservoir, Eden Valley Reservoir, and Fontenelle Reservoir, in addition to numerous Wind River Range high mountain lakes. In the western part of the basin are Viva Naughton and Kemmerer No. 1 Reservoirs. To the south are Meeks Cabin and Stateline Reservoirs, and to the east is the High Savery Reservoir in the Little Snake River watershed.

Miller (2003) delineated six hydrologic regions in Wyoming on the basis of peak flow characteristics. Much of the Green River basin is in the High Desert Region under this delineation. Streams experience relatively lower peak flows. While runoff in upper portions of the basin at higher elevations are dominated by snowmelt, High Desert Region streams such as Bitter Creek are more strongly influenced by low to moderate intensity regional precipitation (Miller 2003). Due to the low precipitation, flows are commonly ephemeral or intermittent in many of these streams with sources not derived from mountainous regions (Mason and Miller 2004). Flows are commonly perennial for snowmelt streams derived from mountainous sources.

All 11 habitat types defined in this SWAP (e.g., sagebrush shrublands, riparian, etc.,) occur in the watershed and are based on combinations of Ecological Systems (ES) developed by NatureServe (Comer et al. 2003, NatureServe Explorer 2009). The determination and delineation of ES is based on land cover maps produced by the Northwest Gap Analysis Project (NWGAP 2010). Land cover mapping under NWGAP for the Green River basin is in USGS mapping zone 22 (Wyoming Basins). Of the 173 ES identified under NWGAP, 66 occur in the Green River basin (excluding developed and open water classes). The most prevalent class by far is Inter-Mountain Basins Big Sagebrush Steppe. The most common SWAP habitats are sagebrush shrublands (53%), desert shrubland (21%), and foothill shrubland (6%). Indeed, the Green River basin is defined by vast expanses of sagebrush. Associated species assemblages, threats, and conservation actions of these and other habitats in this watershed are addressed in separate SWAP chapters.

Land use includes all the customary western public lands players except that the degree of oil and natural gas development is extraordinary and particularly noteworthy. Two large energy development projects are ongoing in the upper basin: the Pinedale Anticline Oil and Gas Exploration and Development Project and the Jonah Infill Drilling Project (Bureau of Land Management 2006a, 2008c). These projects involve hundreds of well pads and hundreds of miles of access roads and pipeline. These projects re-inject produced water or use it for drilling and dust control, and extensive hydraulic fracking has occurred with unknown impacts to groundwater. The areas drain to the New Fork River, Green River, and Big Sandy. Many of these minor drainages are intermittent and ephemeral (Clark and Davidson 2009). Large energy developments in the Muddy Creek drainage basin include the Continental Divide-Creston Natural Gas Development Project and the Atlantic Rim Natural Gas Field Development Project (Bureau of Land Management 2006b, 2006c). Wind energy development projects have been pursued extensively in recent years and include the Chokecherry and Sierra Madre Wind Energy Project in the Muddy Creek drainage (Bureau of Land Management 2009). A water pipeline has been proposed to transfer water from the Green River across Wyoming to Colorado's Front Range, and an Environmental Impact Statement (EIS) is being prepared (U.S. Army Corp of Engineers 2010).

Land management in the Green River basin is dominated by three BLM District Offices: Pinedale, Rock Springs, and Rawlins. Resource Management Plans (RMPs) developed for these

districts describe land management direction, resources, and allocation of uses (Bureau of Land Management 1997, 2008a, and 2008b). In addition to mineral development, livestock grazing is one of the most obvious and long-term land uses in the basin. Irrigated acreage throughout the basin is primarily directed toward livestock forage, and alfalfa is grown where conditions allow (Green River Basin Water Plan 2001). Irrigation is almost exclusively via flood irrigation application, although localized areas of heavier sprinkler use occur around the communities of Farson and Eden in the Big Sandy drainage. Seasonal dewatering of tributary stream segments occurs (e.g., LaBarge, Middle Piney, Cottonwood, and South Piney creeks near their confluence with the Green River). Larger municipalities include Green River, Rock Springs, Pinedale, Kemmerer, and Baggs.

Like geology, water quality varies dramatically throughout the basin. Fremont Lake and the Green River upstream from the New Fork River confluence to the Wilderness boundary are designated by the Wyoming Department of Environmental Quality (DEQ) as class 1 water, recognizing their outstanding features and protecting them from water quality degradation (Wyoming Department of Environmental Quality 2001). Salinity control measures have been implemented to reduce input of salts into the Green River from irrigated agriculture, particularly in the Big Sandy sub-basin (Wyoming Department of Environmental Quality 2010). Water quality monitoring by the DEQ is ongoing in Dry Piney Creek in the LaBarge Creek sub-basin to determine if oil wells, seeps, and stream degradation are affecting aquatic resources. Bitter Creek and its tributary Killpecker Creek, both Green River tributaries, flow through Rock Springs and are on the 303(d) List for elevated fecal coliform (Wyoming Department of Environmental Quality 2010). High chloride concentrations in these streams are believed to derive from local soils and turf grass recreational areas in Rock Springs (Wyoming Department of Environmental Quality 2010). Another impaired water in the basin is a reach of the Hams Fork River in Kemmerer, known for high pH, associated with nutrient enrichment. The Blacks Fork River is on the 303(d) List for exceeding *E. coli* criteria. Finally, the Smiths Fork and its tributary East and West Forks and Willow Creek were also listed for issues with *E. coli* and stream channel degradation. Habitat improvement efforts have improved conditions and resulted in removal of the East and West Forks from the 303(d) List (Wyoming Department of Environmental Quality 2010).

Aquatic Wildlife

Fish

The native fish community of the Green River basin in Wyoming is arguably the most imperiled in the state. Twelve species and subspecies were found historically in the basin, three of which have been extirpated. The basin is also home to four of Wyoming's five NSS1 fishes, the bluehead sucker *Catostomus discobolus*, flannelmouth sucker *Catostomus latipinnis*, roundtail chub *Gila robusta*, and the federally endangered Kendall Warm Springs dace *Rhinichthys osculus thermalis* (Table 3). The native community also included at least three of the four federally endangered species of the Colorado River basin, the Colorado pikeminnow *Ptychocheilus lucius*, razorback sucker *Xyrauchen texanus*, and bonytail *Gila elegans,* all of which have been extirpated from the state. The Colorado pikeminnow and razorback sucker were historically found in the torrential, big river habitat in canyon reaches of the Green River, downstream of the Wyoming/Utah state line, which are now inundated by Flaming Gorge Reservoir. Both species were likely seasonal residents in Wyoming waters of the Green River below the town of Green River. No conclusive observations of the humpback chub *Gila cypha* are known for the Green River in Wyoming. If present historically, the humpback chub was likely a rare migrant from steep gradient, canyon reaches of the Green River in Utah now inundated by Flaming Gorge Reservoir.

The native chub community of the Green River basin in Wyoming is known to have included bonytail and roundtail chub *Gila robusta*.

However, historic Wyoming accounts of bonytail and roundtail chub are impossible to discern because these species were not consistently distinguished. Simon (1951) describes *Gila robusta robusta* as the "River Roundtail; Bonytail" and his records probably included both species. Bosley (1960) refers to *Gila robusta robusta* as the "bonytail" and based on the photographs in his report, his records likely also include both the roundtail chub and the bonytail. He reported that "There appears to be a change in the physical characteristics of the fish in the extreme lower section of the study area, from Flaming Gorge downstream. Many of the fish taken in this section of the Green River had a very pronounced hump," and he refers to these as "humpback bonytails." The majority of Bosley's "bonytail" were probably "roundtail chub," and the fish he referred to as "humpback bonytails" were probably bonytail, but may have included a few humpback chub.

Table 3. Fishes present in the Green River Basin. * denotes Species of Greatest Conservation Need (SGCN). X denotes extirpated from Wyoming. E denotes federally endangered species. U denotes fishes that may have been present in Wyoming, but historic presence has not been confirmed.

Native game	Native nongame	Nonnative game	Nonnative nongame
Colorado River cutthroat trout*	Razorback sucker XE	Bonneville cutthroat trout	Bonneville redside shiner
Mountain whitefish*	Colorado Pikeminnnow XE	Brook trout	Common carp
	Bonytail XE	Brown trout	Creek chub
	Humpback chub EU	Burbot	Fathead minnow
	Kendall Warm Springs dace* E	Channel catfish	Iowa darter
	Bluehead sucker*	Golden trout	Lake chub
	Roundtail chub*	Grayling	Longnose dace
	Speckled dace	Kokanee salmon	Longnose sucker
	Mottled sculpin	Lake trout	Northern leatherside chub
	Mountain sucker	Largemouth bass	Sand shiner
		Rainbow trout	Utah chub
		Smallmouth bass	Utah sucker
		Snake River cutthroat trout	White sucker
		Splake	
		Tiger trout	
		Yellowstone cutthroat trout	

Based on Bosley (1960) and Binns (1967), it is likely that, prior to the Green River chemical treatment in 1962 and subsequent impoundment of Fontenelle and Flaming Gorge reservoirs, roundtail chub were common in the mainstem Green River downstream from present-day Seedskadee National Wildlife Refuge and in some tributaries, including the Little Snake River and Blacks Fork. Roundtail chub were also found in some of the headwater lakes near Pinedale. It is likely that the bonytail and razorback sucker were seldom found upstream of the steep, canyon sections of the Green River near the Utah border. The Colorado pikeminnow was once found as far upstream as the town of Green River, Wyoming. However, by the 1950s and 1960s, few fish were seen in the Green River downstream of the town of Green River due primarily to water pollution. Raw sewage from the towns of Green River and Rock Springs flowed directly to the Green River beginning in the 1920s or 1930s, as did effluent from a Union Pacific railroad maintenance facility

(Bosley 1960), fouling the river as far downstream as Brown's Park, Utah (Quartarone 1995). Any remaining bonytail, razorback sucker, and Colorado pikeminnow were extirpated at some point following the construction of Flaming Gorge Reservoir when any suitable big river habitat in Wyoming was inundated, and populations below Flaming Gorge were prevented from moving upstream. These three species were extirpated from Wyoming by 1970 (Baxter and Simon 1970) and are now federally listed as endangered, along with the humpback chub.

The bluehead sucker, flannelmouth sucker, and roundtail chub, commonly referred to as the Three Species, were historically distributed more widely than were the endangered Colorado River fishes. The Three Species inhabited a number of tributary streams and headwater lakes, in addition to the mainstem Green River and have persisted in the basin since the chemical treatment project and the construction of Flaming Gorge and Fontenelle reservoirs. However, the distributions and abundances of all three species have continued to decline. Bluehead suckers are now extremely rare in the Green River upstream from Fontenelle Reservoir. A single individual was sampled during electrofishing surveys on the Green River near the town of Daniel, Wyoming in 2008 (Darren Rhea, personal communication). Roundtail chub are no longer found in the mainstem Green River or in the Big Sandy subdrainage. Roundtail chub were last observed in the Big Sandy River at a site below Bone Draw in 1991 (Mark Fowden, personal communication). The species was last seen in the lower Green River (below Fontenelle Reservoir) in September 1986 (Johnson and Oberholtzer 1987), and a single individual was observed above Fontenelle Reservoir in 1993 (Dave Zafft, personal communication).

The WGFD initiated a detailed status assessment of the Three Species in the Green River basin in 2002. A total of 377 sites in 13 subdrainages throughout the basin were sampled over the next 5 years, 309 of which contained fish. This project provided information needed to accurately assess the relative abundances of the Three Species, describe current distributions, and assess threats. Detailed results of this assessment and management recommendations for the Three Species are provided in Gelwicks et al. (2009). Although flannelmouth sucker were found at 84 sites across 13 subdrainages, and bluehead sucker were found at 22 sites in seven subdrainages, nearly all sites contained larger populations of the introduced white sucker. The persistence of both native catostomid species is threatened by hybridization with the white sucker. Flannelmouth sucker were found in the absence of white sucker only in upper Bitter Creek. Similarly, bluehead sucker were found in the absence of white sucker only in Ringdahl Reservoir, a 13-acre reservoir on the divide between the Blacks Fork and Henrys Fork sub-basins (Gelwicks et al. 2009). Roundtail chub were found at 10 sites in the Little Snake River drainage and 18 sites in the Blacks Fork drainage (Gelwicks et al. 2009). Lentic populations of roundtail chub and flannelmouth sucker are also known from New Fork, Willow, Fremont, Halfmoon, Little Halfmoon, and Burnt lakes in the Green River headwaters. The status assessment clearly indicated that immediate and aggressive management actions were necessary to conserve these species in the Green River basin in Wyoming.

The mountain sucker *Catostomus platyrhynchus* is the most widespread of the native sucker species in the basin. However, Simon (1951) did not consider the mountain sucker native to the Green River basin and likely attributed many early observations of this species to the meristically similar bluehead sucker (Gelwicks et al. 2009). The mountain sucker was sampled at 173 of the sites sampled from 2002–2006 and was present in 12 of the 13 sub-drainages sampled (Gelwicks et al. 2009). The species is also present in the six large headwater lakes mentioned above. Speckled dace *Rhinichthys osculus* and mottled sculpin *Cottus bairdi* were the two most common native species during the 2002–2006 surveys and were found at 226 sites

(13 basins) and 135 sites (11 basins), respectively.

The Kendall Warm Springs dace is endemic to Kendall Warm Springs, a 384 ft stream originating from thermal springs tributary to the upper Green River. The Federally Endangered species has been studied in detail, including investigations into life history, behavior, ecology, and habitat. Extensive monitoring is conducted to monitor the status of the species.

Two gamefish are native to the Green River basin, the mountain whitefish *Prosopium williamsoni* and the Colorado River cutthroat *Oncorhynchus clarkii pleuriticus*. The mountain whitefish was the most common species in the Green and New Fork rivers above their confluence prior to construction of Fontenelle Reservoir and were less abundant, but common in the Green River below the confluence (Bosley 1960, Binns 1977). Gelwicks (2009) collected mountain whitefish at 30 sites in 6 of the 13 sub-basins sampled, including the upper Green and New Fork rivers. Biologists are concerned that anecdotal observations suggest that mountain whitefish have been extirpated from some of the large glacial lakes on the southern slope of the Wind River range and populations in many other parts of the Green River basin have declined recently.

The Colorado River cutthroat is native only to the Green River basin in Wyoming. The subspecies was abundant in the Green River headwaters and many tributaries in the basin in the mid-1800s (Trotter 1987), but by the middle of the last century, this cutthroat was known to be rare and relegated to headwater streams in the Green and Little Snake drainages (Simon 1951). In 1972, Robert Rush Miller included the subspecies on his list of threatened freshwater fishes of the United States (Trotter 1987).

Beginning in 1964, the WGFD initiated a long-term study to determine the status of remaining Colorado River cutthroat populations in Wyoming. Forty tributary streams and two lakes were found to contain populations of native cutthroat trout, but only twelve streams and two lakes contained populations with little or no evidence of hybridization with nonnative trout. All of the remaining populations of Colorado River cutthroat were on small tributaries of the Green, Blacks Fork and Little Snake rivers. Binns (1977) attributed the decline to hybridization and competition with introduced trout, as well as habitat changes associated with timbering, livestock, and irrigation practices. Soon after this assessment was complete, the WGFD began funding and initiating projects to further describe the remaining cutthroat populations, habitat needs, and threats (Jespersen 1981, Jespersen and Conder 1986, Oberholtzer 1987, Quinlan 1980, and Remmick 1981). The WGFD also began to develop plans to conserve the species. The first Colorado River cutthroat five-year management plan was completed in 1987 and included activities to conserve the subspecies within all of the major enclaves in Wyoming. A number of other interagency plans followed (CRCT Coordination Team 1994 and Little Snake River Working Group 1994), culminating in the preparation of the 2001 Conservation Agreement and Strategy developed by the WGFD, the Utah Division of Wildlife Resources, the Colorado Division of Wildlife, US Forest Service, and the Bureau of Land Management (CRCT Task Force 2001).

The Colorado River cutthroat trout was petitioned for listing as endangered in December 1999. In 2007, following years of inaction, lawsuits, and status reviews, the U.S. Fish and Wildlife Service determined that listing the subspecies as threatened or endangered under the Endangered Species Act was not warranted. The petitioner sued again in November 2009, challenging the 2007 ruling. A decision has not yet been issued.

The Green River basin is also home to nearly 30 species of nonnative fishes. Sixteen introduced gamefish species and thirteen introduced nongame species are now found in the basin (Table 3). These species sustain many of the most important sport fisheries in southwest Wyoming, including the Green River trout fishery and all of the important large reservoir

fisheries in the region. However, exotic fishes pose one of the primary threats to the persistence of native game and nongame species in the Green River basin.

Aquatic Reptiles
No turtles are native to the Green River basin, and none have been introduced.

Freshwater Mollusks and Crayfishes
Wyoming is still in the discovery phase in terms of its freshwater mussels and gastropods, and few published accounts exist (Beetle 1989, Henderson 1924, Hoke 1979, Hovingh 2004); however, no native mussels are known from the Green River basin.

Beetle (1989) contains some of the only published observations of gastropods in Wyoming, listing species occurrences by county. In 2009, the WGFD funded a project at the University of Wyoming (UW) to conduct a literature review, identifying the current and historical information on freshwater gastropod distributions in Wyoming and to develop gastropod collection methods for the WGFD, and assess the distribution of freshwater gastropods in the Bighorn and North Platte river drainages in Wyoming. This project did not include sampling in the Green River basin, but the UW research project will provide gastropod sampling protocols. Baseline survey data are needed for all gastropods in the Green River basin.

No crayfish species are known to be native to the Green River basin in Wyoming; however, during a 1985–1987 survey, *Orconectes immunis* and *O. virilis* were found in the Green River drainage where they have been introduced (Hubert 1988). A second survey in 2007–2009 verified the presence of *O. immunis* in Fontenelle Reservoir and the Big Sandy River. The distribution of *O. virilis* was much more widespread and included occurrences in the Green, Black's Fork and Hams Fork Rivers, Flaming Gorge Reservoir, Jim Bridger Pond, and the Little Snake River and a number of its tributaries. The species was also documented in Meadow Lake, in the headwaters of Pole Creek in the New Fork River drainage (Hubert 2010).

Table 4. Species of Greatest Conservation Need present in the Green River Basin

Fish
Bluehead sucker
Colorado River cutthroat
Flannelmouth sucker
Kendal Warm Springs dace
Mountain whitefish
Roundtail chub

Identification of Conservation Areas

Conservation areas have been identified for the Three Species and Colorado River cutthroat trout.

Five priority subdrainages for the management of Wyoming's Three Species were recently identified based on status and distribution assessments: 1) Muddy Creek (tributary to the Little Snake River), 2) Big Sandy River, 3) Little Sandy Creek, 4) Upper Bitter Creek, and 5) the Finger Lakes near Pinedale (Senecal et al. 2010).

Ringdahl Reservoir also supports an isolated population of bluehead sucker.

Priority conservation areas for the Colorado River cutthroat trout include multiple waters in the Little Snake River drainage, the Blacks Fork River drainage, and tributaries to the mainstem Green River. *Little Snake River enclave* conservation areas include: North Fork, West Branch of the North Fork, and the upper Roaring Fork of the Little Snake River; Dirtyman Creek watershed and upper Deep, Mill, Hatch, and Hells Canyon creeks in the Savery Creek watershed; Haggarty Creek; and Littlefield Creek in the Muddy Creek watershed. *Blacks Fork River enclave*: conservation areas include Muddy Creek, upper Sage and Gilbert creeks; and all tributaries to the upper Hams Fork River. Conservation areas in the *Green River Westside tributaries:* include the LaBarge, Horse, and Cottonwood creek watersheds;, North Piney Lake and the Lake Creek watershed, upper Beaver Creek and Trail Ridge creeks in the South Piney watershed, Tosi,

Tepee, Rock, Klondike, Jim, and Gypsum creeks.

The Wyoming Game and Fish Department Strategic Habitat Plan (WGFC 2009) references multiple goals, two of which are to conserve and manage wildlife habitats that are crucial for maintaining terrestrial and aquatic wildlife populations for the present and future, and to enhance, improve, and manage priority wildlife habitats that have been degraded. . Crucial habitat areas were identified to accomplish the first goal, and enhancement areas were identified to accomplish the second. . All of the conservation areas listed above are also identified as crucial habitat areas in the Strategic Habitat Plan.

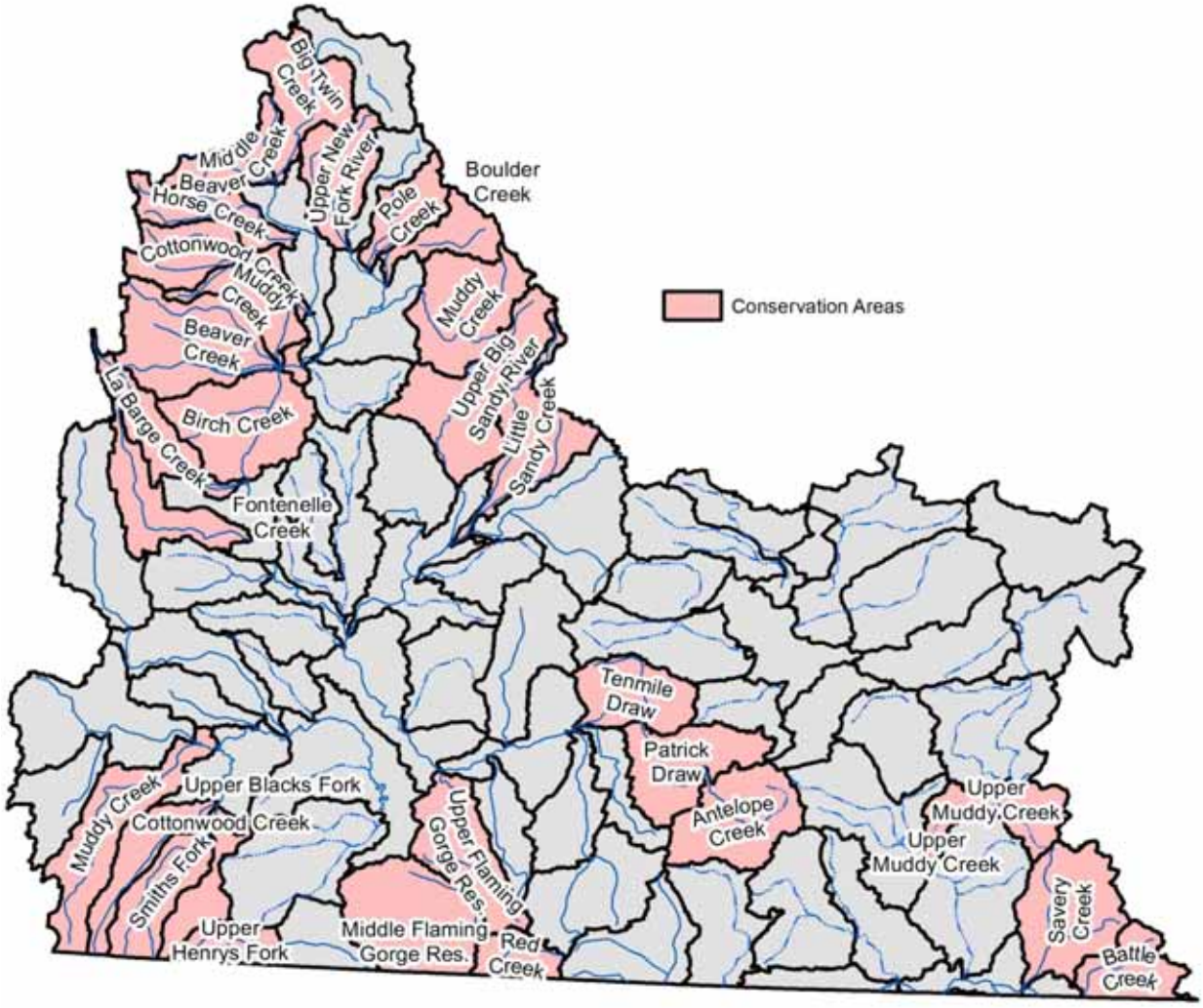

Figure 4. Aquatic Wildlife Conservation Areas in the Green River Basin.

Threats

Energy development – High
The diversity and intensity of ongoing and potential energy development constitutes a threat to the persistence of aquatic wildlife. Energy development as a leading conservation challenge in Wyoming is explored in a separate chapter of this SWAP. Native fish distributions in sub basins like Muddy Creek, Bitter Creek, Blacks Fork, Currant Creek, Big Sandy and Upper Green River are all potentially threatened

by water quality, water quantity, sediment, fragmentation, or other effects from energy development activities. Exploration and development of natural gas, oil, coal bed methane, wind, and oil shale involve various degrees of road building and other surface disturbances that can directly or indirectly increase sediment supply. Runoff from road systems and hardened areas may enhance such sediment issues. Culvert crossings associated with new roads threaten fish passage and access to habitats if not installed correctly. Spills from pipelines or machinery can impair water quality. Surface or groundwater pumping for drilling, fracking, or other methods can result in localized habitat loss.

Invasive species – High

Although many of the introduced species in the basin compete with, prey upon, hybridize with, or otherwise negatively impact native species, the white sucker, burbot, and brook trout pose the most significant and immediate threats. White sucker are currently found throughout the basin and threaten the persistence of native flannelmouth and bluehead suckers through competition and hybridization. Burbot, a voracious exotic predator, are expanding in the basin and pose a significant threat to flannelmouth and bluehead suckers in the Green and Big Sandy Rivers and to the Three Species (bluehead sucker, flannelmouth sucker and roundtail chub) in the Blacks Fork and Hams Fork. Brook trout pose a significant threat to the important conservation populations of Colorado River cutthroat trout.

Aquatic invasive species (AIS) including fish, pathogens, plants, and mollusks are currently present in Wyoming, most notably the New Zealand mudsnail and the parasite that causes whirling disease. These AIS can alter the native species in a watershed through competition, disease, shifts in food availability, and direct mortality. While AIS currently in Wyoming can cause problems and need to be controlled, the most significant known threat to Wyoming's native species is from zebra and quagga mussels, based on their proximity to Wyoming and demonstrated negative impacts in other areas. Zebra and quagga mussels can out-compete native mussels for space and resources and will attach to and smother native mussels causing mortality (Cummings and Mayer 1992, Strayer 2008). They filter plankton out of the water column at high rates (up to a liter per day per individual) so that little plankton remains available for fish populations, resulting in their decline (Benson 2009). In addition, invasive mussels produce pseudofeces which can lead to harmful algal blooms affecting numerous aquatic species.

The Wyoming Aquatic Invasive Species Act of 2010 allowed the WGFD to implement the Wyoming AIS Program with the goal of executing a coordinated strategy to prevent, control, contain, monitor, and whenever possible, eradicate aquatic invasive species from the waters of the state. The Wyoming AIS Management Plan of 2010 is the framework for this three-part strategy which includes 1) outreach and education, 2) inspection of watercraft to increase boater awareness of AIS threats and prevention and to intercept high risk watercraft that may be transporting AIS, and 3) monitoring of waters to allow for early detection and rapid response to any new AIS populations in the state.

Water development/altered flow regimes – High

Natural flow regimes in stream segments around the state have been altered by human activities including irrigation diversions and water developments for more reliable water supply, hydropower, and flood control. These altered flow regimes are also a consequence of broad-scale changes in land use and management associated with agriculture, grazing, timber harvest, and housing development (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes). The majority of the Green River basin is publicly owned. Because it is such an arid region, the limited amount of irrigated cropland has a significant impact on aquatic wildlife in some areas. Besides the direct effects of dewatering, irrigation diversions impede movement, and some fish are lost to entrainment into the

irrigation ditches. Lateral and longitudinal hydrologic connectivity and physical access by fish populations to all habitats necessary to complete their life history is limited throughout the drainage. In-channel obstructions and increased dewatering have reduced some populations of native fishes.

The need for additional water for human use will intensify in the immediate future, and that trend will be especially evident in the western U.S. This trend has multi-faceted consequences for fish and wildlife and the habitats upon which they depend. In Wyoming, trans-basin water diversions are not uncommon and are likely to be further proposed and pursued. Energy diversification, including hydropower development, may increase as the nation's energy demands rise. Warmer conditions with more erratic precipitation— which some predict for Wyoming's future climate—may heighten the need for additional water development (water storage) for municipal and agricultural purposes.

The likely trend will be water development projects closer to the delivery point and conveyance via pipelines instead of stream channels. Additional emphasis will likely be placed on lining irrigation ditches and other practices to more efficiently use water for consumptive purposes. The net effect of all such water management practices will be to alter the timing, magnitude, and duration of natural hydrographs and reduce intra- and inter-annual variability in Wyoming's streams and associated riparian corridors (see Wyoming Leading Wildlife Conservation Challenges – Climate Change, and the Riparian habitat chapter).

Several water development projects have been proposed for the upper Green River Basin. Proposed sites are located on the Green River and Wyoming Range and Wind River tributaries (Green River Basin Water Plan 2001). Several of these proposals are located within CRC conservation areas. Dam construction has been proposed on the Green River and several tributaries in CRC conservation areas.

While water development can threaten native species, some introduced species, including those in popular sport fisheries, have thrived in the face of water development. The simplification of natural systems by human development tends to favor species with generalized and broad habitat requirements. For example, the lake trout fisheries in Flaming Gorge Reservoir depends on the consistent deep water and forage production inherent in this man-made water body. Stable stream flow releases from dams, with relatively low peak flows and relatively high base flows, perpetuate productive sport fisheries like the Green River below Fontenelle Reservoir.

Drought and climate change – moderate
Climate change may increase air and surface water temperatures, alter the magnitude and seasonality of precipitation and runoff, and shift the reproductive phenology and distribution of plants and animals (Seavy et al. 2009) (see Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Changes in precipitation patterns under various climate change scenarios are predicted to produce peak flows earlier in the yearly cycle and to lower base flows (Barnett et al. 2004). Drought lowers water tables, leading to reduced plant growth and reproduction. Riparian vegetation declines lead to lower bank stability, higher siltation and altered stream habitat quality and quantity. Lower water levels increase water temperatures and reduce the habitat available to fish and other aquatic wildlife. All these conditions can be detrimental to the health and reproductive success of all aquatic wildlife species.

Conservation Initiatives

The first Colorado River cutthroat trout five-year management plan in Wyoming covered the years 1987–1992. This plan included activities within all the major enclaves: the Green River, Blacks Fork, North Fork Little Snake River, and Big Sandstone Creek drainages. Status reports were prepared for each enclave, including the Green River westside tributaries (Remmick and Nelson 1992). Recommendations from this

status report included the need for separate management plans for each enclave.

In 2001, a Conservation Agreement and Strategy was developed to reduce or eliminate threats to remaining populations of Colorado River cutthroat trout. This strategy was revised in 2006 (CRCT Coordination Team 2006).

The WGFD Pinedale and Green River fisheries management crews have actively worked to conserve populations of the Colorado River cutthroat trout in the westside tributaries to the Green River, the north tributaries to the Uinta Mountains, and in the headwaters of the Little Snake River basin. Chemical treatments and barriers have been used to remove nonnative salmonids from important conservation populations of cutthroat trout. The first chemical treatments in the Little Snake River drainage were conducted in Deep and Haggarty creeks in 1987 and in Mill Creek in 1988. Since that time, chemical treatments in the Little Snake sub-basin have been conducted to remove nonnative salmonids from the entire North Fork Little Snake drainage and portions of Deep Creek, the upper Roaring Fork, Littlefield Creek, and upper Muddy Creek.

In 2008 and 2009, WGFD personnel utilized State Wildlife Grant funding to evaluate the impacts of water diversion structures on Colorado River cutthroat populations in the headwater tributaries of the Little Snake River. Biologists investigated entrainment and evaluated impacts to upstream or downstream movements of cutthroat (Luginbill 2010).

The largest fish restoration project ever conducted in Wyoming was conducted in the LaBarge Creek drainage, a westside tributary to the Green River, to restore Colorado River cutthroat trout to approximately 58 miles of this stream and tributaries. The chemical treatment project culminated with the initial stocking of cutthroat in August 2007.

A detailed assessment of the status of the Three Species as of 2006 was completed by Gelwicks et al. (2009). Numerous other research projects have also been conducted to answer questions necessary to facilitate conservation of the Three Species in Wyoming (Beatty 2005, Bower 2005, Compton 2007, Douglas and Douglas 2008a, Douglas and Douglas 2008b, Douglas and Douglas 2008c, Douglas et al. 2008, McDonald et al. 2008, Sweet 2007, Banks 2010, and Laske 2010), most of which were funded by the WGFD and U.S. Bureau of Reclamation. Information from these projects was used to develop conservation plans for the Three Species (Cavalli 2006, Senecal et al. 2010). Long-term plans include the removal of nonnative species from Big Sandy River and Little Sandy and Muddy Creeks.

Chemical treatments and temporary fish passage barriers have been used to eliminate nonnative fishes from the Muddy Creek drainage (Little Snake River) upstream of McKinney Creek to restore Colorado River cutthroat. Long-term plans include the restoration of native bluehead sucker and flannelmouth sucker populations downstream to the Weber head cut stabilization structure in this drainage.

The WGFD has utilized funding from the Wyoming Governor's office to begin removal efforts and planning for additional chemical treatment projects in priority drainages in the Green River basin. Fish weirs, seining, single- and three-pass electrofishing techniques were used to remove invasive fish and sample fish populations in 2009. More than 15,000 nonnative fish were removed from the Big Sandy River and the Little Sandy, Bitter, and Muddy Creek drainages, including nearly 12,000 white sucker and white sucker hybrids and more than 700 burbot. Mechanical removal efforts resumed in 2010. Department personnel are also investigating methods to salvage and hold native flannelmouth and bluehead suckers during chemical treatment. Native sucker–white sucker hybrids and mountain suckers are being used as surrogates in experimental holding operations at the University of Wyoming's Red Buttes Laboratory. The objectives of this project are to develop effective methods for transportation, holding, feeding, and eventual repatriation of native suckers following chemical treatments in priority drainages.

The WGFD is also planning to begin work on the design of a fish passage barrier on Big Sandy River to prevent recolonization of the area that is slated for eventual chemical treatment to remove nonnative species. Funding from the Wyoming Governor's office was also used to fund a project conducted by the Colorado State University Larval Fish Laboratory to determine the abundance of flannelmouth and bluehead sucker larvae that might drift over the proposed barrier and be lost from the upstream population. Construction of the barrier is contingent upon the results of this research project.

Unique lentic populations of roundtail chub occur in a number of lakes. In 2009 WGFD transplanted roundtail chub from Little Halfmoon Lake to Scab Lake located in the southern foothills of the Wind River Mountain range. These populations are threatened by predation by introduced lake and brown trout. The WGFD has been working to identify potential refuge lakes for roundtail chub. In 2009, the WGFD transplanted roundtail chub to Scab Lake. Additional transplants may occur if suitable refugia are identified in the next couple years.

The WGFD's Fish Division has developed basin management plans to guide management across the state. These plans provide background and history of aquatic wildlife management as well as management direction for sportfish, SGCN, and aquatic habitat. The management direction includes reference to the SWAP and the Strategic Habitat Plan, attempting to incorporate management direction from those two plans that is relevant to each basin into each basin management plan.

The WGFD has the opportunity to comment on most environmentally sensitive construction or management actions submitted through the National Environmental Policy Act (NEPA) review process. Projects include state and federal lands and private ventures that require action by state or federal agencies. The WGFD regularly provides recommendations to protect habitat and populations of aquatic wildlife at the project level. Department efforts are guided by Wyoming Game and Fish Commission mitigation policy (WGFC 2008).

The WGFD has a rigorous collection permitting system that restricts commercial, scientific, and educational activities (WGFC 2005a) and provides protection to aquatic wildlife. The regional fisheries supervisor reviews all requests for permits and recommends either approval or rejection of the request based on merit and impacts to the resource in question.

The movement of fish by WGFD employees is critical to address many of the aspects, thus the intent, of our mission. However, the act of moving or importing fish also presents risks that could potentially jeopardize that mission. To address this conflict, a method to determine the relative level of risk associated with any proposed fish importation and/or transplant was developed. The WGFD utilizes Hazard Analysis and Critical Control Point (HACCP) procedures (Gunderson and Kinnunen 2001) and has developed a risk assessment matrix from these procedures to manage transplants, thereby protecting the aquatic resources within the state. Using these procedures and matrix, WGFD fisheries managers develop documentation that explains whether a transplant is nearly free of risk. The documentation must address all aspects of the transplant including, but not limited to, verifying that the fish being transplanted are disease free, the water source is disease free, and non-target species are excluded from transplant. Source populations of salmonids are verified disease free by collecting a standardized number of fish, having them inspected by an American Fisheries Society-certified Fish Health Inspector for all known pathogens, and receiving disease free certification. The resulting documentation is reviewed and either approved or denied by the WGFD Chief of Fisheries. No whirling disease-infected trout, native or nonnative, are stocked by the WGFD, and they are not allowed to be stocked by others (WGFC 2003).

In Wyoming, state Game and Fish Commission policy precludes the stocking of fish into waters that are capable of maintaining satisfactory, self-sustaining fisheries (WGFC 1998). A common

sense, biologically based protocol for fish rearing and stocking has historically been followed in Wyoming, with emphasis on management for native fish and wild fish wherever possible (Wiley 1995). Only 3% of the streams listed in the Wyoming Game and Fish Department database inventory are stocked annually. Maintenance of native cutthroat trout subspecies has been a management priority for more than 40 years (Stone 1995), and protection from stocked predators of native nongame fishes has been an important consideration for at least the last decade.

Wyoming has regulations prohibiting unauthorized stocking of fish or fish eggs. Private citizens can only stock waters in Wyoming following a WGFD permitting system that includes review by the responsible regional fisheries supervisor (WGFC 2005a). The WGFD has increased education efforts regarding the problems associated with illegal introductions of fish. The Wyoming Legislature increased the penalties for illegal fish stocking in 2010, and the Wyoming Wildlife Protectors Association has offered $2,500 rewards for information leading to the conviction of individuals found illegally moving or stocking fish.

Habitat management efforts are guided by the Strategic Habitat Plan (SHP) that was adopted by the Wyoming Game and Fish Commission in January 2009. The SHP includes five goals: 1) Conserve and manage wildlife habitats that are crucial for maintaining terrestrial and aquatic wildlife populations for the present and future, 2) Enhance, improve, and manage priority wildlife habitats that have been degraded, 3) Increase wildlife-based recreation through habitat enhancements that maintain or increase productivity of wildlife, 4) Increase public awareness of wildlife habitat issues and the critical connection between healthy habitat and abundant wildlife populations, and 5) Promote collaborative habitat management efforts with the general public, conservation partners, private landowners, and land management agencies. Efforts are focused in priority areas in each of the management regions and include "crucial" areas essential for conservation of important species and communities, and "enhancement" areas, which represent places where work should be conducted to manage or improve wildlife habitat.

Studies of relationships between stream flow and habitat for Colorado River cutthroat trout have occurred throughout the Green River basin. Thirty instream flow water rights have been filed by the WGFD and Wyoming Water Development Office and permits approved by the State Engineer. These instream flow water rights permits protect 107 miles of streams distributed among all of the Colorado River cutthroat trout enclaves from junior water appropriators (Paul Dey, personal communication).

Habitat enhancement and restoration work in recent years has increased the resiliency and improved the condition of aquatic habitats for Colorado River cutthroat trout and the Three Species. Watershed restoration work in the Little Mountain Ecosystem east of Flaming Gorge, including prescribed burns, grazing management, and beaver restoration, has improved portions of the Currant Creek, Red Creek, Trout Creek and Sage Creek watersheds. The Muddy Creek drainage, key for the Three Species, has been the focus of careful livestock management, riparian enhancement and protection efforts, and riparian monitoring to maintain or improve stream conditions.

The Kendall Warm Springs dace (KWD) is federally listed as an endangered species. The U.S. Fish and Wildlife Service is updating the recovery plan for KWD. WGFD is participating in the process to update that plan.

Aspen treatment projects in the Wyoming Range have been on-going for several years. The plan is to complete treatments along the entire Wyoming Front Range within the next 10 years.

Triple Peak Forage Reserve and Wyoming Range Allotment Complex are two forage reserves/closures that have occurred in the Wyoming Mountain Range in the last 5 years.

Triple Peak Forage reserve is 58,675 acres and covers the headwaters of North Piney and Cottonwood watersheds, important Colorado River cutthroat conservation populations. The Wyoming Range Allotment complex is 67,000 acres and protects the headwaters of North Horse and South Horse creek watersheds.

The Wyoming Landscape Conservation Initiative (WLCI) coalesced in the mid 2000s and is a long-term science-based effort to assess and enhance aquatic and terrestrial habitats at a landscape scale in Southwest Wyoming. To ensure Southwest Wyoming's wildlife and habitat remain viable in areas facing development pressure, the U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Geological Survey, USDA Forest Service, National Park Service, the U.S. Bureau of Reclamation, the Wyoming Department of Agriculture, the Wyoming Game and Fish Department, local conservation districts, and local counties are implementing the WLCI. Details about WLCI conservation actions and science in southwest Wyoming are available at http://www.wlci.gov.

The Wyoming Legislature created the Wyoming Wildlife and Natural Resource Trust (WWNRT) in 2005. Funded by donations, legislative appropriation, and interest earned on a permanent account, the purpose of the program is to enhance and conserve wildlife habitat and natural resource values throughout the state. Any project designed to improve wildlife habitat or natural resource values is eligible for funding. The WWNRT is an independent state agency governed by a nine-member citizen board appointed by the Governor. The WGFD has partnered with the WWNRT to successfully implement a wide range of projects to benefit a broad array of Wyoming's wildlife.

Landscape Conservation Cooperatives (LCCs) are a new program of the U.S. Fish and Wildlife Service. The vision is that they serve as applied conservation science partnerships focused on a defined geographic area that inform on-the-ground strategic conservation efforts at landscape scales. LCC partners include U.S. Department of Interior agencies, other federal agencies, states, tribes, non-governmental organizations, universities, and other stakeholders. It is hoped that LCCs will enable resource management agencies and organizations to collaborate in an integrated fashion within and across landscapes. LCCs are intended to provide scientific and technical support to inform landscape-scale conservation using adaptive management principles. They are proposed to engage in biological planning, conservation design, inventory and monitoring program design, and other types of conservation-based scientific research, planning and coordination. It is hoped that LCCs will play an important role in helping partners establish common goals and priorities, so they can be more efficient and effective in targeting the right science in the right places. Products developed by LCCs should inform the actions of partners and other interested parties in their delivery of on-the-ground conservation. The WGFD will continue to participate in the LCC process as appropriate.

The National Fish Habitat Action Plan (NFHAP) was developed by a coalition of fisheries professionals, state and federal agencies, tribes, foundations, conservation and angling groups, businesses and industries, all determined to reverse the declines of America's fish habitats. In its design, the plan encompasses five important lessons that emerge from America's past efforts to protect and restore fish habitat: 1) Be strategic rather than merely opportunistic, 2) Address the causes of and processes behind fish habitat decline, rather than the symptoms, 3) Provide increased and sustained investment to allow for long-term success, 4) Monitor and be accountable for scientifically sound and measurable results, and 5) Share information and knowledge at all levels from local communities to Congress. The WGFD has been heavily involved with the development and implementation of the NFHAP. The WGFD is involved with three NFHAP partnerships: – the Great Plains Fish Habitat Partnership, the Western Native Trout Initiative, and the Desert Fishes Habitat Partnership. The latter two cover the Green River basin.

The mission of the Western Native Trout Initiative (WNTI) is: "To serve as a key catalyst for the implementation of conservation or management actions, through partnerships and cooperative efforts, resulting in improved species status, improved aquatic habitats, and improved recreational opportunities for native trout anglers across western states." Their vision is: "An increase in healthy, fishable western native trout populations resulting from sharper focus and commitment to action on common conservation needs of western native trout; enhanced public benefit resulting from multiple partners working together, sharing resources, and speaking with a united voice about the conservation and value of western native trout; and increased funding to accomplish strategic actions as a result of greater community and financial support from initiative partners and collaborators." By working together, the partners in WNTI are striving to implement the most strategic actions needed to benefit these trout. And by working together to establish secure populations, WNTI will also benefit anglers by enhancing recreational fishing opportunities for unique trout species across the West.

The Desert Fish Habitat Partnership's purpose is to conserve aquatic habitat in the arid west for desert fishes for the American people by protecting, restoring, and enhancing these unique habitats in cooperation with and in support of, state fish and wildlife agencies, federal agencies, tribes, conservation organizations, local partners, and other stakeholders. The Desert Fish Habitat Partnership seeks to address fish and habitat issues over a broad geographic area that encompasses the entirety of the Great Basin and Mohave deserts, and those portions of the Sonoran and Chihuahuan deserts that lie within the United States. The benefits of aquatic habitat conservation extend beyond desert fishes to include humans and other animal and plant species. Riparian habitats that depend on surface water not only support a significant number of terrestrial and avian species identified as priority conservation species in SWAPs, but also function to store water that supplements groundwater recharge. The declining status of so many desert fishes highlights the importance of preserving these aquatic habitats so that water is available not only for the native fish, but also for future generations of humans. The Partnership can play an important role in conserving water in the West for future generations.

Recommended Conservation Actions

Secure and enhance populations and habitats in SGCN priority areas.
Evaluate the feasibility of reducing populations of or removing nonnative fishes from priority conservation areas in the basin.

Determine the status and distribution of native aquatic wildlife assemblages with emphasis on Colorado River cutthroat trout, bluehead sucker, flannelmouth sucker, and roundtail chub.
Continue basin-wide surveys to identify fish distribution, relative abundance, and habitat preferences.

Conduct baseline surveys of aquatic gastropods in the Green River basin.

Assess the genetic purity of Colorado River cutthroat trout, bluehead sucker, flannelmouth sucker, and roundtail chub populations.
Collect and store tissue samples from individual populations for future genetic analysis.

Identify and reduce threats to native fish populations from nonnative species.
Eradicate burbot from conservation areas in the basin. Monitor burbot and white sucker distribution within the drainage.

Conduct annual monitoring of the Flaming Gorge Reservoir fish populations in order to assess the effects of burbot on the fishery.

Investigate feasibility and utility of building a barrier on the Big Sandy River to facilitate nonnative fish removal above the barrier.

Transplant native fish to areas of refuge from competing and hybridizing species.

Investigate options to reduce the spread of burbot to the Green River watershed upstream of Fontenelle Reservoir. Implement actions to suppress burbot throughout the basin.

Implement existing plans and agreements to conserve SGCN.
Implement the WGFD short-term plan for the Three Species in the Green River drainage (Senecal et al. 2010).

Represent the WGFD on the interagency Three Species conservation team and help implement the Range-wide Conservation Agreement and Strategy for the Three Species (Colorado River Fish and Wildlife Council 2004).

Represent the WGFD on the interagency Colorado River cutthroat trout conservation team and help implement the Range-wide Conservation Agreement and Strategy for Colorado River cutthroat trout (CRCT Coordination Team 2006).

Continue working with U.S. Fish and Wildlife Service on revising the recovery plan for Kendall Warm Springs dace. Continue working with U.S. Forest Service to protect Kendall Warm Springs.

Increase educational efforts about the ecological, economic, and social values of aquatic SGCN.
The importance and role of aquatic SGCN is poorly understood by the general public. Efforts should be enhanced to increase public education in this area.

Continue building voucher collections for all aquatic wildlife.
Continue to fill voids in voucher inventory for fish per WGFD protocol (Zafft and Bear, 2009).

.Determine if there is interest in voucher specimens of gastropods. If so, expand the voucher program to include those organisms.

Continue aquatic habitat work in the basin.

Supply flow or other information to the State Engineer's Office and Water Development Office to facilitate adjudication of instream flow water rights.

Monitor instream flow segments for compliance with approved instream flow levels. Pursue compliance as needed when water is available and in priority.

Develop instream flow water rights recommendations and filings for streams in the Muddy Creek drainage to maintain habitat for Colorado River cutthroat trout and the Three Species. Investigate feasibility of a water right recommendation in Bitter Creek for flannelmouth suckers.

Ensure ongoing diversion rehabilitation work on the Little Snake River includes features to facilitate upstream passage of native adult flannelmouth sucker, bluehead sucker, roundtail chub and Colorado cutthroat trout.

Continue protecting and enhancing riparian willow and sedge communities in the Muddy Creek drainage.

Investigate the feasibility of obtaining a water right in Bitter Creek for flannel mouth sucker.

Continue working with the BLM and Grizzly Wildlife Habitat Unit lessees to develop and implement livestock grazing plans that protect and maintain thriving riparian vegetation and sustain Muddy Creek drainage stream channels.

Explore water management approaches that enhance fish habitat.
Identify opportunities to work with private water right holders to manage water diversions and uses with the goal of restoring natural flow regimes. Where opportunities exist, develop cooperative strategies with landowners and other partners to implement strategies that are beneficial to aquatic resources.

Identify stream segments where habitat and available flow regimes indicate a need to file instream flow water rights for SGCN. As opportunities are identified, conduct needed

studies and file for state-held instream flow water rights.

Identify fish and wildlife mitigation for new reservoirs as they are proposed including instream flow regimes and minimum fishery pools. Ensure that mitigation recommendations are included as conditions in applicable permits.

Follow up on recommendations from the graduate research project on gastropods. The WGFD-funded graduate project at the University of Wyoming will provide direction for sampling methods. Those recommendations should be followed, and baseline gastropods surveys should be conducted in the Green River basin.

Monitoring

Establish standardized monitoring protocols and locations for native SGCN. Monitor water quantity and temperature in areas containing important native SGCN populations.

Monitor the establishment and spread of invasive species.

Monitor burbot and white sucker distribution within the drainage. Conduct annual monitoring of the Flaming Gorge Reservoir fish populations in order to assess the effects of burbot on the fishery.

Monitor populations of Colorado River cutthroat trout, mountain whitefish, and the Three Species.

Monitor riparian and stream channel conditions in the Muddy Creek drainage to influence progressive grazing management and maintenance or improvement of riparian and stream channel habitat for the Three Species and Colorado River cutthroat trout.

Monitor instream flow segments for compliance with approved instream flow levels.

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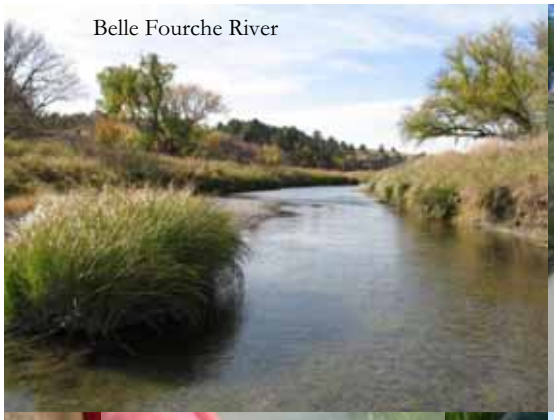
Northeastern Missouri River Basin


Belle Fourche River

Cheyenne River

Western spiny softshell turtle

Lance Creek

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Watershed Description

Three of the nation's major river systems have their headwaters in Wyoming: the Missouri, Colorado, and Columbia Rivers. Their watersheds provide a natural basis for delineating aquatic conservation areas. Six major watersheds were identified for conservation planning purposes under this State Wildlife Action Plan (SWAP) using hydrographic boundaries and fisheries assemblage and management considerations (Figure 5). These areas are consistent with the aquatic ecosystems identified for freshwater biodiversity conservation worldwide by Abell et al. (2008). The watershed areas are also synonymous with aquatic zoogeographical units and ecological drainage units identified under The Nature Conservancy's (TNC) hierarchical classification framework (Higgins et al. 2005). A systematic, hydrologic unit code (HUC)-based approach allows the nesting of multiple spatial and temporal scales for planning and for prioritizing conservation actions.

The Northeastern Missouri River basin includes four 6-digit HUCs, all direct tributaries to the mainstem Missouri River (Figure 5). These include the Little Missouri (101102), Belle Fourche (101202), Cheyenne (101201), and Niobrara River (101500) watersheds (Figure 5). Thirteen 8-digit HUCs and 52 10-digit HUCs occur in this area. These watersheds span an area of about 12,000 square miles in northeastern Wyoming's Crook, Weston, Campbell, Converse, Niobrara, and Goshen counties. Land ownership is 81% private. Public land is held primarily by the State of Wyoming (6%), Bureau of Land Management (5%), and U.S. Forest Service (4%).

The Northern Great Plains Steppe terrestrial-based ecoregion, as defined by Bailey (1995) and adapted by The Nature Conservancy, occupies most of the Northeastern Missouri River basin. Remaining portions of this basin are covered by TNC's Black Hills ecoregion. Elevations range from 3,125 feet where the Belle Fourche River leaves the state to over 6,600 feet in the Black Hills. Underlying geology consists of sandstone, shale, limestone, and igneous and metamorphic rocks. The Pierre Formation, Fort Union Formation, and Lance Formation underlie the area and consist of shales, sandstones, and thick coal beds (Lageson and Spearing 1988). This region has not experienced continental glaciation and hence lacks the U-shaped valleys and material deposit features associated with glacial activity.

The Northeastern Missouri River basin overlaps part of Wyoming climate division 5 and all of divisions 6 and 7 (Curtis and Grimes 2004). These climate divisions are the warmest of the 10 climate divisions in Wyoming with average monthly temperatures of 71° F in July. The coldest month is January and averages about 20° F. The Belle Fourche drainage receives the highest monthly precipitation in the state with nearly 3 inches falling in June on average over the period 1931–2000 (Curtis and Grimes 2004). The Cheyenne and Niobrara drainages receive about 2.5 inches during the peak month of May. The Northeastern Missouri River basin is different from Wyoming's other river basins in that it receives the bulk of its annual precipitation during the warmest portion of the year. Annual precipitation ranges from about 13 inches to approximately 30 inches at high elevation along the eastern edge of the Black Hills.

Knight (1994) describes a diverse floristic community in the Black Hills with representative flora from eastern deciduous forests, the Rocky Mountains, the Great Basin, the Boreal Forest, and the Southern Great Plains. The ponderosa pine woodland and savannah grass understory of the Black Hills region constitutes a distinct vegetation community. The remaining watershed area can generally be described as largely prairie grassland and sagebrush steppe. A systematic and more detailed description of land cover follows.

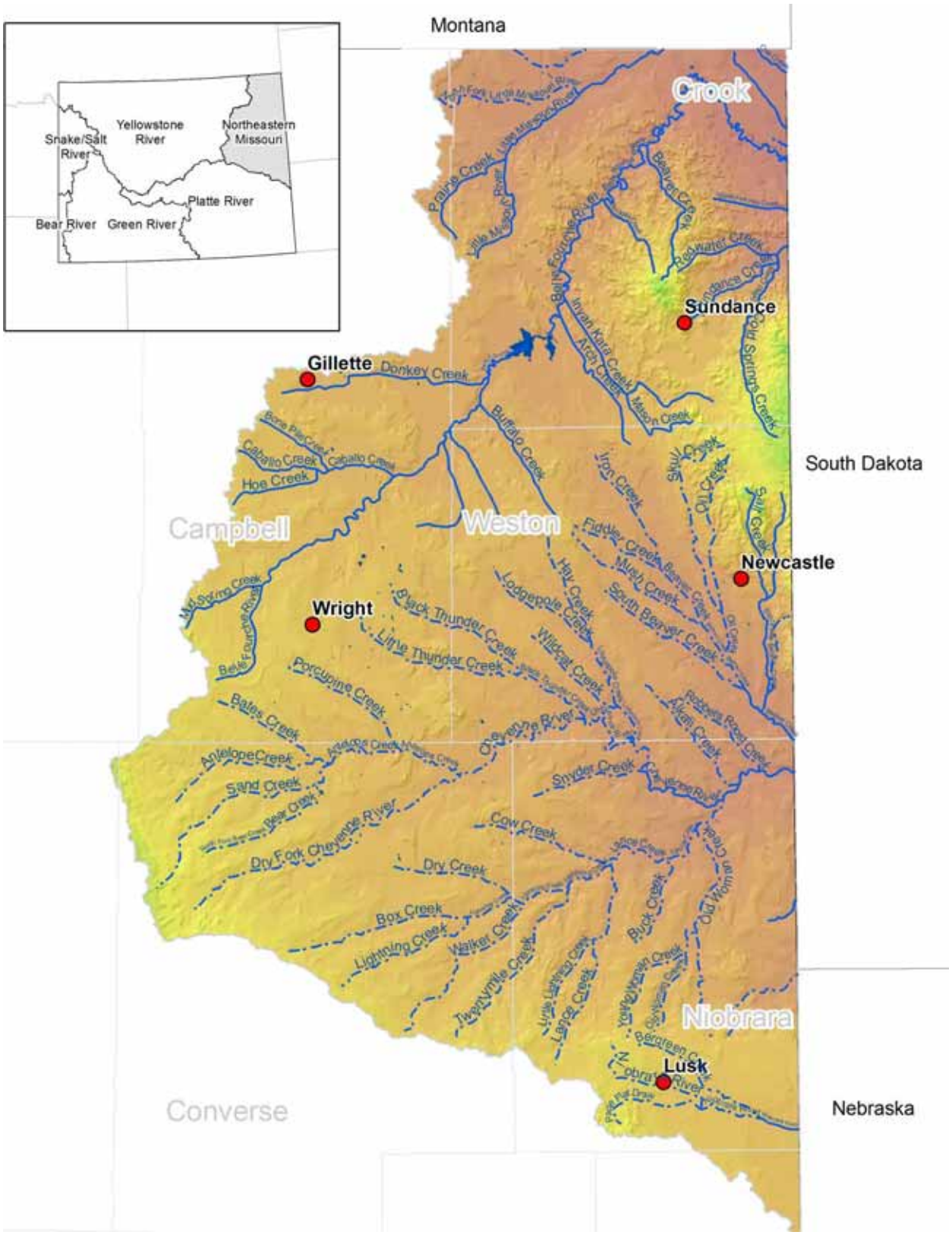

Figure 5. Northeastern Missouri River Basin.

The 11 habitat types defined in this SWAP (e.g., sagebrush shrublands, riparian, etc.,) are based on combinations of Ecological Systems (ES) developed by NatureServe (Comer et al. 2003a, NatureServe Explorer 2009). The determination and delineation of ES is based on land cover maps produced by the Northwest Gap Analysis Project (NWGAP 2010). Lennartz et al. (2007) provides technical details on the ES classification for USGS mapping zone 29, in which the whole of the Northeastern Missouri River basin occurs. Of the 173 ES classes identified under NWGAP, 73 classes occur in the Northeastern Missouri River basin (excluding developed and open water classes). The most prevalent classes are the Northwestern Great Plains Mixed Grass Prairie and the Inter-mountain Basins Big Sagebrush Steppe which are associated with the prairie grasslands (42% of watershed area) and sagebrush shrublands (38% of watershed area) habitat types. These habitats and their associated species assemblages, threats, and conservation actions are covered in separate habitat chapters of this SWAP.

Land use is primarily livestock grazing on the plains. Oil, gas, and coal deposits occur, and coal mining is extensive (Chapman et al. 2004). Coal bed methane production occurs primarily on the western edge of the basin. Within the Black Hills, timber harvest has been historically extensive (Knight 1994). Other Black Hills activities include gold, copper, and gypsum mining, recreation, and ranches in the valley bottoms (Chapman et al. 2004).

The Belle Fourche, Cheyenne, Little Missouri and Niobrara Rivers in Wyoming have their headwaters almost entirely in the plains. From a GIS analysis of the 2010 Version 2.0 National Hydrological Database (NHD) at 1:100,000, there are approximately 44,000 miles of streams in the Northeastern Missouri River basin. This equates to a drainage density of about 3 ½ miles of stream per square mile land area. While it is certain that many of the line segments depicted as streams in the NHD are intermittent or ephemeral, providing a precise estimate of perennial stream miles is fraught with uncertainty. A rough surrogate may be named stream miles from the NHD layer, which constitutes about 8,000 stream miles. Major named streams include the Little Missouri River, Belle Fourche River, Redwater Creek, Beaver Creek, Blacktail Creek, Lytle Creek, Miller Creek, Inyan Kara Creek, Donkey Creek, Arch Creek, Cheyenne River, Antelope Creek, Lightning Creek, Lance Creek, Beaver Creek (Cheyenne River basin), and Stockade Beaver Creek, and the Niobrara River (Northeastern Wyoming River Basins Water Plan Final Report, 2002).

The largest water body in the Northeastern Missouri River basin is Keyhole Reservoir on the Belle Fourche River with an active capacity of 185,800 acre feet (af) (Northeastern Wyoming River Basins Water Plan Final Report, 2002). Other reservoirs having significant capacity are few and much smaller and include Tract 37 Reservoir on the North Fork Little Missouri River (2,454 af), Spencer Reservoir on Stockade Beaver Creek (2,162 af) and Gillette Reservoir on Donkey Creek (2,080 af). Stock ponds are defined by the Wyoming State Engineers Office as 20 af or less impoundments; 5,093 permitted stock ponds occur in the basin (Northeastern Wyoming River Basins Water Plan Final Report, 2002).

Total annual runoff among the major drainages includes 4,900 acre feet per year on the Cheyenne River at Riverview (5,160 square mile drainage area) and 16,550 acre feet per year from the Belle Fourche River below Moorcroft (1,690 square mile drainage area) (Clark and Mason 2007). Higher yields per area in the Belle Fourche drainage occur from additional precipitation in the higher elevations of the Black Hills. Runoff patterns include spring peaks from lowland snowmelt, intermittent peaks following rainstorms, and extended periods of low flow (Clark and Mason 2007). The Cheyenne River commonly has extended periods of no flow. Stream gradients are generally low in the plains streams, under 1.0%, and consist of meandering sinuous channels. Corresponding water velocities are generally low as well, though localized regions of high

velocities occur in addition to high velocities during peak flow events.

Water quality is influenced strongly by the slow moving nature of the streams as they flow over soluble geologic materials (Clark and Mason 2007). For example, median conductance values in the Belle Fourche drainage ranged up to 2,800 μS/cm (Clark and Mason 2007). Dissolved sodium, sulfates, and carbonates are common with the highest levels for the Northeastern Missouri River basin occurring in the Cheyenne River drainage.

Aquatic Wildlife

Fish

The first fish community surveys in the Northeastern Missouri River basin were conducted in the 1890s (Evermann and Cox 1896). Fifty years passed before James Simon published the first edition of *Fishes of Wyoming*, which includes the results of his fish surveys which began in 1933 (Simon 1951). He surveyed 11 sites in the Northeastern Missouri River basin. Over the next three decades, a few projects provided some additional information on distribution of fishes in this watershed (Eiserman 1966, Baxter and Simon 1970, Fleisher 1978, Fleisher and Stone 1978); however, many gaps remained in the survey data.

In 1992, the WGFD funded a PhD project at the University of Wyoming to conduct a detailed fisheries survey of warmwater fishes in the Missouri River drainage in Wyoming. The dissertation and publications associated with this survey of 181 locations from 1993-1995 are some of the most cited references pertaining to warmwater fishes in Wyoming and include estimates of species richness and relative abundance, in addition to rankings of the relative conservation value of 83 streams for native fish species (Patton et al. 1995, Patton 1997, Patton et al. 1998, Patton 2001). This survey included five sites in the Little Missouri River watershed, eight sites in the Belle Fourche, nine sites in the Cheyenne, and five sites in the Niobrara River watershed. Information from Patton's 1993 surveys was included in the fourth edition of *Fishes of Wyoming* (Baxter and Stone 1995). In 2002, the WGFD conducted a large-scale literature and data review and produced a series of twelve reports (Weitzel 2002) that describe the distribution, status, and life histories of 41 native, nongame fishes. Eight of these reports pertain to fishes native to the Northeastern Missouri River basin. Miller and Weitzel (2003) prioritized native nongame fishes for future conservation efforts and made recommendations for management of these species. These reports (Weitzel 2002, Miller and Weitzel 2003) provided much of the information that was used to develop fish portions of the 2005 Comprehensive Wildlife Conservation Strategy for Wyoming.

In 2004, a State Wildlife Grant (SWG) project was initiated to gain additional information regarding native fish distributions and their habitats in eastern Wyoming prairie streams to begin developing strategies to manage and conserve native fish species. In 2004 and 2005, surveys were conducted at a total of 41 sites in the Little Missouri (8 sites), Cheyenne (28 sites), and Niobrara River (5 sites) watersheds using the Warmwater Stream Assessment (WSA) (Quist et al. 2004). The results of this project were summarized in two completion reports. Barrineau et al. (2007) includes results of surveys in the Little Missouri and Cheyenne River drainages. Bear and Barrineau (2007) includes results for the Niobrara River surveys. Both reports include descriptions of habitat conditions and threats to native species in each watershed, the results of fish and habitat surveys, and management recommendations for these prairie streams. The Belle Fourche watershed was not surveyed as part of this project.

In 2005 and 2006, a number of fisheries surveys were conducted in the Belle Fourche and Cheyenne River drainages to describe communities in areas undergoing extensive coalbed methane development (Peterson et al. 2009). In March 2008, two 2-year SWG

projects (Northeastern Wyoming Prairie Fish Conservation and Southeastern Wyoming Prairie Fish Conservation) were initiated. As part of the Northeastern Wyoming project, detailed fish and habitat surveys were conducted in the Belle Fourche River and Redwater Creek watersheds (McGree et al. 2010, Moan et al. 2010).

The fish community in the Northeastern Missouri River basin has been sampled for more than 100 years. Survey intensity has increased dramatically in the last 20 years. Results show that tThe Northeastern Missouri River basin is home to the most diverse fish community in the state. Forty-seven fish species are found in the watershed, 23 of which are native and 10 of which are Species of Greatest Conservation Need (SGCN). No native species has been completely extirpated from the Northeastern Missouri River basin, but two species that are SGCN elsewhere in the state have been introduced to the watershed; Snake River cutthroat trout and plains killifish. The plains topminnow (SGCN) was most likely native only to the Niobrara River basin, but has been documented in the Cheyenne River basin.

The native gamefish community is composed only of three ictalurids: channel catfish, black bullhead, and stonecat. The nonnative fish community consists of 25 introduced species, of which 14 are game species that have been stocked to provide fishing opportunities in standing waters. Introduced game species include important sport fishes such as trout, walleye, yellow perch, northern pike, tiger muskie, bass, crappie, and sunfishes.

High stream flow fluctuation, high summer water temperatures, stream flow alteration, long periods of low flow, high turbidity, and siltation limit the potential of most streams and standing waters in the drainage to support game fish, particularly cold water species.

Streams originating west of the Black Hills are typified by extreme flow fluctuations. They are often intermittent in the summer but may flood at any time during summer storm events. Low steam flow can result in a variety of environmental and abiotic stressors and conditions for fish, and the continuing drought over at least the last decade has most certainly affected fish in the Cheyenne River basin (Barrineau et al. 2007).

Comparisons of data collected in the 1960s and the 1990s suggest that of the fish species present within the Belle Fourche River basin, nine have declined over this 30-year period (Patton 1997). The finescale dace (FSD), flathead chub (FHC), fathead minnow (FHM), lake chub (LKC), mountain sucker (MTS), shorthead redhorse (NRH), plains minnow (PMN), river carpsucker (RCS), and stonecat (STC) have declined on spatial scales described by Patton as site, stream, subdrainage, and drainage levels, compared with those of the 1960s sampling conducted by Baxter and Simon. Patton (1997) suggests that it is critical to monitor fish distributions and abundances, and to identify conservation needs prior to irreversible imperilment. McGree et al. (2010) found that five species (FHC, LND, MTS, PMN, and STC) had declined when comparisons were made to Patton (1997).

Aquatic Reptiles

Three turtles are found in the Northeastern Missouri River basin, all of which are native species. The western painted and western spiny softshell turtles are SCGN, but the eastern snapping turtle is not. The western spiny softshell turtle is believed to have the widest distribution in the watershed of the three. All three species are suspected to reside in subdrainages throughout the Northeastern Missouri River basin. However, actual observations are very limited (see Species Accounts). The eastern snapping turtle has been documented in the Niobrara, Cheyenne and Belle Fourche drainages and is suspected to occur in the Little Missouri River. The western painted turtle has been documented in the Cheyenne and Belle Fourche, whereas the western spiny softshell has only been documented in the Belle Fourche. Baseline survey data are needed for all turtles in the Northeastern Missouri River basin.

Table 5. Fishes present in the Northeastern Missouri River Basin. Species of Greatest Conservation Need (SGCN) are followed by an asterisk (*).

Native game	Native nongame	Nonnative game	Nonnative nongame
Black bullhead	Creek chub	Black crappie	Brook stickleback
Channel catfish	Brassy minnow*	Bluegill	Carp
Stonecat	Central stoneroller*	Brook trout	Emerald shiner
	Fathead minnow	Brown trout	Freshwater drum
	Finescale dace*	Green sunfish	Gizzard shad
	Flathead chub*	Largemouth bass	Golden shiner
	Goldeye*	Northern pike	Grass carp
	Iowa darter*	Rainbow trout	Longnose sucker
	Lake chub	Smallmouth bass	Plains killifish
	Longnose dace	Snake River cutthroat	Spottail shiner
	Mountain sucker	Tiger muskie	
	Pearl dace*	Walleye	
	Plains minnow*	White crappie	
	Plains topminnow*	Yellow perch	
	Red shiner		
	River carpsucker		
	Sand shiner		
	Shorthead redhorse		
	Western silvery minnow*		
	White sucker		

Freshwater Mollusks and Crayfishes

All native mussels, clams, and gastropods are considered SGCN by WGFD due to a lack of information regarding status. Few published accounts exist (Beetle 1989, Henderson 1924, Hoke 1979, Hovingh 2004), but native mussel populations are currently present in every major drainage of Wyoming, except the Green River and Great Divide. Wyoming is still in the discovery phase in terms of its freshwater mussels and gastropods, but the WGFD has intensified sampling efforts in recent years. One biologist on the aquatic assessment crew has been assigned to coordinate mollusk sampling and collect observations. Field personnel have been trained and instructed to record mussel observations during other routine fieldwork and submit specimens. A voucher specimen collection was established at the University of Colorado Natural History Museum in Boulder, Colorado, in 2007.

As of late 2010, seven species of native mussels were known to inhabit Wyoming waters. Two of these species, the giant floater and the white heelsplitter, have been documented in the Northeastern Missouri River basin. Giant floater have been documented in portions of the Little Missouri and Belle Fourche river drainages while heelsplitter have been found only in the Blacktail Creek drainage in the Belle Fourche watershed.

Little is known about the current distribution of Wyoming gastropods. Beetle (1989) contains some of the only published observations in Wyoming, listing species occurrences by county. Beetle (1989) reported pouch snails (genus *Physa* and *Gyraulus*) and pond snails (genus *Lymnaea*) in the Belle Fourche and Cheyenne River drainages. No observations were reported in the Niobrara or Little Missouri River drainages, but sampling sites were extremely sparse.

In 2009, the WGFD funded a project at the University of Wyoming (UW) to conduct a literature review, identifying the current and

historical information on freshwater gastropod distributions in Wyoming and to develop gastropod collection methods for WGFD and assess the distribution of freshwater gastropods in the Bighorn and North Platte river drainages in Wyoming. This project did not include sampling in the Northeastern Missouri River basin. The results of the UW research project will provide direction for sampling methods. Baseline survey data are needed for all gastropods in the Northeastern Missouri River basin.

Little information is available on the distribution of Wyoming crayfishes. All native crayfishes are considered SGCN. Between 1985 and 1987 a survey of crayfishes was conducted (Hubert 1988). During that survey five species of crayfishes were found in Wyoming: *Pacifasticus gambelii, Orconectes immunis, O. virilis, O. neglectus, and Cambarus diogenes*. During subsequent surveys conducted from 2007-2009, *Orconectes immunis* was the only species documented in the Northeastern Missouri River basin (Hubert 2010). More detailed surveys are needed to describe the distribution and status of crayfishes in the state.

Table 6. Species of Greatest Conservation Need present in the Northeastern Missouri River Basin.

Fish
Brassy minnow
Central stoneroller
Finescale dace
Flathead chub
Goldeye
Iowa darter
Pearl dace
Plains minnow
Plains topminnow
Western silvery minnow

Reptiles
Western painted turtle
Western spiny softshell

Crustaceans
Calico crayfish

Mollusks
Giant floater mussel
White heelsplitter mussel

Identification of Conservation Areas

The 2004–2005 (SWG) projects on eastern Wyoming prairie streams (described above) evaluated the utility of the Warmwater Stream Assessment (WSA) methodology for assessing stream habitat conditions and greatly refined our understanding of the distribution of native fish species. Data from this project were used to prioritize large watersheds in eastern Wyoming based on conservation value for native species. Most of the watersheds identified are also regional Aquatic Habitat Priorities.

The priority watersheds that were identified in northeastern Wyoming include Lance, Indian and Black Thunder creeks in the Cheyenne River watershed, and the Little Missouri and Niobrara River watersheds. At least 11 SGCN occur in one or more of these watersheds: finescale dace (NSS2), pearl dace (NSS2), western silvery minnow (NSS2), goldeye (NSS3), Iowa darter (NSS3), plains minnow (NSS3), plains topminnow (NSS3), brassy minnow (NSS4), central stoneroller (NSS4), and flathead chub (NSS4).

One of the objectives of the two 2-year SWG projects initiated in March 2008 was to use results from additional fish surveys to prioritize watersheds at the 10-digit HUC level for native fish conservation efforts. Detailed surveys were conducted at 11 sites in the Little Missouri River drainage, 36 sites in the Belle Fourche River drainage, 24 sites in the Cheyenne River drainage, and 17 sites in the Niobrara River drainage.

Priority fish conservation areas (Figure 6) include the Little Missouri (HUC 10110201), Niobrara River drainage (HUC 10150002), lower Cheyenne River (HUCs 1012010304 and 1012010601), and Black Thunder Creek (HUC 1012010302) and Lance Creek (HUC 10120104) in the Cheyenne River drainage (10120106).

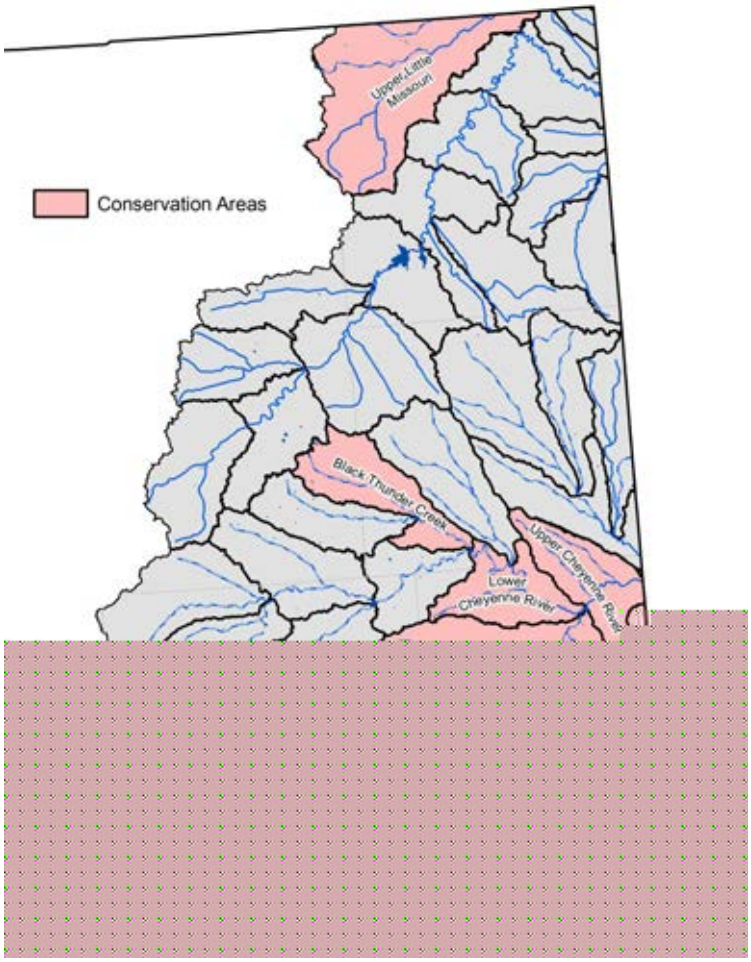

Figure 6. Aquatic Wildlife Conservation Areas in the Northeastern Missouri River Basin.

Threats

Water development/altered flow regimes – Moderate

Natural flow regimes in stream segments around the state have been altered by human activities including irrigation diversions and water developments for more reliable water supply, hydropower, and flood control. These altered flow regimes are also a consequence of broad-scale changes in land use and management associated with agriculture, grazing, timber harvest, and housing development (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes). The majority of the Northeastern Missouri River basin is grasslands or sagebrush. There is some irrigated cropland and relatively few water storage reservoirs.

Groundwater use in prairie systems has been shown to negatively impact stream flow, increasing the extent and duration of dry or intermittent stream channels. Native prairie fishes evolved in a highly dynamic system and readily recolonize areas that periodically dry out. Key to the ability to recolonize is lateral and longitudinal hydrologic connectivity and physical access by fish populations to all habitats necessary to complete their life history. In-channel obstructions and increased drying have reduced some populations of native stream fishes.