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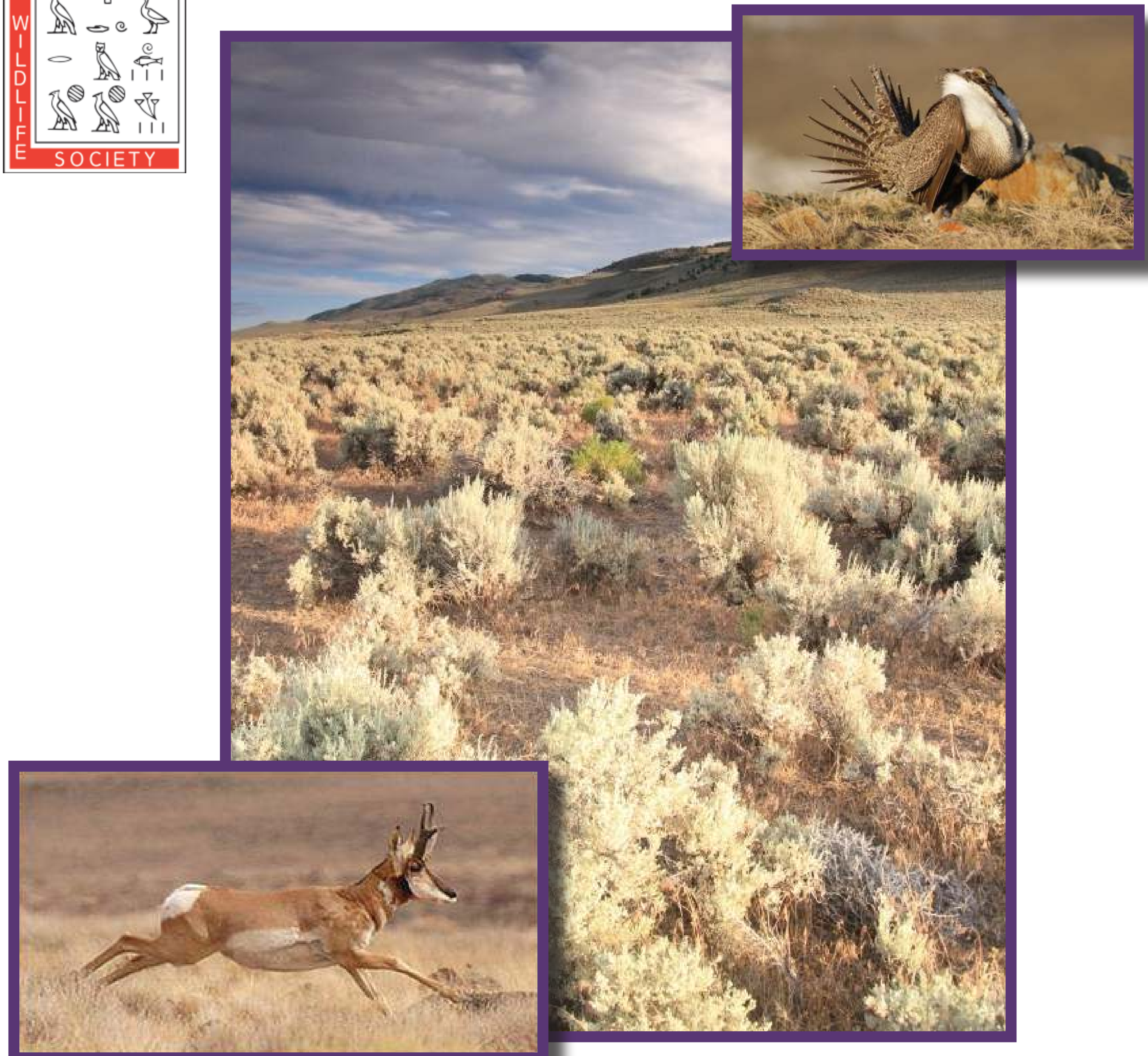

Impacts of Crude Oil and Natural Gas Developments on Wildlife and Wildlife Habitat in the Rocky Mountain Region

Technical Review 12-02
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ISBN: 978-0-9830402-1-7

Large center photo: Sagebrush (*Artemesia spp*.) Ecosystem of western North America. Credit: Jeremy R. Roberts/ Conservation Media

Top right: A male greater sage-grouse (*Centrocercus urophasianus*) engaging in a competitive mating display. Credit: Jeremy R. Roberts/Conservation Media

Bottom left: American pronghorn (*Antilocarpa americana*) racing across Hart Mountain National Antelope Refuge. Credit: Marilyn Gregory/USFWS

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FOREWORD

Presidents of The Wildlife Society occasionally appoint ad hoc committees to study and report on select conservation issues. The reports ordinarily appear as either Technical Reviews or position statements. Technical Reviews present technical information and the views of the appointed committee members, but not necessarily the views of their employers. Position statements are usually based on Technical Reviews, and the preliminary versions are made available for comment by Society members. Following the comment period, revision, and approval by The Wildlife Society's Council, position statements are published as official positions of The Wildlife Society.

Citation: Riley, T. Z., E. M. Bayne, B. C. Dale, D. E. Naugle, J. A. Rodgers, and S. C. Torbit. 2012. Impacts of crude oil and natural gas developments on wildlife and wildlife habitat in the Rocky Mountain region. The Wildlife Society Technical Review 12-02. The Wildlife Society, Bethesda, Maryland, USA.

ACKNOWLEDGMENTS

We thank Past-President Bruce D. Leopold for developing the charge for this Technical Review. We also thank President Paul J. Krausman, Past-Presidents Thomas J. Ryder, Thomas M. Franklin, John F. Organ, and W. Daniel Svedarsky of The Wildlife Society Council for assistance in helping us address this important and longstanding issue. We also thank Jim R. Heffelfinger of the Arizona Game and Fish Department for providing a review of the manuscript.

We are grateful to Laura M. Bies, Director of Government Affairs, Terra Rentz, Deputy Director of Government Affairs, and Christine Carmichael, Government Affairs Associate, of The Wildlife Society, and to Rollin D. Sparrowe (retired) and Steve Belinda of the Theodore Roosevelt Conservation Partnership, for their guidance and review of previous drafts of this document.

SYNOPSIS

Crude oil and natural gas developments are widespread throughout North America and continue to expand due to the reliance of our society on these resources. As development continues, it is important to identify the impacts of this industry on various species of wildlife, and recognize that these effects likely are cumulative. This report summarizes information on the impacts of the oil and gas industry on wildlife in the Rocky Mountain region of North America, and identifies the current extent of developments, processes used to develop oil and gas resources, direct and indirect impacts to habitats of multiple species, cumulative impacts, and mitigation.

Oil and gas development is common in shrub-dominated basins that provide important seasonal habitats to many ungulates. Habitat quality and quantity greatly influence ungulate population persistence, but are weakened by energy development-related activities such as road and well pad construction and exotic reseeding. Research has shown that ungulates often avoid habitats with large amounts of development and human use because these species perceive such areas to present a higher predation risk. Further, development might cause an increase in competition for scarce resources between elk and deer, and subsequently an increase in damage to crops.

Greater sage-grouse (*Centrocercus urophasianus*) today occupy approximately half of their historic range (Schroeder et al. 2004), and the lesser prairie-chicken (*Tympanuchus pallidicinctus*) occupies less than 10% of its historic range (Robb and Schroeder 2005). Energy development planned for areas with some of the highest densities of these species is a cause for concern. Current research indicates clear negative impacts on breeding populations of greater sage-grouse at common well densities of 3 wells per km^2 (8 wells per mi^2) for natural gas and 6 wells per km^2 (16 wells per mi^2) for oil (Evers 2012), including lower female survival and avoidance of wintering grounds (Robel et al. 2004, Holloran 2005, Walker et al. 2007a).

Waterfowl in North America also are directly and indirectly impacted by oil and gas development. Seismic lines used in exploration can alter wetland hydrology and fragment habitat. This fragmentation is compounded by the addition of roads and the construction of drilling pads. Tailings, and in particular tailings ponds, pose a threat to waterfowl, which may land on these settling areas and become lethally coated in oil and other toxins. Tailings ponds also might accidentally release toxins into water systems. One of the greatest threats to waterfowl is from produced water which is generated by the oil and gas extraction process and may contain the hydrocarbons extracted, chemicals and additives used in the extraction process, and other contaminants. This produced water may be discharged into lakes, rivers, and wetland systems, negatively influencing aquatic organisms. Many different impacts of produced water on waterfowl exist and often are situational and difficult to calculate.

Oil and gas development overlaps with habitat for many songbird species. In particular, grassland songbirds are of concern because of significant habitat conversion and population declines. Oil and gas development may introduce exotic plants, waste fluids, and toxic by-products, leading to poisoning, traffic collisions, haying during breeding season, and changes to early-successional habitats. Songbirds demonstrate avoidance of developed areas, and the creation of edge and fragmentation of habitat is a concern. Ecological traps, causing reduced breeding success, also are a concern.

As oil and gas development continues in North America, biologists must continue to better understand this industry's impacts on wildlife and develop feasible mitigation strategies to minimize these impacts. Mitigating known harmful impacts of this industry and avoiding such impacts where possible are important steps forward in the management of this energy resource and a landscape that provides vital habitat to many species.

INTRODUCTION

The Rocky Mountain region plays a significant role in meeting the energy needs of North America and in sustaining a variety of the fish and wildlife species relied upon by many interests, including sportsmen, nature enthusiasts, and tourist-dependent businesses. As a result of these competing demands, the establishment of management policies historically has generated philosophical debates about the appropriate priority given to user groups, as well as tension among the various stakeholders. Recently, these tensions have been exacerbated because United States (U.S.) federal and Canadian Provincial land-management agencies have accelerated the issuance of leases and permits for millions of acres of land in the Rocky Mountain region for crude oil and natural gas developments in an attempt to increase domestic energy production (Shore 2004).

The current system of leasing and developing crude oil and natural gas resources in the Rocky Mountains does not appear to be satisfactory to any of the stakeholders. Energy developers face delays in processing lease and permit applications. Sportsmen and other wildlife enthusiasts are concerned that the pace of development, the lack of scientific data and monitoring, and the uneven application of environmental restrictions are jeopardizing fish and wildlife resources and related economic activity.

As development of oil and gas resources continues in the Rocky Mountains, its effects are compounded with additional anthropogenic disturbances, including those from other forms of energy development. Alternative forms of energy such as solar, wind (Technical Review 07-2), and biofuels (Technical Review to be released in 2012) also have negative impacts on wildlife. Together, these forms of energy development create a vast array of transmission lines, pipelines, and other related infrastructure, the cumulative effects of which often are unknown.

This Technical Review examines the effects of crude oil and natural gas developments in the Rocky Mountains on wildlife and wildlife habitat through a review of the existing peer-reviewed scientific literature and other published and unpublished reports. The purpose of this review is to better understand the strengths and shortcomings of the current management of crude oil and natural gas development projects on wildlife. In particular, this report examines two questions:

1. Are crude oil and natural gas energy developments affecting the abundance, reproduction, movements, or distribution of big game, game bird, waterfowl, or songbird populations?
2. Can a process be established to more efficiently facilitate crude oil and natural gas developments while protecting wildlife resources and other associated amenity values?

PART 1: EXTENT OF CRUDE OIL AND NATURAL GAS DEVELOPMENT IN NORTH AMERICA

World demand for energy increased by more than 50% in the last half-century, and a similar increase is projected between 2000 and 2030 (National Petroleum Council 2007). Fossil fuels will remain the largest source of energy worldwide, with oil, natural gas, and coal accounting for more than 80% of world demand. Projected growth in U.S. energy demand is 0.5% to 1.3% annually (National Petroleum Council 2007), and development of domestic reserves will expand through the first half of the twenty-first century. The U.S. Department of Energy (2009) has predicted that demand for natural gas will rise another 25% over the next 15 years. In Canada, a 35% increase in energy demand is expected by 2030 (National Energy Board 2007). In the U.S., production of natural gas increased by 20% from the early 1990s to 2010 (U.S. Department of Energy 2011). Western states and provinces will continue to play a major role in providing additional domestic energy resources to the U.S. and Canada, which is expected to place unprecedented pressure on the conservation of wildlife populations throughout the West.

The economies of Canada, Mexico, and the U.S. depend substantially on the use, import, and export of natural gas and crude oil, much of which is imported by the U.S. In fact, the U.S. currently imports roughly 55% of its crude oil and 15% of its natural gas (U.S. Department of Energy 2011). As domestic demand for these fuels grows, imports also are expected to grow, leaving the U.S. more vulnerable to world events that can disrupt foreign supplies. Moreover, this dependence on foreign sources of fossil energy results in a massive transfer of wealth out of the U.S., contributing to its trade deficit. Consequently, there is considerable value in developing domestic sources of crude oil and natural gas.

In Canada, worldwide energy demand will encourage the continuation of oil sands development and conventional oil and natural gas production within the country. In 2010, Canada was the world's fourth-largest exporter of natural gas and, in 2009, the fourteenth-largest exporter of oil and oil products (Central Intelligence Agency 2011). Canada also imports oil and gas, primarily in the East, where less development of this resource has occurred. In 2010, Canada imported 778,000 barrels per day (b/d) of crude oil (National Energy Board 2011a), and 2.2 billion cubic feet (bcf) per day of natural gas (National Energy Board 2011b). Oil and natural gas production comprises approximately 6.8% of the Canadian Gross Domestic Product (GDP) and 16% of all investments in Canada, making this industry a significant component of the country's economy (Energy Council of

Pictured here is an energy development facility in Montana. Energy development creates a vast array of transmission lines, pipelines, and other related infrastructure, of which the cumulative effects on wildlife are often unknown. (Photo credit: Jeremy R. Roberts, Conservation Media).

Canada 2007). Though economically important, the growth of this industry has caused public concern and raised fears of widespread environmental degradation that may result.

UNITED STATES

The U.S. Geological Survey (USGS) estimates that 1 trillion cubic feet (tcf) of technically recoverable natural gas remain in the U.S., exclusive of federal waters (U.S. Department of Energy 2007). On U.S. federal lands, an estimated 320 bcf of undiscovered, recoverable gas in conventional fields (onshore) exist, 27% of which are located in the Rocky Mountain region. The U.S. produces roughly 19 bcf of natural gas per year (2007), 2.1 bcf (11%) coming from U.S. federal lands (onshore). Total consumption of natural gas in the U.S. exceeds 23 bcf per year and has remained relatively steady for the past 4 years (2007-2010). If fully developed, this estimated 320 bcf of technically recoverable natural gas reserves on U.S. federal lands (onshore) could supply the nation with natural gas for more than 13 years, assuming an average consumption of 2 bcf per month. Technically recoverable natural gas in the Rocky Mountain region alone could supply the U.S. demand for about 4 years.

The USGS estimates that 92 billion barrels (BB) of technically recoverable crude oil remain in the U.S., exclusive of federal waters (U.S. Department of Energy 2007). On U.S. federal lands, an estimated 30 BB of undiscovered crude oil exist in conventional fields (onshore), 25% of which are located in the Rocky Mountain region. In 2010, the U.S. produced around 5.5 million barrels per day (MMb/d) of crude oil. The top crude oil producing areas at this time included the Gulf of Mexico (1.6 MMb/d), Texas onshore (1.1 MMb/d), Alaska's North Slope (0.954 MMb/d), California (0.707 MMb/d), Louisiana onshore (0.274 MMb/d), Oklahoma (0.181 MMb/d), and Wyoming (0.150 MMb/d). The U.S. contains

Table 1. Acres of U.S. federal land (federal mineral estate) in the Rocky Mountain region open or closed to crude oil or natural gas development (U.S. Department of Energy and U.S. Department of the Interior 2003).

State	Open to drilling (Acres)	Closed to drilling (Acres)
Colorado	16 million	600,000 (3.5%)
Montana	18 million	400,000 (2%)
New Mexico	28 million	1.3 million (4%)
Utah	20 million	3 million (12%)
Wyoming	28 million	700,000 (2.5%)

more than 500,000 producing crude oil wells, the vast majority of which are considered "marginal" or "stripper" wells that produce only a few barrels of crude oil per day.

The U.S. consumed an average of about 20 MMb/d of crude oil in 2011, up from 19.8 MMb/d in 2002 (U.S. Department of Energy 2011). Total petroleum demand in the foreseeable future in the U.S. is projected to grow by 420,000 b/d, or 2.1%. Undiscovered, technically recoverable crude oil in the Rocky Mountain region could supply U.S. demand for about 1 year. Technically recoverable reserves—located primarily outside of known fields—are oil and gas deposits that may be produced as a consequence of natural pressure, artificial lift, pressure maintenance, or other secondary recovery methods, but without any consideration of economic viability. The amount of economically recoverable crude oil reserves in the Rocky Mountains fluctuates with the price of crude oil, but is significantly less than technically recoverable reserves. Economically recoverable reserves are the portion of the technically recoverable resources that is recoverable under imposed economic and technologic conditions.

Availability of U.S. Federal Lands for Crude Oil and Natural Gas Development

For decades, federal public lands in the U.S. have been the focus of efforts to produce crude oil and natural gas. Although these lands in the West do not contain sufficient economically recoverable crude oil and gas to substantially reduce dependence on foreign sources of energy, the development of these resources can have localized economic benefits and might marginally ease supply constraints, which are likely to become more severe in the future.

The Bureau of Land Management (BLM), an agency within the U.S. Department of the Interior (DOI), is charged with managing hundreds of millions of acres of federal public lands, primarily in the West. The agency is responsible for carrying out a variety of programs for the management and conservation of public resources on approximately 252 million surface acres, as well as approximately 699 million acres of subsurface federal mineral estate, primarily in the 12 western states. These public lands make up about 13% of the total land surface of the U.S. and more than 40% of all land managed by the U.S. federal government.

Part of the BLM's charge is to oversee the exploration and development of crude oil and natural gas resources on federal public lands in the U.S. The BLM also issues mineral leases on federal public lands managed by the U.S. Fish and Wildlife Service (FWS) within the DOI, and the U.S. Forest Service (USFS), an agency of the U.S. Department of Agriculture (USDA). Both the FWS and the USFS make decisions regarding the availability of the lands they manage for oil and gas development.

The vast majority of federal lands within the Rocky Mountain region are available for crude oil and natural gas development (U.S. Department of Energy and U.S. Department of the Interior 2003). In fact, about 90% of the federal mineral estate administered by the BLM within the "Overthrust Belt" allows energy development (Table 1). The only state that falls below this level is Utah, where 88% of the federal mineral estate is available for crude oil or natural gas development.

More than 110 million acres – 31% of the U.S. federal public land area in the Rocky Mountain region – fall within areas known to have recoverable gas and crude oil reserves. The most well-known of these areas include the Book Cliffs (Utah), Grand Mesa (Colorado), Greater Red Desert (Wyoming), High Plains (New Mexico), Otero Mesa (New Mexico), Powder River Basin (Wyoming and Montana), Roan Plateau (Colorado), Rocky Mountain Front (Montana), San Juan Basin (New Mexico), Upper Green River Valley (Wyoming), and Valle Vidal (New Mexico).

Table 2. U.S. federal lands leased for crude oil or natural gas development in the Rocky Mountain region (Pace 2004).

State	Leased lands not producing crude oil or natural gas (%)
Colorado	71
Montana	83
Nevada	99
New Mexico	36
Utah	77
Wyoming	80

Extent of Crude Oil and Natural Gas Development on Leased U.S. Federal Lands

In certain areas of the West, crude oil and natural gas development is occurring rapidly. For example, the Powder River Basin in Montana and Wyoming is in the midst of a rapidly developing boom in exploration and development of coal-bed methane (natural gas) reserves. Industry sources and the BLM suggest that as many as 40,000 to 50,000 new wells might be developed in this area. With the possible addition of more than 10,000 new sites in the Green River Basin alone, and the potential of this huge new development in the Powder River Basin, it is quite clear that the habitat of many wildlife species, including greater sage-grouse, will be affected directly in various ways.

Similarly, 95% of the federal public land with technically recoverable crude oil and natural gas reserves in the High Plains of eastern New Mexico already has been leased and is being developed for crude oil and natural gas (D. Burger, Pecos District Office, BLM, personal communication). The only areas that remain undeveloped have been reserved by the BLM for lesser prairie-chickens and the dunes sagebrush lizard (*Sceloporus arenicolus*), both of which have been identified by the FWS as needing protection under the Endangered Species Act (ESA). Few prairie chickens have been documented in the leased areas during the past decade, but a new stakeholder-developed conservation strategy for the species might result in a notable population increase area wide.

Although most (88%) federal lands are available for crude oil and natural gas development (particularly in the Rocky Mountains), most of the leased lands in the region are not producing any energy (Pace 2004). In fact, of the roughly 36 million acres of U.S. federal lands that have been leased for crude oil or natural gas developments, only about 10 million actually are producing energy (Table 2).

It is not entirely clear why these leased lands are not being developed for energy production. According to an Associated Press report (Pace 2004), the BLM does not have any data on the extent to which these lands have been the subject of exploratory efforts to determine their production potential. Probably many factors are responsible. Difficulties in obtaining leases or permits to drill do not appear to have hindered development. Three-fourths of the U.S. federal public lands under lease have not been developed, while over the last decade more than 25,000 permits have been issued, leading to the drilling of about 19,000 wells. The following factors all might be playing a role in discouraging development:

1. Price volatility in the crude oil field supply and service sectors (National Energy Policy Development Group 2001);
2. Fluctuating world prices of natural gas and crude oil, although now it appears that high crude oil and natural gas prices might become the norm;
3. Some of the leased lands are the subject of existing applications for a permit to drill (APDs) that are in various stages of evaluation but have yet to be approved for active drilling;
4. Some energy companies might be resisting pursuing APDs if they believe that permit stipulations or new requirements to cover the costs of monitoring will make drilling uneconomical; and
5. Since energy companies list their entire federal lease holdings, including those that are undeveloped, as assets in their financial records, they have an incentive to put as much ground under lease as possible, even if they do not have immediate plans to develop those leases (Pace 2004). This asset can attract future investors and might explain why a number of companies have exceeded federal limits on the acquisition of leased acres in any one state.

Oil shale plays in North America, 2011. (Photo credit: U.S. Energy Information Administration).

CANADA

Canada is the third-largest producer of natural gas worldwide, producing an average of 6.4 tcf per year (Canadian Association of Petroleum Producers 2011a). It is also the second-largest exporter of natural gas. Proven reserves of 1.754 trillion m^3 exist in Canada (Central Intelligence Agency 2011). In 2009, Canada contributed 87% of all natural gas imports to the U.S., accounting for 12% of consumption within the country (Government of Canada 2009). Natural gas accounts for 28% of annual Canadian energy consumption, equaling approximately 3.1 tcf per year (Natural Resources Canada 2008). The provinces of Alberta and British Columbia are the first- and second-largest producers of natural gas in Canada, respectively (Canadian Association of Petroleum Producers 2011b). Alberta produces approximately 4.1 tcf per year, and reserves in the province hold a potential 223 tcf of conventional gas (Government of Alberta 2011a). In British Columbia, production equals approximately 3.36 bcf and provincial reserves hold a potential 19.07 tcf (Centre for Energy 2010). The surplus natural gas is exported, with shipments to the U.S. totaling 3.8 tcf in 2007. The province of Alberta alone is the second largest exporter of natural gas worldwide and has been the primary source of American imports of this resource for the past 6 years. In areas of Canada farther from the western supply, natural gas is imported from the U.S.

Crude oil production in Canada includes extraction from conventional oil deposits, as well as non-conventional sources of oil such as oil sands, heavy oil, oil shale, and carbonate oil (Blake Cassels and Graydon LLP 2008a). The province of Alberta is the largest producing area of oil in North America and possesses the second largest crude oil reserves in the world (Government of Alberta 2010). British Columbia produces conventional oil at a production level of 21,799 b/d (Centre for Energy 2010), far below the 525,000 b/d produced in neighboring Alberta (Government of Alberta 2011b). Canada requires 2.209 MMb/d of oil for consumption and produces a total of approximately 3.483 MMb/d. Today, Canada is thought to have the third-largest potential supply of oil worldwide, with proven reserves of 175.2 BB (Central Intelligence Agency 2011).

Currently, the Athabasca oil sands of Alberta are Canada's largest petroleum resource. The oil sands alone account for greater than two-thirds of investments within the province, and $100 billion of investments generate economic activity worth $1 trillion (Government of Alberta 2010). The oil sands account for an additional production of 1.5 MMb/d in Alberta (Government of Alberta 2011c).

Availability of Canadian Provincial Lands for Crude Oil and Natural Gas Development

Most of Canada's oil and gas resources are owned by provincial governments, with federal and private lands comprising a much smaller proportion of oil and gas ownership (Blake Cassels and Graydon LLP 2008a). Most federal ownership within the country is on national park and Indian Reserve land. Privately owned oil and gas are referred to as "freehold," and within the province of Alberta, 14% of oil and gas currently is considered freehold. Typically, these private landowners lease their substances to industry, which possesses the resources for extraction.

The greatest proportion of onshore reserves in Canada is found within the province of Alberta, primarily in the form of oil sands. These sands contain an estimated 1.8 trillion barrels of crude bitumen (Government of Alberta 2011c). Currently, less than 10% of this amount (169.9 BB) is considered recoverable. More than 34 million acres fall within areas known to have recoverable crude bitumen reserves. The Alberta Department of Energy owns 97% of this area, and the remaining 3% is held by the federal government within Aboriginal reserves as freehold rights.

The Alberta Energy Resources Conservation Board (ERCB), an independent, quasi-judicial agency of the government of Alberta, regulates Alberta's energy resources, including oil, natural gas, and oil sands. As of 2010, the ERCB regulated 179,400 operating natural gas and oil wells, 392,000 km of pipelines, and 54 commercial oil sands plants (Energy Resources Conservation Board 2011). The Ministry of Environment and Water, charged with protecting the province's environment and natural resources, also is heavily involved in the regulatory approval process and monitoring of oil and gas operations.

Extent of Crude Oil and Natural Gas Development on Canadian Provincial Lands

Oil and gas development in Canada is occurring at a rapid pace. In Alberta, more than 300,000 wells have been drilled, and more than 350,000 km of pipeline have been constructed (Government of Alberta 2011d). In total, approximately 2,470,000 acres are associated with oil and gas development in Alberta. Each year, 10,000 to 15,000 new wells are drilled, leading to a development rate of 300 acres per day within the province. In British Columbia, approximately 1,416 wells are drilled each year (Ministry of Energy and Mines 2006).

PART 2: PROCESSES USED TO DEVELOP CRUDE OIL AND NATURAL GAS IN NORTH AMERICA

UNITED STATES

Despite the fact that crude oil and natural gas developments generally adversely affect wildlife, historically, areas are leased and developed before the specific local landscape issues, concerns, and potential ecological impacts are understood (Weller et al. 2002, O'Gara and McCabe 2004). Most Resource Management Plans (RMPs) were prepared several decades ago by the BLM, and, subsequently, probably fail to address the environmental impacts of most new technologies related to crude oil or natural gas development (Western Governors' Association 2008, Zimmerman 2008).

At the local level, landscape changes associated with intensive crude oil and natural gas developments can be remarkable, yet the bureaucratic process of leasing, permitting, and developing oil and gas on the federal estate can be quite confusing. Opportunities exist for state wildlife agencies and wildlife advocates to influence leasing and development decisions. The process is briefly outlined below to summarize its key provisions and to suggest opportunities to include consideration for wildlife resources and their habitats.

Legislation Governing Oil and Gas Leasing

The primary statute governing oil and gas leasing and development on federal public lands is the Mineral Leasing Act of 1920, as amended by the Federal Onshore Oil and Gas Leasing Reform Act of 1987 (FOOGLRA, Zimmerman 2008). This statute authorizes the Secretary of the Interior to issue leases to private individuals and corporations so that they might extract oil and gas from federal public lands. The primary objective of the Mineral Leasing Act is to ensure that the U.S. federal government receives royalties from the sale of these public resources. This legislation, however, contains no provision for the protection of other natural resources.

FOOGLRA was passed by Congress to ensure a greater return to the federal treasury from the issuance of oil and gas leases than was authorized under the Mineral Leasing Act. Most leases issued under the authority of the Mineral Leasing Act were on a "first come, first served" basis and for a minimal fee. FOOGLRA requires that all U.S. federal public lands must be offered for lease at auction.

Important provisions of FOOGLRA are directed specifically at protection of other natural resources on federal public lands in the U.S. For example, the 1987 amendments gave the USFS veto authority over leases issued on lands administered by that agency. Although it is the BLM that has the authority to lease oil and gas reserves beneath federal public lands administered by the USFS, it can do so only with the specific approval of the USFS. A plan of operation must be submitted and approved before permission to drill is granted, and it requires lessees to pay an upfront fee to restore the land on which they plan to develop and drill. Although the Mineral Leasing Act authorizes the BLM to issue oil and gas leases, it does not require that leases be issued for all federal public lands in the U.S.

Land-use Plans

The Federal Land Policy and Management Act of 1976 (FLPMA) requires that land-use plans (or RMPs) be prepared for all federal public lands managed by the BLM (Zimmerman 2008). These plans identify areas closed or open to oil and gas leasing and areas that require special development practices to preserve other resource values. The agency also makes decisions about individual oil and gas development operations. The RMP stage is a critical opportunity for state wildlife agencies to become active participants in all of these decisions. At least two decisions concerning oil and gas leasing and development should be addressed at the land-use planning stage:

1. Identification of areas available for oil and gas leasing and development; and
2. Identification of any special development practices, protective stipulations, or requirements that might limit oil and gas development activities in certain areas (management directives).

All future BLM oil and gas decisions within the planning area, such as the issuance of leases or approval of drill permits, must conform to the RMP.

Availability of Specific Federal Public Lands.—The BLM has considerable discretion in determining whether particular public lands ought to be leased. The agency can decide that recreational, scenic, wildlife, or other values on the surface exceed the benefit of leasing the underlying public oil and gas resources. If there are lands that should not be developed because of their particular wildlife resources, state wildlife agencies can and should raise these concerns with the BLM Resource Area Manager during the development of any proposed land-use plan. The land-use plan also can require phased development of oil and gas resources within the planning area to ensure, for example, that not all wildlife habitats are disturbed at the same time. Phased development requires that wildlife functions be restored before additional habitat is made available for development.

Management Directives.—A land-use plan also should include management directives for how oil and gas operations will be conducted on different lands within the planning area. For example, the land-use plan might require that exploration be suspended in elk (*Cervus elaphus canadensis*) habitat during the calving season. These limitations become part of the lease and are known as "seasonal" or "timing" stipulations. The plan also might include a "no surface occupancy" (NSO) stipulation for fragile areas, which, in its strictest application, means no development or disturbance whatsoever of the land surface, including establishment of wells or construction of well pads, roads, pipelines, or power lines.

Recognizing that the environmental analysis of oil and gas development contained in many existing RMPs might no longer be adequate because of either changed circumstances or new information, the BLM recently instructed its state directors to prepare Master Leasing Plans (MLPs) for some public lands (U.S. Bureau of Land Management 2010). These MLPs must be prepared for areas where the development of oil or gas resources could conflict with other public land values and where a substantial portion of the area is not yet leased. A BLM instruction memorandum specifically requires consultation with state wildlife agencies regarding whether parcels nominated should be offered for oil and gas leasing and whether leases should contain NSO or timing stipulations. Once a lease is sold, placing additional stipulations on the development of that lease becomes more difficult. MLPs also might identify additional measures to mitigate the impacts of oil and gas development on fish and wildlife, including caps on new surface disturbance within important habitats. This is another key opportunity for the expertise of state wildlife agencies to be included in designing the timing and manner of oil and gas development within habitats.

Individual (Site-Specific) Project Processes

Public notice that lands have been proposed for leasing must be posted at least 90 days prior to the sale. Formal protests of the sale of any parcel must be filed within 30 days of the public notice (U.S. Bureau of Land Management 2010). Prior to conducting any oil and gas related activity on federal public lands in the U.S., the lessee first must obtain a mineral lease from the BLM.

The application for a permit to drill (APD) is the final stage before the drill bit breaks the ground and therefore is a critical time for state wildlife agency involvement. A complete APD must contain both a drilling plan and a surface-use plan of operations. The drilling plan must describe the drilling program, provide a map of surface and subsurface locations to be disturbed, provide geological data, identify potential hazards (such as releases of oil into nearby streams or wetlands), and propose ways to avoid such hazards or to minimize their effects. The surface-use plan of operations must describe the location of roads and drill pads, provide specifics of well-pad construction, detail methods for containing and disposing of waste materials, and set out plans for reclaiming the surface. Before activities can begin, the BLM must approve both plans. For lands administered by the USFS, the agency must approve the surface-use plan of operations. State wildlife agencies can work with the BLM and the USFS to develop surface-use plans of operations that include mitigation of impacts to wildlife and restoration of habitat.

Commenting on Environmental Impact Statements.—The National Environmental Policy Act of 1969 (NEPA) requires the BLM to prepare an environmental impact statement (EIS) whenever it proposes to take an action "significantly affecting the quality of the human environment" (Section 102(C) [42 USC § 4332], Zimmerman 2008). Preparing a new land-use plan or making major amendments to an existing plan almost always requires an EIS. Approving permits to drill for oil or gas on federal public lands in the U.S. might require an EIS, depending on the circumstances. States can become "cooperating agencies" in the development of an EIS. In essence, "Cooperating Agency Status" gives the state a seat at the table. Issuance of leases, approval of drill permits, and authorization of exploration activities might, depending on the circumstances, have a significant impact on the environment and require an EIS. The BLM normally does not prepare an EIS prior to the issuance of leases. Instead, the agency often relies on the EIS it prepared for the applicable land-use plan. In many instances, where individual leases or drill permits are issued, the BLM will prepare a shorter document called an environmental assessment (EA). An EA must include a brief discussion of the need for the project, alternatives to the proposed project, and the environmental impacts of the proposed action and alternatives. This discussion must be sufficiently detailed to determine whether impacts might be significant and the preparation of an EIS is required.

CANADA

The Constitution Act of 1867 granted ownership of minerals and royalties to the original joining provinces of Canada (Blake Cassels and Graydon LLP 2008a). Upon joining Canada, the provinces of British Columbia, Prince Edward Island, and Newfoundland were also granted these rights, with Alberta, Saskatchewan, and Manitoba following suit in 1930. The federal government maintained ownership of minerals on national park lands and on Indian Reserves.

Today, oil and gas leases in Canada typically are managed by the provincial Crown. Private land gained through a grant or sale by the government typically does not include a transfer of subsurface mineral rights (Campbell and Howard 2004). This means that these interests are held by the provincial government, which can sell the subsurface rights to another party for exploration and production. The acquiring party rarely is denied access to the surface private property. In Alberta, the Department of Energy manages approximately 81% of the 66 million hectares (ha) (163 million acres) owned by the provincial Crown (Government of Alberta 2009). A smaller proportion of oil and gas rights in Canada are held in freehold estates, whereby the province or federal government has granted the rights to these resources to an individual or corporation (Blake Cassels and Graydon LLP 2008a).

The only substantial oil and gas development occurring on federal lands in Alberta is on military reservations, such as the Cold Lake Air Weapons Range and the Canadian Forces Base Suffield. Land in Canada that is held by the federal government is open for oil and gas exploration and development, as long as it is not already occupied (Blake Cassels and Graydon LLP 2008a, Davies Ward Phillips and Vineberg LLP 2010). If the land is occupied, permission must be granted by the occupier before companies may access the surface.

Legislation Governing Oil and Gas Leasing

The National Energy Board (NEB) is the primary federal oil and gas regulatory body in Canada (Davies Ward Phillips and Vineberg LLP 2010). The NEB regulates projects that are inter-provincial, such as pipelines, and those on federal lands. The ERCB regulates oil and gas in the province of Alberta along with the Ministry of Environment and Water (Energy Resources Conservation Board 2011). In Alberta, facilities cannot be constructed or operated for the recovery of oil sands or crude bitumen without the approval of the ERCB, pursuant to the Oil Sands Conservation Act. The Oil and Gas Conservation Act serves to conserve and maximize benefit from such resources for all Albertans. The ERCB also is responsible for surface facility approvals, subsurface development approvals, production information and compliance, and inspections (Energy Resources Conservation Board 2011). The Ministry of Environment and Water is responsible for establishing environmental standards, issuing approvals, reviewing environmental impact assessments (EIAs), reclamation and remediation, and compliance and inspections within the province. Alberta Sustainable Resource Development (SRD) is the ministry that regulates surface access on provincial public lands, land use coordination, and exploration on public and private lands. The Alberta Surface Rights Board (SRB) is in charge of rights of entry when consent from the surface occupant has been denied. The SRB also serves as a body to hear disputes that occur between a landowner and an operator regarding compensation (Blake Cassels and Graydon LLP 2008a, Energy Resources Conservation Board 2011). The board is not used when alternative dispute resolution procedures are recognized within the written lease (Blake Cassels and Graydon LLP 2008a).

In British Columbia, the Ministry of Energy and Mines (MEM) oversees the development and alteration of oil and gas regulations, laws, and other management-related oil and gas interests (Campbell and Howard 2004). These laws and regulations are implemented by the Oil and Gas Commission (OGC), which is a consolidated regulatory agency. The OGC regulates all stages of oil and gas development, from road construction to site remediation. The Ministries of Water, Land and Air Protection (MWLAP), Sustainable Resource Management (MSRM), and Forests (MOF) play a smaller role in British Columbia oil and gas regulation, and often many of their responsibilities have been delegated to the OGC in situations where oil and gas are involved. MWLAP implements environmental laws such as the Environmental Management Act, the Wildlife Act, the Pesticide Control Act, and the Park Act, regulating the transport of hazardous materials, site remediation, and emissions. MSRM regulates land use, planning, and approval in British Columbia. The responsibilities of the MOF have been diminished, because the OGC is now responsible for the regulation and approval of road and well sites in forested areas. The MOF still implements the Forest and Range Practices Act and the Forest Act. The province of British Columbia also has a Mediation and Arbitration Board that exists to resolve disputes over the terms and conditions of access to private lands between the landowner and oil and gas companies.

Conservation and Reclamation Requirements

Federal environmental legislation and regulations apply to oil and gas developments occurring on federal lands that received federal financing or that impact fish habitats or species at risk (Davies Ward Phillips and Vineberg LLP 2010). The Canadian Environmental Protection Act 1999 (CEPA) requires that oil and gas companies report their releases, disposal, and transfers of toxic substances to Environment Canada. The Fisheries Act also may apply to oil and gas activities in Canada. The Fisheries Act serves to protect fish habitat and prohibits the pollution of water used by fish through the addition of deleterious substances. Limits on the amount of oils and phenols that may be deposited into the environment are included under the definition of deleterious substances. The Fisheries Act also establishes sampling, environmental monitoring, and reporting obligations. The federal Species at Risk Act protects species at risk and their habitat, and may have applications to oil and gas development occurring in certain areas.

Provincial environmental legislation also may apply to oil and gas development. For example, the Alberta Environmental Protection and Enhancement Act (EPEA) prohibits the unlawful discharge of substances that may have significant negative impacts (Davies Ward Phillips and Vineberg LLP 2010). The EPEA additionally requires reclamation plans to be submitted to the government for approval. The Ministry of Environment and Water and the SRD regulate the reclamation process for oil sands activity. Currently, approximately 60,200 ha (148,757 acres) of land have been directly disturbed by oil sands extraction in Alberta, and only 6,700 ha (16,556 acres) of land have been reclaimed (Blake Cassels and Graydon LLP 2008b). Limits also are being placed on the amount of water used by oil and gas companies through the Athabasca River Water Management Framework.

In British Columbia, oil and gas companies are responsible for site remediation (Campbell and Howard 2004). This means that once reserves have been depleted, the company must remove their equipment, re-seed, and perform any other actions necessary to return the area to its previous condition. The OGC requires that each company post a $7,500 reclamation bond per well to be reserved for remediation, though often much more money is required. Some issues have arisen due to company bankruptcy or changes in ownership.

Individual (Site-Specific) Project Processes

Surface Rights and Leases.—In Alberta, the government grants a license for exploration and a lease for drilling (Blake Cassels and Graydon LLP 2008a). Licenses last for 2 to 5 years and are sold through a bidding system. Leases also are sold through a bidding system but have a primary term of 5 years, which can be extended. Leases are transferrable, by permission of the minister. Lessees also must pay a royalty set by the Crown. Subsurface mineral rights, such as through a lease, must be obtained before exploration or development commences, as required by the Alberta Surface Rights Act. Consent of surface rights owners and occupants must be obtained, or the interested party must gain a right of entry order. In both Alberta and British Columbia, the interested party often must provide compensation to the owner or occupant for surface access (Campbell and Howard 2004, Blake Cassels and Graydon LLP 2008a). The surface rights owner is entitled to be given notice, to be heard, and to receive an order ensuring compensation is paid (Blake Cassels and Graydon LLP 2008a). Due to varying circumstances, regulations vary slightly for the Alberta oil sands in contrast to the rest of the province. For example, in the Alberta oil sands, permits are issued for a 5-year period during which the holder can apply to convert the permit into a primary lease for the oil sands rights for a term of 15 years (Vlavianos 2007).

In British Columbia, a company must obtain the subsurface rights for a mineral resource in a given area before it can begin drilling (Campbell and Howard 2004). Exploration normally occurs by the company before it approaches the Ministry of Energy and Mines (MEM) to auction the rights. Landowners are not given advance notice of these sales, but tenures under consideration for sale by MEM are shown on pre-tenure maps.

Pipelines and Well Sites.—Licensing and approvals for well drilling and road and pipeline construction are distinct from the surface rights legislation (Blake Cassels and Graydon LLP 2008a). An operator must obtain a right of entry order for the construction and operation of wells, access roads, and pipelines. Approval also is required to construct these structures. Pipelines fall under both provincial and federal jurisdiction (Blake Cassels and Graydon LLP 2008a). In Alberta, the Pipeline Act authorizes the expropriation of land for pipelines within the province based on surface rights legislation that require the surface owner to be compensated. Federal inter-provincial and international pipelines are regulated by the NEB, and land acquisition is regulated under the National Energy Board Act (Davies Ward Phillips and Vineberg LLP 2010). Upon receipt of an application, the NEB may grant an immediate right of entry, which allows for the construction, maintenance, and operation of pipelines (Blake Cassels and Graydon LLP 2008a). The NEB also regulates compensation for entry, as well as voluntary land acquisition and negotiation and compensation orders. In British Columbia, the OGC is responsible for the regulation of all provincial pipelines (Land Tenures Branch 2011). Entry to land where a well site exists or is proposed is governed under surface rights legislation (Blake Cassels and Graydon LLP 2008a).

Access and compensation are provided based on the area required for drilling and maintenance. In Alberta, Mineral Surface Leases (MSLs) may be issued under section 76 of the Public Lands Act (Schneider 2001). An application for an MSL must be accompanied by an Environmental Field Report (EFR) (Sustainable Resource Development 2008), in which environmental areas of concern are identified. EFRs must include information on how environmental standards will be met through the construction, operation, and reclamation phases of the proposed project. EFRs are also required for other disposition types such as compressor site (Pipeline Installation Lease [PIL]), pipeline (Pipeline Right-of-Way [PLA]) and access road (Licence of Occupation [LOC]) applications. The EFR is reviewed by various government departments before approval or rejection.

Environmental Impact Assessments.—The Canada Environmental Assessment Act requires an EIA to be conducted whenever a federal authority proposes a project or grants land or money to a project, or when a regulatory duty is required for a project (Blake Cassels and Graydon LLP 2008a). Typically, an EIA is required before exploration (Davies Ward Phillips and Vineberg LLP 2010). The extent, scope, and timeline for the EIA are determined by the federal government (Blake Cassels and Graydon LLP 2008a). Once the EIA is complete, the government will determine if potential environmental effects are significant and whether the project should proceed.

EIAs also are required provincially in Alberta under the Environmental Protection and Enhancement Act (Sustainable Resource Development 2011). An EIA commences when a company announces its intent to begin a new activity and is completed when Alberta SRD grants access to public lands. The EIA must report on impacts to fish, forests, public lands, and wildlife. The completed EIA is made public and is reviewed by the Ministry of Environment and Water, ERCB, and other provincial agencies (Davies Ward Phillips and Vineberg LLP 2010). EIAs are required in British Columbia also pursuant to the Environmental Management Act and must report on potential effects to water quality, air quality, land use, water use, aquatic ecology, and terrestrial ecology (Government of British Columbia 1981).

PART 3: IMPACTS OF CRUDE OIL AND NATURAL GAS DEVELOPMENT ON WILDLIFE IN NORTH AMERICA

UNGULATES

Large reserves of natural gas exist within the intermountain West (U.S. Department of Energy 2009). Most are located on federal public lands and occur in shrub-dominated basins (Sawyer et al. 2009). These shrub-dominated basins are important seasonal habitats for many species of wildlife including native ungulates, and significant concern has arisen over the design and development of natural gas reserves and the corresponding impacts to native wildlife. Western ungulates generally move between seasonal ranges because of decreasing food quality and weather events (Wallmo et al. 1977, Toweill and Thomas 2002, O'Gara and Yoakum 2004). The habitat value of seasonal ranges, particularly winter ranges, and the routes connecting them are critically important in maintaining ungulate populations. Oil and gas development and its associated infrastructure affect both these seasonal ranges and migration routes.

Although historical efforts to restore western ungulates were largely successful, some ungulate species have recently experienced significant population declines. Research conducted throughout the West identified a reduction in the quality and quantity of habitat as a likely reason for observed declines in mule deer (*Odocoileus hemionus*) populations, whereas the role of predation and other factors had little or no noticeable impact (Gill et al. 1999, 2001, Lutz et al. 2003, Bergman et al. 2007, Hurley and Zager 2007, Bishop et al. 2009). Mule deer declines are magnified further by threats to habitat that stem from human development, particularly unregulated energy resource extraction on quality habitats, which also might interfere with doe and fawn habitat fidelity (Garrott et al. 1987).

O'Gara and Yoakum (2004) clearly stated that to survive, pronghorn *(Antilocapra americana)* must

Pronghorn share sagebrush habitats with greater sage-grouse in this area northwest of Billings, Montana. (Photo credit: Jeremy R. Roberts, Conservation Media).

have suitable, expansive rangelands where they can forage and migrate without impediments to quality seasonal habitats. Historically, pronghorn made large movements to avoid the deep snows of winter. However, pronghorn movements have become more difficult because of human-made impediments such as roads, fences, and railroads (O'Gara 2004).

Elk also need large landscapes and seasonal ranges to continue to successfully populate their historic habitats, but these large landscapes are being fragmented and important winter ranges are being developed for human uses. As these challenges continue, elk habitats are becoming more compressed, resulting in significant management issues and reduced human tolerance (Wisdom and Cook 2000, Toweill and Thomas 2002).

Direct Impacts

Removal of habitat features, including foraging, watering, and security areas, directly affects the ability of ungulates to persist. Whether caused by exurban development or mineral extraction, the resulting footprint of homes, well pads, roads, or mining infrastructure equates to a measurable loss of habitat (Watkins et al. 2007). Invasion of highly competitive, fast-growing, and non-palatable or poisonous weed species precipitated by removal of native vegetation, blading, pipeline construction, road building, or other soil disturbances also results in direct habitat loss. When left unchecked, these invasive weeds can dominate a landscape quickly, making a poor habitat situation even worse. For example, expansion of cheatgrass (*Bromus tectorum*) has caused dramatic declines in productivity and habitat quality in the intermountain West (DiTomaso 2000, Schaffer et al. 2003). Surface disturbances can allow invasive weeds to expand into new areas (Bradford and Lauenroth 2006), out-compete native forage, change fire regimes, and influence reclamation success (Pilkington and Redente 2006). The direct mortality of ungulates from unrestrained dogs (Lowry and McArthur 1978), illegal take (Berger and Daneke 1988), fencing (Riddle and Oakley 1973, Sheldon 2005), and other sources associated with fossil fuel developments also has been documented.

Indirect Impacts

Big game species have demonstrated varying degrees of avoidance around areas of energy development. The collective area of disturbance might encompass just 5-10% of the land; however, the influence of each facility (e.g. well pad, road, overhead power line) extends to a larger surrounding area, where the proximity of disturbance causes stress and avoidance by wildlife. For mule deer, alert and flight reactions have been detected up to 0.3 miles from the source of disturbance (Freddy et al. 1986), whereas habitat avoidance responses might extend to distances of 2.5-4.3 miles (Sawyer et al. 2009). Deer respond negatively to roads with high traffic levels associated with winter drill sites. Zones of negative response can reach more than 0.5 miles for elk on open winter ranges (Johnson and Lockman 1979, 1981; G. S. Hiatt and D. Baker, Wyoming Game and Fish Department, unpublished report; Brekke 1988, Hayden-Wing Associates 1990). Edge (1982) reported elk avoidance of areas within 0.75 km (0.47 miles) of roads and 1−1.5 km (0.62-0.93 miles) of active logging, and also noted that elk responded to the level of human activity at logging operation sites (e.g., elk avoidance declined with declining human activity). Landon et al. (2003) reported that pronghorn used areas of lower noise levels (less than 45 decibels) more than expected, and used areas of higher noise levels (greater than 55 decibels) less than expected.

As densities of well pads, roads, and facilities increase, habitats within and near well fields become progressively less attractive until most animals no longer use them. Kuck et al. (1985) concluded that mining exploration might cause elk to abandon spring calving range. Animals that remain within the affected zones are subjected to increased physiological stress. This avoidance and stress response reduces the capability of wildlife to use suitable habitat. In addition, physical or psychological barriers might lead to fragmentation of suitable habitats, further limiting access.

Energy expended by deer (Mautz and Fair 1980, Freddy 1984, Parker et al. 1984, Freddy et al. 1986) and elk (Parker et al. 1984) increases significantly as they transition from lying to walking to running, particularly in snow. For example, Freddy et al. (1986) reported that deer disturbed by humans increased energy expenditure from 9 calories while lying to 54-127 calories while running.

Energy expenditures in response to disturbance are of greatest concern during winter months when energy conservation is fundamental to survival and reproductive fitness in deer. Oil and natural gas development might negatively affect deer by increasing energy expenditure and decreasing forage availability. Combined, these factors synergistically increase the rate at which nutrient body stores are depleted. If these impacts are of sufficient magnitude to cause increased overwinter mortality or reduced neonate production and survival, populations will decline.

Cumulative Impacts

The cumulative effects of development on habitat probably represent the greatest threat to ungulate populations (Hebblewhite 2008). The magnitude of effects (i.e., biological significance) is directly related to the intensity of the specific development. Oil and gas development of federal public land often is leased, assessed, and permitted on a piecemeal basis, and rarely do the decision makers evaluate cumulative impacts. The Green River Basin Advisory Committee identified the inadequacy of existing assessments and the increasing need for an effective cumulative impact analysis during its efforts to provide more meaningful guidance in planning for oil and gas development on federal public land in the mid-1990s (U.S. Bureau of Land Management 1996). The inability to assess the cumulative impacts of oil and gas development on public lands has direct implication to the concomitant and, in many instances, more intense natural gas development that is occurring on private property (Naugle 2011).

Cumulative effects of habitat loss and degradation are expected to increase the potential for competition between deer and elk (Stewart et al. 2002, Watkins et al. 2007). Research has established that disturbance associated with oil and gas development likely will increase movements of elk, potentially to areas with existing mule deer and elk groups in those areas, leading to direct or indirect forage competition (Watkins et al. 2007). Although oil and gas development initially might not cause a decrease in elk numbers, it might cause elk to negatively impact mule deer populations, thereby compounding the direct effects of energy extraction on mule deer.

Mitigation

Mitigation of oil and gas impacts for ungulates is most effective prior to surface disturbance when it is designed as an integral component of the leasing and field-development design phases (Wyoming Game and Fish Department 2010). Leasing that is structured, organized, and staged over time to assure that leases are not sold in a chaotic manner is best for wildlife. Leasing in a phased manner that methodically and thoughtfully allows development to proceed across the landscape is preferable to the current process of nominating parcels in a random manner. Developing a well field in small incremental phases (phased development) with considerations for landscape-level conservation can reduce the overall impact of a high-density field. The ecological parallel of the current model of unplanned, chaotic leasing is scramble competition, and the results are similar: increased stress and reduced population performance. Orderly development of resource extraction provides predictability to wildlife professionals as they assess impacts, and can provide secure habitats as refugia for big game over the long term.

Design of oil and gas extraction can help mitigate impacts to wildlife if it is done with the following parameters as part of the planning process. First, the disturbance footprint should be minimized (Western Governors' Association 2008). Reducing direct habitat disturbance will yield more habitats available for wildlife. Second, human presence on the production field should be minimized (Sawyer et al. 2009). New technologies exist for gathering the liquids produced as a result of condensation of natural gas and transmitting performance data without frequent human entry. Sawyer et al. (2009) verified the benefits of using liquid gathering systems (LGS) to reduce indirect habitat impacts and directly benefit mule deer in Wyoming, documenting a 38%-63% decrease in indirect habitat loss with the use of LGS. These systems can be employed more often, and their implementation should be a standard procedure in seasonally important big game habitats. Restricted human access also reduces vehicle collisions and illegal take of big game in oil and gas fields. Third, invasive weeds should be managed and controlled from the beginning of field development. Reclamation of disturbed habitats must begin as soon as possible to restore soil fertility and vegetative production of native plants and to control invasive weeds and water erosion. Finally, monitoring of both habitat vitality (including reclamation and weed control) and big game population performance must be designed and carried out for the life of the project. Only in this manner can problems be identified quickly and adjustments or redesigns implemented. On-site mitigation likely will not protect or compensate for development impacts because the animals stop using the otherwise available habitats near developments, and therefore off-site mitigation should be considered to more-fully ameliorate the impacts of development (Sawyer et al. 2009).

Both the Wyoming Game and Fish Department (WGFD) and the Colorado Division of Parks and Wildlife recently and independently proposed the concept of impact thresholds regarding intensity of oil and gas field development. Both agencies have suggested escalating the mitigation measures based on the level of development, thus customizing mitigation recommendations. Responding to rule-making designed to protect wildlife, Colorado wildlife managers stressed that minimizing the density of oil and gas development can minimize impacts to wildlife and also can provide flexibility for future mitigation (Colorado Division of Wildlife 2008). Similarly, Wyoming has established an approach requesting design accommodation for wildlife and mitigation options based on well densities (Wyoming Game and Fish Department 2010).

The critical periods for elk survival are during winter due to reduced forage quantity and quality and increased metabolic requirements, and during calving season when reproductive success can be compromised. Mitigating potential impacts of development activities during these periods appears to be most valuable in sustaining viable elk populations. For crucial mule deer winter ranges and partition areas, WGFD considered 1 pad per mi^2 or 20 acres of disturbance per mi^2 a moderate impact level. The extreme level of impact was reached when development included 4 pads per mi^2 and greater than 60 acres of disturbance per mi^2. Similarly for pronghorn, the WGFD (2010) suggested that moderate impacts for crucial winter ranges were reached with 4 pads per mi^2 or 20 acres of disturbance per mi^2. Extreme impact thresholds were reached for pronghorn when more than 16 pads or more than 80 acres were disturbed per mi^2. For elk, the WGFD (2010) concluded that elk were too sensitive to oil and gas developments to provide "moderate impact" thresholds. Therefore, they suggested impacts reached high levels when 4 pads or 60 acres of disturbance occurred per mi^2. Extreme impact thresholds were achieved when well pad densities exceeded 4 pads or 60 acres of disturbance per mi^2. Mitigation methods that minimize disturbance should lessen the likelihood that development will negatively affect both elk and mule deer.

Two discrete opportunities exist for mitigating impacts of oil and gas development to mule deer, elk, and pronghorn. State and federal permitting authorities have the opportunity to restrict development activities as part of timing stipulations to a lease. Few states implement wildlife protective measures, but in the U.S., the federal government can impose lease restrictions that minimize impacts to the environment on federal public lands. Lease stipulations are frequently applied and are intended to minimize impacts to wildlife during the drilling phase. More detailed mitigation opportunities exist during the operational phase of oil and gas development and include specific requirements for traffic, noise, and reclamation. Both types of mitigation are important, and, therefore, must be considered as a package by those designing and implementing oil and gas development in ungulate habitats.

For wintering ungulates, state and federal agencies have proposed restrictions to eliminate human activity on critical winter ranges. Often the designation of most critical winter range applies to less than half of the total winter range. These recommendations usually vary between two periods, a closure from mid-November to late April or from January 1 to March 31. Such restrictions lessen disturbance to mule deer, pronghorn, and elk at a time when energy conservation is most critical to survival. The restriction also might reduce direct mortality by minimizing deer and elk vehicle collisions, particularly if it causes a reduction in overall traffic volume to and from development areas. Optimal timing stipulations for ungulates would limit activity on all winter ranges from

Leks such as this one are vital gathering areas for male greater sage-grouse that engage in competitive mating displays. However, these areas are threatened by energy development activities. (Photo credit: Jeremy R. Roberts, Conservation Media).

early or mid-December through late April to afford maximum protection. From a biological perspective, these timing restrictions represent the least restrictive standard that is likely to have any mitigating effect on ungulate populations. The BLM commonly employs timing stipulations for wintering big game as part of oil and gas leases. However, these stipulations are ineffective, largely because they often are waived or modified by BLM, and although they form the foundation of pre-development mitigation and represent a public commitment to minimize impacts to wildlife, they frequently are removed from leases without cause and without applying other compensatory mitigation (Benson 2011).

For pronghorn and elk, minimizing disturbance facilitates uninterrupted foraging activity. This includes both movements and distribution, which might lead to greater utilization of preferred habitat. It is well known that malnutrition causes mortality in pronghorn populations (O'Gara 2004). O'Gara (2004) also suggested that malnutrition can lead to low birth weights, a factor in decreased neonatal fawn survival in some years in the Middle Park, Colorado, pronghorn population (Fairbanks 1993). Reduced disturbance also would lessen the likelihood that elk would move to undeveloped areas, which, subsequently, would lessen the potential for long-term habitat degradation and competition with mule deer (Sawyer et al. 2007, Watkins et al. 2007). Likewise, reduced disturbance should lessen the probability that elk would move onto agricultural lands and cause damage conflicts (Conner et al. 2001).

Although the BLM's timing limitations are designed to lessen disturbance, they apply only to the construction and drilling phase of oil and gas operations. Timing stipulations do not apply to the production phase of natural gas projects, and production can last for 20-50 years. Ongoing oil and gas operations are spread out spatially and temporally; they displace animals and cause animal avoidance beyond the construction phase of development (Bromley 1985). Timing stipulations offer only temporary and incomplete mitigation for oil and gas development.

Impacts to wildlife do occur during the production phase of oil and gas development, and additional strategies to avoid, minimize, and mitigate impacts of development are needed. Design strategies should include enhanced reclamation for wildlife species, off-site and compensatory mitigation that conserves large blocks of habitat spatially and temporally, and changes in operational practices to minimize disturbance to animals. Timing limitations alone do not alleviate declines in habitat quality caused by habitat loss and fragmentation. If winter-range carrying capacity is reduced, research indicates that increased densities of deer on remaining habitat will cause a reduction in survival because of density dependence (White et al. 1987, Bartmann et al. 1992, White and Bartmann 1998, Bergman et al. 2007, Watkins et al. 2007, Bishop et al. 2009).

Knowledge Gaps

Too often, oil and gas interests have tried to use annual state and provincial population data to assess the impacts of oil and gas development on wild ungulates. These data frequently are consulted as a "pre-treatment" population assessment. However, population data gathered by wildlife agencies are neither sufficiently robust nor designed to provide data on a small scale to delineate impacts of a specific development (J. Ellenberger, Colorado Division of Wildlife, personal communication; H. Harju, Wyoming Game and Fish Department, personal communication). These types of data are collected for an entirely different purpose and cannot be used to establish development impacts on the appropriate spatial or time scale. Research that includes controls and pre- and post-development data of sufficient scale and for adequate time periods has not occurred to a significant degree for ungulates (Hebblewhite 2008), largely due to funding requirements and the time commitment necessary to demonstrate population-level cause-effect relationships.

Some insights exist into population-level impacts of oil and gas development, but definitive population information accumulates slowly. In a study of pronghorn response to oil development on winter range, Easterly and Guenzel (1992) reported that pronghorn densities around active oil fields were lower than around areas outside oil fields. However, this relationship did not hold for inactive oil fields, because the researchers could not detect that pronghorn avoided areas with inactive oil fields. The authors also found that the mean distance of pronghorn from well sites was farther during active drilling compared to before and after drilling, suggesting that pronghorn moved away from well sites during active drilling. Those authors cautioned that their inferences might be biased because some data were collected from roads. To date, no research efforts have supported or refuted population-level impacts on pronghorn exposed to energy development.

Another factor that must be understood is the effect of energy development on pronghorn migration and movements (Berger 2004, Sawyer et al. 2005, Hebblewhite 2008). Movement corridors in Wyoming have been documented to be very traditional, and some corridors have very narrow bottlenecks (Berger 2004). Additional work is needed to identify other such sensitive areas and the possible effects of development on pronghorn movement and survival.

Only a few studies have investigated elk responses to oil and gas development, but other studies have evaluated energy exploration activities in relation to elk distribution and movements. Additionally, several studies have assessed non-energy development human activities on elk behavior. Similar to most other large ungulate species, elk population-level responses to energy development have not been demonstrated or refuted.

SAGE-GROUSE

The sagebrush ecosystem is representative of the struggle to maintain biodiversity in a landscape that bears the burden of our ever-increasing demand for natural resources (Naugle 2011). One species affected by domestic energy production is the greater sage-grouse (*Centrocercus urophasianus*, hereafter "sage-grouse"), a game bird endemic to semi-arid sagebrush (*Artemisia spp.*) landscapes in western North America (Schroeder et al. 1999). Previously widespread, the sage-grouse has been extirpated from approximately half of its historic range (Schroeder et al. 2004), and populations have declined by 1.8%-11.6% annually over the past four decades in about half of the populations studied (Garton et al. 2011). Energy development has emerged as a major issue in conservation because areas currently under development contain some of the highest densities of sage-grouse (Connelly et al.

2004) and other sagebrush obligate species (Knick et al. 2003) in western North America.

Sage-grouse need large, intact sagebrush habitats to maintain robust populations (Connelly et al. 2011). As a result, the size of sage-grouse breeding populations often is used as an indicator of the overall health of the sagebrush ecosystem (Hanser and Knick 2011). Few early studies have evaluated impacts of energy development on sage-grouse populations (Naugle et al. 2011a), but research has increased rapidly in concert with the pace and extent of development. Naugle et al. (2011b) found 14 studies that reported negative impacts from energy development on sage-grouse, and none of the studies reported any positive influences on populations or habitat.

Direct Impacts

Loss and degradation of sagebrush habitat from development can reduce carrying capacity of local breeding populations of sage-grouse (Swenson et al. 1987, Braun 1998, Connelly et al. 2000a, Connelly et al. 2000b, Crawford et al. 2004). Studies show breeding populations of sage-grouse have been affected severely at well densities commonly permitted (8 pads per mi^2) in conventional oil and gas fields in Montana and Wyoming (Holloran 2005, Walker et al. 2007a). Direct collisions with power lines and vehicles on roads—infrastructure commonly associated with energy development—also is responsible for sage-grouse mortality year-round (Patterson 1952, Beck et al. 2006, Aldridge and Boyce 2007). In addition, ponds created by coal-bed natural gas development might increase the risk of sage-grouse mortality from West Nile virus (WNv) in late summer (Walker et al. 2004, Zou et al. 2006, Walker et al. 2007b, Schrag et al. 2010).

Indirect Impacts

Male sage-grouse gather in areas known as leks to take part in competitive mating displays, but the presence of oil or gas wells adjacent to leks decreases male attendance (Harju et al. 2010). Of leks active in 1997, only 38% inside gas fields remained active as of 2004–2005, compared with 84% outside energy development areas (Walker et al. 2007a). Male lek attendance in the Pinedale Anticline Project Area in southwest Wyoming decreased with proximity to the nearest active drilling rig, producing gas well, and main haul road, and declines were most severe (40%–100%) at breeding sites within 3.1 miles of an active drilling rig or within 1.86 miles of a producing gas well or main haul road (Holloran 2005). Leks with at least one oil or gas well within a 0.25 miles radius had 35%–91% fewer attending males than leks with no well within this radius (Harju et al. 2010). Declining lek attendance also is associated with a higher landscape-level density of well pads (Harju et al. 2010). Lek attendance at a well-pad density of 8 well pads per mi^2 was 77%–79% lower than attendance at leks with no well pad within 5.3 miles. In an endangered population in Alberta, Canada, where low chick survival (12% surviving to 56 days) limited population growth, risk of chick mortality in the Manyberries Oil Field was 1.5 times higher for each additional well site visible within 1 km (0.62 miles) of a brood location (Aldridge and Boyce 2007).

Sage-grouse populations decline when birds avoid infrastructure in 1 or more seasons (Doherty et al. 2008, Carpenter et al. 2010). Avoidance of energy development at the scale of entire oil and gas fields should not be considered a simple shift in habitat use but rather a reduction in the distribution of sage-grouse (Walker et al. 2007a). Avoidance likely will result in true population declines if density dependence, competition, or displacement of birds into poorer-quality adjacent habitats lowers survival or reproduction (Holloran and Anderson 2005, Aldridge and Boyce 2007, Holloran et al. 2010).

Mechanisms that lead to avoidance and decreased fitness have not been tested empirically but rather suggested from observational studies. For example, abandonment might increase if leks are repeatedly disturbed by raptors perching on power lines near leks (Ellis 1984), by vehicle traffic on nearby roads (Lyon and Anderson 2003), or by noise and human activity associated with energy development during the breeding season (Holloran 2005, Kaiser 2006). Increased predation by raptors also might increase mortality of birds at leks (Connelly et al. 2000a). Roads and power lines might affect lek persistence indirectly by altering productivity of local populations or survival at other times of the year. Alternatively, birds might simply avoid otherwise suitable habitat as the density of roads, power lines, or energy development increases (Lyon and Anderson 2003, Holloran 2005, Kaiser 2006, Doherty et al. 2008, Carpenter et al. 2010).

Studies also have quantified the distance from leks at which impacts of development become negligible and have assessed the efficacy of the stipulation by the

BLM of no surface disturbance within 0.4 km (0.25 miles) of a lek (Naugle et al. 2011a). Impacts to leks from energy development were most severe near the lek, but they remained discernible out to distances of more than 6 km (3.73 miles) (Holloran 2005, Walker et al. 2007a, Tack 2009, Johnson et al. 2011) and often resulted in extirpation of leks within gas fields (Holloran 2005, Walker et al. 2007a). A 0.4-km (0.25 mile) buffer leaves 98% of the landscape within 3.2 km (2 miles) of a lek open to full-scale development. In a typical landscape in the Powder River Basin, this amount of landscape development reduced the average probability of lek persistence from 87% to 5% (Walker et al. 2007a). Two recent studies found negative impacts apparent out to 12.3 km (7.6 miles) on large leks (more than 25 males; Tack 2009) and out to 18 km (11.2 miles) on long-term trends in average number of sage-grouse counted on leks each year (Johnson et al. 2011), the largest scales that have yet been evaluated.

High site fidelity in sage-grouse also suggests that unfamiliarity with new habitats might reduce survival, as in other grouse species (Yoder et al. 2004). Sage-grouse in the Powder River Basin were 1.3 times more likely to occupy winter habitats that had not been developed for energy (12 wells per 4 km^2 [10.35 mi^2]), and avoidance of developed areas was most pronounced when it occurred in high-quality winter habitat with abundant sagebrush (Doherty et al. 2008). In a similar study in Alberta, avoidance of otherwise suitable wintering habitats within a 1.9-km (1.18-mile) radius of energy development resulted in substantial loss of functional habitat surrounding wells (Carpenter et al. 2010). Scientists therefore recommend at least a 1.9-km (1.18-mile) setback distance for future energy developments from all winter habitats identified as critical habitat under the federal Species at Risk Act for this endangered species in Canada.

Cumulative Impacts

Long-term studies in the Pinedale Anticline Project Area in southwest Wyoming present the most complete picture of cumulative impacts and provide a mechanistic explanation for declines in populations (Naugle et al. 2011a). Early in development, nest sites were farther from disturbed than undisturbed leks. The rate of nest initiation from disturbed leks was 24% lower than for birds breeding on undisturbed leks, and 26% fewer females from disturbed leks initiated nests in consecutive years (Lyon and Anderson 2003). As development progressed, adult females remained in traditional nesting areas regardless of increasing levels of development, but yearlings that had not yet imprinted on habitats inside the gas field avoided development by nesting farther from roads (Holloran 2005). One study confirmed that yearling females avoided infrastructure when selecting nest sites, and yearling males avoided leks inside development areas and were displaced to the periphery of the gas field (Holloran et al. 2010). Recruitment of males to leks also declined as distance within the external limit of development increased, indicating a high likelihood of lek loss near the center of developed oil and gas fields (Kaiser 2006).

The most important finding from studies in Pinedale was that sage-grouse declines are explained in part by lower annual survival of female sage-grouse and that the impact on survival resulted in a population-level decline (Holloran 2005). However, a clear picture is lacking of the long-term effects of behavioral avoidance coupled with decreased survival. High site-fidelity but low survival of adult sage-grouse combined with lek avoidance by younger birds (Holloran et al. 2010) resulted in a time lag of 3–4 years between the onset of development activities and lek loss (Holloran 2005). The time lag observed by Holloran (2005) in the Anticline matched that for leks that became inactive 3–4 years after natural gas development in the Powder River Basin (Walker et al. 2007a). Analysis of 7 oil and gas fields across Wyoming showed time lags of 2–10 years between activities associated with energy development and its measurable effects on sage-grouse populations (Harju et al. 2010). This knowledge of time lags suggests that ongoing development in the Cedar Creek Anticline will result in additional impacts on fringe populations in eastern Montana and western North and South Dakota (Tack 2009).

In a new unpublished report, viability analyses in southeast Montana show a 12% population decline with 0.4 well pads per km^2 (1 well pad per mi^2) (R. L. Taylor et al., Bureau of Land Management, unpublished report), and losses were exacerbated by the interacting and negative effects of West Nile virus (WNv) and tillage agriculture, the two other major stressors on populations in Montana and the Dakotas. A human footprint of 0.4 well pads per km^2 (1 well pad per mi^2) following a WNv outbreak reduced populations by 61%, and the addition of tillage agriculture reduced populations to 26% of their former abundance (R. L. Taylor et al., Bureau of Land Management, unpublished report).

Mitigation

The unequivocal question to energy development in the West is where can resources be extracted to meet the increasing domestic demand for energy while reducing environmental impacts. The U.S. government already has leased more than 7 million ha (17.3 million acres) of the federal mineral estate, and the number of producing wells tripled from 11,000 in the 1980s to more than 33,000 in 2007 (Naugle et al. 2011b). Managers struggling to keep pace with development have implemented reactive measures in hopes of mitigating disturbance around leks. Protective measures, such as not allowing energy infrastructure within varied distances around leks and timing restrictions on drilling, have failed to maintain populations, and it has become apparent that sage-grouse conservation and energy development are incompatible in the same landscapes. Budgetary constraints on the ability to study and maintain wildlife populations during energy development mean that conservation triage, defined here as the prioritization of limited resources to maximize biological return on investment, is unavoidable to meet the high social and economic costs of maintaining sage-grouse populations (Bottrill et al. 2008).

The focus for sage-grouse conservation should be to prioritize and conserve remaining intact landscapes rather than trying to maintain small declining populations at the cost of further loss in the best remaining areas. The challenge will be to implement conservation on a scale that matches energy development to offset the spatial extent of anticipated impacts. Scientists need to work with managers to develop proactive decision-support tools that identify priority landscapes that will maintain large populations, develop management prescriptions that increase populations in priority landscapes and offset losses in developed landscapes, and identify ecological corridors among priority populations to maintain connectivity. Despite ongoing development, no comprehensive range-wide plan is in place to conserve large and functioning landscapes necessary to maintain sage-grouse populations.

Analytical frameworks are available to evaluate options for reducing impacts on sage-grouse populations at highest risk of oil, gas, and wind power development (Kiesecker et al. 2009, 2010, 2011). For example, Doherty et al. (2011) used lek count data ($N = 2{,}336$ leks) to delineate high-abundance population centers, or core areas, that contained 25%, 50%, 75%, and 100% of the known breeding populations in Wyoming, Montana, Colorado, Utah, and North and South Dakota. Core areas can be overlaid spatially with authorized oil and gas leases and the potential for commercial development of wind energy. The resulting output then can be used to identify the core populations that are least at risk from energy development to prioritize for immediate conservation. Areas that share high energy development potential and high sage-grouse density will need policy reforms to reduce threats, whereas areas with high energy potential but low biological value can act as areas to “trade” development for conservation.

Clumped distributions of populations suggest that a disproportionately large number of breeding birds can be conserved within core areas. For example, 75% of the breeding population in the eastern range of sage-grouse was captured within only 30% of the area (Doherty et al. 2011). Wyoming is key to conservation of the species, because it contains 64% of the known eastern breeding population and is at greatest combined risk from wind energy and oil and gas development (Doherty et al. 2011). Risks to core areas vary dramatically, and each state and province must do its part to ameliorate these risks to maintain sage-grouse distribution and abundance. Successful implementation of landscape conservation in one state or province is insufficient to compensate for losses in others.

Core areas provide a vision for decision makers to spatially prioritize conservation targets. Core-area analyses and associated geo-databases are publicly available online for use in range-wide sage-grouse planning (Doherty et al. 2010a). Several western states adopted the initial concept and subsequently have refined core areas by linking them with the best available habitat maps and expert knowledge of seasonal habitat needs outside the breeding season. Core areas have been heralded as a way of partnering with industry to fund conservation in priority landscapes and as a basis for forecasting development scenarios to aid in conservation design. Identification of core areas provides a biological foundation for implementing community-based landscape conservation. Landscape-scale conservation in priority areas is the most defensible and realistic solution to the dilemma between

One method to improve habitat for sage-grouse would be to reduce the impacts of heavy grazing by moving cattle in and among pastures, as this rancher is doing in central Montana. (Photo credit: Jeremy R. Roberts, Conservation Media).

energy development and sage-grouse conservation in the West. Maintaining large landscapes with minimum disturbance is paramount to sage-grouse conservation and will require collaborative efforts from a diverse group of stakeholders.

Mandatory off-site mitigation for sage-grouse beyond that of voluntary compliance and the corporate mantra of sustainability might someday become a reality. If and when it does, biodiversity offsets could provide a mechanism to compensate for unavoidable damage from new energy development as the U.S. increases domestic production. To date, proponents argue that offsets provide a partial solution for funding conservation, while opponents contend the practice is flawed because offsets are negotiated without the science necessary to back up resulting decisions. Missing in negotiations is a biologically based currency for estimating sufficiency of offsets and a framework for applying proceeds to maximize conservation benefits.

One new study provides a common currency for offsets for sage-grouse by estimating number of birds affected at levels of oil and gas development commonly permitted (Doherty et al. 2010b). Analyses used lek-count data from across Wyoming (N=1,344) to test for differences in rates of lek inactivity and changes in bird abundance at 5 intensities of energy development, including control leks with no development. Impacts are indiscernible at 12 wells per 32.2 km^2 (about 1 well pad per mi^2). Above this threshold, lek losses were 2-5 times greater inside than outside development areas, and bird abundance at remaining leks declined by 32%-77% (Doherty et al. 2010b). Documented impacts relative to development intensity can be used to forecast biological tradeoffs of newly proposed or ongoing developments, and when drilling is approved, anticipated bird declines form the biological currency for negotiating offsets.

Implications from this study suggest that offsetting risks using sage grouse abundance and lek numbers per unit area of developed habitat as the currency can be implemented immediately; monetary costs for offsets will be determined by true conservation cost to

Tailings ponds, such as this one near Fort McMurry in east-central Alberta, Canada, often are open-air, creating hazards for waterfowl that land on these ponds to rest, and then become coated in oil. Incidents like this are often fatal, pointing to the need to implement mitigation measures. (Photo credit: Todd Powell, Alberta Fish and Wildlife Division).

mitigate risks to other populations of equal or greater number. If this information is blended with landscape-level conservation planning, the mitigation hierarchy can be improved. On-site mitigation with associated biologically based costs to mitigate unavoidable impacts from energy development can be achieved by locating planned developments away from areas of high conservation value, ensuring that compensatory mitigation projects deliver a high return for conservation, and providing on-site mitigation recommendations.

Knowledge Gaps

A pressing need in conservation plans is the need to obtain a better understanding of connectivity between and among sage-grouse populations (Oyler-McCance and Quinn 2011). Our understanding of sage-grouse movements, dispersal, and connectivity is limited because telemetry studies have not been conducted to document how individual populations move during dispersal or seasonal migration (Knick and Hanser 2011). Analytic advances in landscape genetics (Murphy et al. 2010) and noninvasive sampling of genetic material from feathers collected off leks might provide an efficient means of quantifying connectivity between sage-grouse populations (Storfer et al. 2007). However, genetic samples alone can obscure emerging or disrupted patterns of animal movements (Fedy et al. 2008). New GPS technology is a promising technique to identify sage-grouse movements that might be critical to population persistence but might be missed by radio telemetry and might not be detected by genetic approaches (i.e., migration).

Researchers also should focus on finding links between prescriptive management actions and sage-grouse productivity. The initial requirement is an understanding of how different vital rates influence overall population growth and the plasticity and ability to manage influential vital rates. Once key vital rates are identified, management practices that bolster vital rates should be implemented to help maintain and enhance populations. Tools to manage sage-grouse populations will vary across the species' range with biotic and abiotic characteristics of different landscapes and local constraints to populations. Some populations might benefit from changing grazing regimes, removing conifers, or managing invasive species, yet ultimately these will depend on the site. The ultimate measure of our management success will be the biological return on investment, as measured in number of birds.

WATERFOWL

In the larger perspective of ecosystem management, waterfowl serve as one of the measurable indicators of the health of the wetland-riparian ecosystems of the Rocky Mountains. Riparian areas are lands adjacent to wetlands, creeks, streams, ponds, rivers, and lakes where vegetation is influenced by the presence of water. Riparian areas are considered some of the most biologically diverse habitats, providing food and cover for a variety of wildlife and fish. Wetland habitats support the highest population densities of both breeding and non-breeding birds, including songbirds, shorebirds, waterfowl, and raptors. Waterfowl in the Rocky Mountain region rely on these wetlands and riparian areas and face many hazards throughout their long migrations and annual cycles, including loss and contamination of wetland and riparian habitats at migration stopovers.

New oil and gas drilling techniques and transportation systems are environmentally safer than ever before, but direct and indirect impacts on waterfowl from these activities still do occur (Ringelman 2009). In the exploratory phase, seismic lines crisscross sensitive ecosystems, fragmenting the landscape and altering wetland hydrology. During the development and extraction phases, construction of drilling pads and access roads compounds these impacts. Although industry strives to make oil extraction and transport as safe as possible, accidental spills and contamination of soil and water do occur.

Direct Impacts

The extraction of petroleum from oil sands is a concern to waterfowl and wetland ecologists. When oil sands reserves are developed, the overlying soil must be removed, the ore crushed, and hot water added in the extraction process (Ringelman 2009). This process requires large amounts of fresh water diverted from lakes, wetlands, and major river systems. After processing, tailings (the materials that are left over after separating the oil from the uneconomic fraction containing clay, sand, and water), as well as the residual oil, are held in vast networks of settling ponds. Migrating waterfowl that stop to rest on these ponds become coated in oil and other toxins and often succumb to the deadly effects. An even greater concern is that settling ponds will fail, releasing tailings into surrounding lakes, wetlands, and river systems. Open pits, where waste fluids from hydrocarbon production are stored, pose a significant mortality threat to birds in some situations (Trail 2006). In 2009, more than 500 ducks were killed in a tailings pond in the tar sands of boreal Alberta.

The most obvious effect on ducks from oil is the resultant matting of feathers. Microscopic examination of oiled feathers shows a greatly-deranged appearance when compared to the orderly arrangement of normal feathers (Hartung 1967). Severe matting of feathers can reduce the insulating quality of duck plumage and increase metabolic rates, often resulting in an increase in the depletion of fat reserves. Once fat reserves are depleted, mortality rates increase, particularly at lower ambient temperatures. Exposure of waterfowl to oil can affect reproduction as well. Hartung (1965) reported that one female mallard (*Anas platyrhynchos*) stopped laying eggs for up to 2 weeks after ingesting small amounts (2 gm per kg) of relatively nontoxic lubricating oil. He also found that small quantities of oil on mallard eggs reduced their hatchability to 21% compared to 80% for un-oiled mallard eggs. The absence of carcasses in produced-water storage facilities does not mean that the sites are not risks for waterfowl and other birds. Mortality can go undetected because carcasses can sink or remain undetected. Scavengers or people also may remove carcasses (Flickinger and Bunck 1987).

One of the most significant threats to waterfowl from oil and gas developments in the Rocky Mountain region is from produced water. Produced water is any water that is present in a reservoir with the hydrocarbon resource and is produced to the surface with the crude oil or natural gas. In subsurface formations, naturally-occurring rocks generally are permeated with fluids such as water, oil, or gas (or some combination of these fluids). It is believed that the rock in most oil-bearing formations was completely saturated with water prior to the invasion and trapping of petroleum (Veil et al. 2004). The less-dense hydrocarbons migrated to trap locations, displacing some of the water from the formation in becoming hydrocarbon reservoirs. Thus, reservoir rocks normally contain both petroleum hydrocarbons (liquid and gas) and water. Sources of this water might include flow from above or below the hydrocarbon zone, flow from within the hydrocarbon zone, or flow from injected fluids and additives resulting from production activities. When hydrocarbons are produced, they are brought to the surface as a produced-fluid mixture. The composition of this produced fluid is dependent on whether crude oil or natural gas is being produced. It generally includes a mixture of liquid or gaseous hydrocarbons, produced water, dissolved or suspended solids, produced solids such as sand or silt, and injected fluids and additives that might have been placed in the formation as a result of exploration and production activities. Production of coal-bed methane (CBM) involves removal of formation water so that the natural gas in the coal seams can migrate to the collection wells. This formation water also is referred to as produced water. Some CBM projects in the Rocky Mountain region have created impoundments that collect and retain large volumes of produced water. These impoundments might have surface areas of several acres. They provide a source of drinking water for wildlife and offer habitat for fish and waterfowl in an otherwise arid environment. It is important to make sure that the quality of the impounded water will not create health problems for wildlife.

Produced waters can contaminate sediments, and the zone of such contamination correlates positively with produced-water discharge volume and hydrocarbon concentration (Rabalais et al. 1992). The actual fate and effects vary with volume and composition of the discharge and the hydrologic and physical characteristics of the receiving environment. A key concern is the potential for toxic effects on aquatic organisms resulting from produced water discharges to lakes, rivers, and wetland systems. A constituent might be toxic, but unless it is absorbed or ingested by an organism at levels above a sensitivity threshold, effects are not likely to occur. It is important to understand that translating produced-water constituents into actual impacts on waterfowl is not a trivial exercise.

Produced water can have different potential impacts on waterfowl, depending on where it is discharged. For example, discharges into small streams or wetlands likely will have a larger impact than discharges made to the large rivers or lakes by virtue of the dilution that takes place following discharge. Numerous variables determine the actual impacts of produced-water discharge on waterfowl. These include the physical and chemical properties of the constituents, temperature, content of dissolved organic material, humic acids, presence of other organic contaminants, and internal factors such as metabolism, fat content, reproductive state, and feeding behavior (Frost et al. 1998).

Produced-water volumes can be expected to grow as onshore wells age (the ratio of produced water to oil increases as wells age) and CBM production increases to help meet projected natural-gas demand. Treating produced water prior to discharge might become increasingly difficult due to space limitations. This growth will increase produced-water management challenges for which a knowledge and understanding of the constituents of produced water and their effects will be critical. As the amount of produced water increases, the amount of produced-water constituents entering lakes, streams, rivers, and wetlands likely will increase, even assuming concentration-discharge limits are met. Also, because actual impacts of produced-water constituents on waterfowl will depend on the produced water as a whole in the context of the environment into which it is released, it will be important to understand effects of site-specific produced waters rather than addressing individual components.

During the past few decades, strands of plastic flagging have been suspended over pits, ponds, and tanks containing produced water to deter waterfowl and other birds from landing (Ramirez 2002). Flagging and most other deterrents such as propane cannons, strobes, and reflectors are ineffective at excluding birds and other wildlife from oil pits (Esmoil and Anderson 1995). The most effective method to exclude waterfowl and other wildlife from produced water is to cover the pit, pond, or tank with netting.

SONGBIRDS

Passerine birds (songbirds) represent a large proportion of vertebrate biodiversity in North America. For example, the boreal forest has been called North America's bird nursery, with more than 300 species and an estimated 5 billion breeding individuals using this forest each year (Blancher and Wells 2005). The boreal ecosystem remains one of the last unexploited wildernesses on the planet. Relatively few species reliant on this biome have been listed as endangered or threatened to date, although this is changing rapidly. Estimated grassland losses since the mid-1800s exceed 75% in most areas of North America (Samson and Knopf 1994, Gauthier and Wiken 2003). Grassland birds are the guild showing the worst trends in Breeding Bird Survey analyses (Sauer et al. 2008). Although representing a relatively small number of species, 61% of grassland species are declining significantly at a mean trend of -1.48% per year. Many shrub-steppe birds also are in decline (Knick et al. 2003).

Bird-watching provides much recreational pleasure and generates billions of dollars each year in revenue. The role of birds in consuming vast numbers of "pest" species such as grasshoppers (*Caelifera*) or spruce budworm (*Choristoneura fumiferana*) has been long recognized. The act establishing the USDA in 1862 referred to the value of insectivorous birds (McAtee 1953), and entire sections of the USDA were devoted to determining bird food habits. Despite their value both for human enjoyment and ecological function, songbirds have received little attention in the debate over energy development and wildlife conservation. Songbirds have been little studied with regard to oil and gas effects, and so much of the evidence is inferred from their response to similar disturbance. Impacts of oil and gas on birds can be direct through infrastructure collisions and habitat loss, or indirect through habitat alienation due to avoidance, noise, invasion of exotic species, edge fragmentation, and reduced breeding opportunities.

Direct Impacts

Waste fluids from the petroleum industry stored in pits, open tanks, and other areas such as sumps cause the deaths of substantial numbers of birds. Trail (2006) conducted a survey of such waste fluid stores and found mortalities from 172 species, mainly ground-foraging songbirds. An estimated 500,000 to 1 million birds per year are killed in the U.S. in waste pits (Trail 2006). Other toxic by-products also can be associated with mortality events. Natural gas facilities often burn off gases such as hydrogen sulfide. About 3,000 carcasses of at least 26 species of songbirds were found within 75 m of a 100-m (82 yards of a 109-yard) flare stack in boreal Alberta (Bjorge 1987). Pulmonary congestion suggested some deaths resulted from stack emissions, and other birds probably struck the stack. However, losses are not reported consistently or tracked. Like all human infrastructure, energy-sector equipment does result in songbird mortalities, whether through poisoning or collision. However, the magnitude of these effects and how they influence population dynamics are unknown.

Energy production typically results in the creation of communication towers, power lines, well pads, flare stacks, and compressor stations. Height of structures increases the risk of collision by birds and bats (Mabey and Paul 2007). In general, songbird collisions with structures are more common during migration, particularly on nights with heavy cloud cover or poor weather. Towers used at well pads for remote monitoring equipment, and power poles and power lines used to run equipment at energy sector sites, typically are shorter (15-60 m [50-197 ft]) than cell phone towers and therefore should have lower collision rates. However, the cumulative impact of a broad distribution of short vertical structures may potentially be greater than the more obvious mass collision events at tall towers, but at this juncture the magnitude of such collisions is unknown. The footprint associated with energy development at about 6 wells per km^2 (16 wells per mi^2) in grasslands can be 5%-12% of the landscape, and linear features increase by 1 km (0.62 miles) for each new well (Government of Canada 2008). A different estimate found a total footprint of 3.4% $\pm$ 0.3% for similar well densities (Hamilton et al. 2011). Two separate models found footprint (Hamilton et al. 2011) and well density (used as an index of disturbance, Government of Canada 2008) were significant negative factors for occurrence of Sprague's pipit (*Anthus spragueii*), an endemic grassland bird considered threatened in Canada.

Collisions with vehicles also may be a significant source of anthropogenic mortality for songbirds during the breeding and wintering seasons (Forman and Alexander 1998, Higgins et al. 2007, Lloyd et al. 2009). Whether reduced traffic volume or speed effectively reduces avian mortality is unknown. More avian deaths occurred on lower-traffic volume roads with a lower speed limit in Alberta, probably because surrounding vegetation was close to the road (Clevenger et al. 2003). A Saskatchewan study found a gradient of fewer deaths with lower traffic speed and volume (Fortney 2010). However, given the total length of low-speed and low-volume travel lanes associated with the energy sector, resultant collisions may be significant. Unless the organism is visible at 82 feet, reducing speed cannot reduce risk of collision for wildlife (Ramp et al. 2006).

Energy companies may cut hay or shrubs near energy roads and trails as a means to reduce fire risk, increase visibility, or limit snow accumulation. This landscaping, however, negatively affects songbirds. Haying during the breeding and brood-rearing seasons destroys nests, eggs, and young of ground-nesting grassland birds and leads to increased abandonment and predation (Bollinger et al. 1990). Active above-ground nests are almost always destroyed when vegetation is cut with farm machinery (Frawley 1989).

In all habitats, the removal of existing natural habitat by energy sector activities will be a habitat loss for those species that used it and a habitat gain for those species that might prefer the altered conditions. Point counts in boreal forests demonstrate that ovenbirds (*Seiurus aurocapilla*) are never detected singing on pipelines, power lines, or roads or in small clearings (i.e., 0.5-2 ha [1.2-4.9 acre] well pads; Bayne et al. 2008). Early-successional habitats created by energy development therefore are unsuitable for this species. Point counts on pipelines (>15 m [49 ft] wide) rarely detected forest specialist birds singing on lines (Fleming and Schmiegelow 2003). Conversely, generalist birds that prefer early successional habitat such as the American robin (*Turdus migratorius*), chipping sparrow (*Spizella passerina*), Lincoln's sparrow (*Melospiza lincolnii*), Le Conte's sparrow (*Ammodramus leconteii*), swamp sparrow (*Melospiza georgiana*), and common yellowthroat (*Geothlypis trichas*) are more likely to be found on or near energy sector disturbances (Fleming and Schmiegelow 2003).

Indirect Impacts

Avoidance.—The small, but frequent, extent of most energy-sector disturbances creates a considerable amount of edge habitat relative to the area disturbed.

Edge, defined as the transition zone between 2 habitat types, may alter habitat suitability for songbirds (Murcia 1995). Twenty-five studies have assessed abundance of bird species near versus far from energy-sector disturbances in forested habitats across North America. These studies do not share a common metric such as density, which would allow direct comparison of different types of edges associated with energy developments. Four bird species tended to be more abundant in forest interiors than edges in 2 or more studies, and 6 species had a negative edge effect in a single study. Six species had inconsistent responses to edge. Of these, positive effects were most frequently associated with edges of pipelines, power lines, or gravel roads, and negative responses resulted near paved roads. Twelve species showed positive edge responses in at least 2 locations, and 22 species showed a positive response in a single location.

One species well studied with respect to edge use is the ovenbird. The ovenbird nests and forages on the ground in mature deciduous and mixed-wood forests and is widely studied because of its perceived sensitivity to habitat fragmentation (Van Horn and Donovan 1994). Radio telemetry studies indicate ovenbirds do not incorporate conventional seismic lines (8-10 m [26-33 ft] wide) in their territories, defending territories exclusively on 1 side (Bayne et al. 2005). This behavior seems to persist for extended periods of time, and birds show this behavior at 30-year-old lines with significant tree re-growth (H. Lankau et al., University of Alberta, unpublished data). Given that ovenbirds avoid sites disturbed by energy-sector development and that an increasing area of the boreal forest is being disturbed by energy-sector activity, it follows that ovenbird abundance will be lower in highly-disturbed landscapes. This was the case in 2 of 3 locations where this was tested with spot mapping in mature quaking aspen (*Populus tremuloides*) (Bayne et al. 2005) and in mixed-wood forests (Machtans 2006). The studies indicate behavioral avoidance of seismic lines can result in local reductions in population size.

Grassland birds also exhibit avoidance. In Saskatchewan, chestnut-collared longspur (*Calcarius ornatus*), Sprague's pipit, and Baird's sparrow (*Ammodramus bairdii*) each showed a non-significant pattern of reduced abundance in the vicinity of minimal-disturbance gas wells and their access trails compared with more-distant areas (Linnen 2006). Significantly reduced numbers of these same 3 species were observed out to 50, 250, and 350 m (164,

Sprague's pipit, an endemic grassland bird threatened in Canada and a candidate for listing as endangered in the U.S. (Photo credit: Doug Backlund, Wild Photos Photography).

820, and1148 ft) respectively from traditional oil wells and their associated routes in Alberta (Linnen 2008). A separate Alberta study reported Sprague's pipit territories crossed trails less often than expected by chance (Hamilton 2009). Sprague's pipits whose territories were near trails often used the trail as a boundary. Hamilton (2009) postulated that narrow strips of bare ground or reduced vegetation would be visible to an aerial singing bird. Brewer's sparrows (*Spizella brewerii*) and other sage-related songbirds showed reduced abundance within 100 m (328 ft) of narrow, low traffic (10-700 vehicles per day) well-access trails (Ingelfinger and Anderson 2004). Even narrow linear features without vehicles may have an effect on grassland birds. Bird abundance for all species except Lapland longspur (*Calcarius lapponicus*) was lower on old (10-30 years) seismic lines than on nearby controls in upland tundra habitats (Ashenhurst and Hannon 2008). Abundance and nest densities of some bird species were lower near narrow walking paths in Colorado grasslands (Miller et al. 1998). The numbers of Baird's sparrows increased with increasing distance from wells (Great Sand Hills Advisory Committee 2007). In a separate study, counts were conducted near wells to determine actual locations of birds, and Baird's sparrows never were detected within 20 m of wells, and, on average, individuals were found 150 m from wells (H. Bogard, University of Regina, personal communication). The same study found that Sprague's pipits never were encountered within 50 m of wells and on average were at least 150 m from wells (H. Bogard, personal communication). Although not energy-sector specific, several studies have shown a number of grassland songbirds are area or edge sensitive (Davis 2004, Ribic et al. 2009).

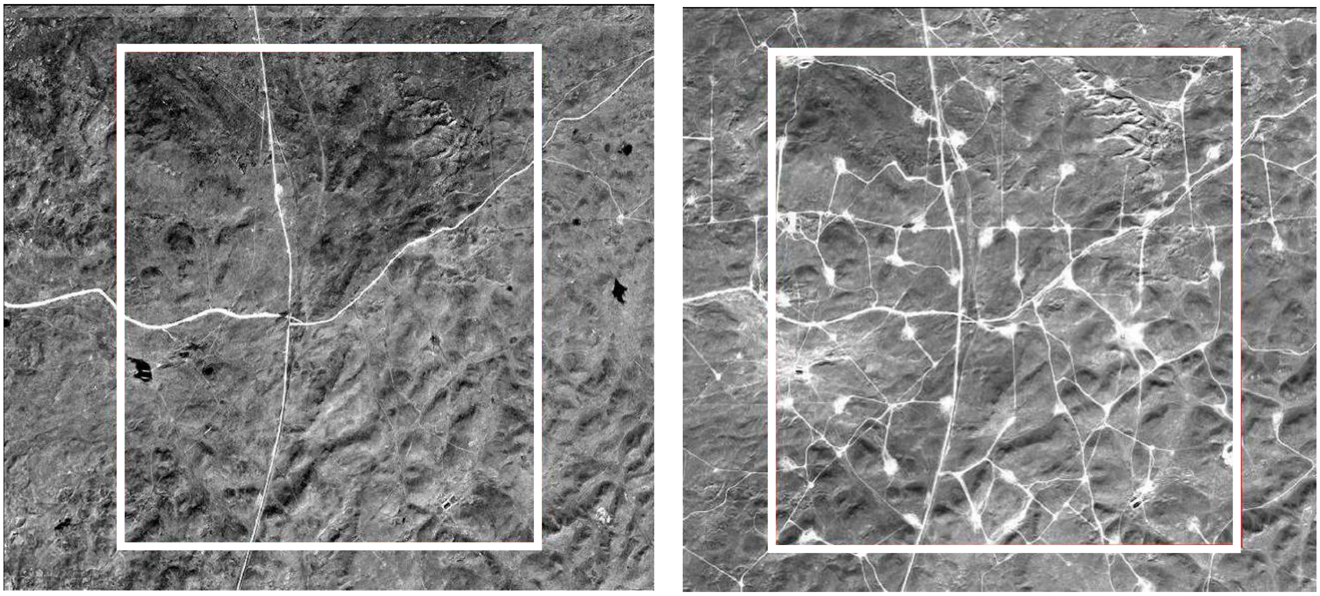
Altered Reproduction.— Birds may settle in habitats that result in poor reproduction, termed ecological traps (Pulliam 1996, Bayne and Hobson 2002). Reduced vital rates are a concern around energy-sector sites. One study examined the relationship between nesting success of boreal birds and energy development (Ball et al. 2009). In 2 study areas (1 with pipeline disturbance and 1 with both pipeline and forestry disturbance) researchers examined about 700 forest passerine nests and found no increase in predation near pipelines or edges. In both study areas the dominant nest predator, the red squirrel (*Sciurus vulgaris*), had similar abundance close to and far from pipeline edges. Sprague's pipit nest densities were lower within 100 m (328 ft) of a pre-cleared construction right-of-way than in grassland farther away, but distance to the pipeline did not influence nest success (Skiffington and Pittaway 2010). Reproductive success in restored grassland sites was too low to maintain positive population growth (Wray et al. 1982).

Invasive Plants.— Invasion of exotic plants also negatively impacts grassland birds. Development that exposes bare soil or mixes soils with machinery (such as by the energy sector) facilitates the introduction and subsequent spread of nonnative plants (Tyser and Worley 1992, Larson et al. 2001, Gelbard and Belnap 2003, Gelbard and Harrison 2003). Vehicles act as a vector for seed dispersal and subsequent establishment along roadways (Von der Lippe and Kowarik 2007), and non-native cover is higher at well pads, pipelines, and access routes than in native prairie (Bergquist et al. 2007; J. Rowland, Canadian Department of Defense, unpublished report). Non-native vegetation often differs in structure from native vegetation. This altered structure can change availability of bird nest sites and microsites for insect prey. For example, crested wheatgrass (*Agropyron cristatum*) has less standing vegetation in the 10 cm (3.94 inches) nearest the ground, less fallen litter, and more bare ground than native prairie (Sutter and Brigham 1998, Christian and Wilson 1999). In a Montana study not specific to the energy industry, chestnut-collared longspur had similar abundance in native prairie and in crested wheatgrass, but nests were less likely to succeed and chicks were smaller in the non-native cover. Crested-wheatgrass cover at well pads and in adjacent prairie habitat increased with well density, yet most Sprague's pipit territories contained no appreciable crested wheatgrass, and average cover in territories was lower than at reference locations (Hamilton 2009).

Given that indirect effects like avoidance and invasion appear to influence Sprague's pipit and Baird's sparrow, it is reasonable to expect that abundance should decrease with energy development. A before-after study within Canadian Forces Base Suffield, Alberta, compared the same areas with 4 well pads per mi^2 and later, under similar habitat conditions, with 8 well pads per mi^2 and found a non-significant reduction in Sprague's pipit of 13% and a significant decrease of 21% for Baird's sparrow (Dale et al. 2009). Species with restricted distributions, a need for shrubs, an aversion to nonnative plants, or an avoidance of edge are most likely to respond negatively to disturbances created by energy development. All open-country birds with a known negative response to energy disturbance share 1 or more of these characteristics (Bayne and Dale 2011).

Noise.— Oil and gas drilling and energy infrastructure construction are short-term, intense events that birds may avoid by movement. The consequences of these movements are unknown. But energy infrastructure has high maintenance needs, which increase human activity at sites. Repeated human visitation creates acoustic, physical, and visual disruptions that birds may avoid indefinitely. Because most songbirds use acoustic signaling to communicate, anthropogenic noise is of particular concern. Sound that interferes with bird communication has the potential to reduce habitat quality. Increased traffic, construction equipment to create and maintain infrastructure, and engines to compress and transport oil and gas through pipelines are all sources of energy-related anthropogenic noise.

Suitable habitat also might be avoided by birds if communication is continually interrupted by noise. Bird density was 1.5 times higher in boreal aspen forests with no anthropogenic noise than the same habitat beside a noise-generating compressor station (Bayne et al. 2008). One-third of the bird species detected were less abundant within 328 yards of the source of the noise. At the same study locales, Habib et al. (2007) found that male ovenbirds in quiet areas were significantly more likely to attract a mate than those near active compressor stations. Noise levels at



These photos depict the same grassland before and after energy development. On this site at the Canadian Forces Base Suffield near Medicine Hat, Alberta, well density increased from 4 to 16 wells per square mile. The white square outline represents approximately 4 square miles. (Photo credit: Government of Canada, Department of National Defence).

compressor stations are between 75 and 90 decibels (dB) at the source, which is similar to a traffic volume of 50,000 cars per day. Alberta alone has more than 5,000 compressor stations, but these are a small part of the noise-generating energy-sector facilities.

Few studies have been completed on the effects of sound on birds in open habitats. Construction sound overlapped with the sound frequency of pipit song, and Sprague's pipit territories shrank during pipeline construction noise (Skiffington and Pittaway 2010). In open habitat, compressor-station sound levels in Kansas were 80-100 dB at 100 m (328 ft) and clearly audible out to 2 km (1.2 miles) (Pitman et al. 2005). In Alberta, drilling-created noise was 70 dB at 50 m (164 ft) from well sites, and maintenance activities were 72 dB (EnCana 2007). A distance of 500 m (547 yards) was required for sound to fall at or below 49 dB, and noise was greater than 25 dB at the farthest distance measured (1.5 km [0.93 miles]).

Just as they do with vegetation changes, generalist species may prosper from noise at the expense of intolerant specialist species of management concern (LaGory et al. 2001, Francis et al. 2009). Spotted towhee (*Pipilo maculatus*) abundance declined when compressor stations were introduced into pinyon-juniper woodlands, and they nested farther from noise. However, some species increased in abundance near the noise-generating station, presumably because their predators were unwilling to come close to the noise.

Cumulative Impacts

Road noise effects on passerine birds have been studied well. Traffic of 10,000 vehicles per day reduced bird density 30%-100% lower in a zone that extends up to 190 m (208 yards) (Reijnen et al. 1997). A 5-fold increase in traffic levels resulted in a 3-fold increase in area affected, and effects were most pronounced in grassland habitats. The energy industry does generate large volumes of traffic beginning with construction and ending with workers traveling to plants or to thousands of individual wells to monitor and conduct maintenance. The potential for significant cumulative impact of such disturbances is real. For example, in boreal Alberta, Highway 63 is the major development route to energy reserves and has traffic levels from 2,000 to 55,000 vehicles per day (Alberta Transportation 2011).

Mitigation

Habitat loss for a given species may not be permanent, depending on whether habitat recovers and the rate at which habitat returns to its previous state. Indications are that recovery of energy-sector sites is slow or absent in some ecosystems. Vegetative studies found tundra seismic lines had less lichen cover, more bare ground, and more vascular plant cover than nearby reference sites more than 30 years later (Kemper and Macdonald 2009a,b). Recovery of energy-related disturbance in forests generally is slow but depends on the level of reuse or recreational traffic. The canopy often grows over conventional seismic lines quickly, whereas regeneration on the ground may take longer (Lee and Boutin 2006). Lee and Boutin (2006) examined conventional seismic lines in boreal Alberta and found only 8.2% reached 50% cover of woody vegetation after 35 years. Recovered lines generally were found in upland forests, whereas lowland lines rarely recovered. Recovery is limited because lines are used for access by industry and recreational users. About 25% of seismic lines never return to forest, because they transition into roads, pipelines, or buildings. A regenerating cut block is expected to have about 10,000 stems per ha (4,049 stems per acre). In northeast Alberta, about 36% of 15-year-old well pads in upland forest have fewer than 1,000 tree stems per ha (405 stems per acre), 24% have 1,000-6,000 stems per ha (405-2,429 stems per acre), and 39% have more than 6,000 stems per ha (2,429 stems per acre) (MacFarlane 2003). Loss of natural propagules, seeding of grass to limit erosion, removal of nutrients with clearing, and soil compaction are factors that limit regrowth on well pads. The energy sector has been working to mitigate its impacts by narrowing seismic lines, and advances in technology allow exploration with seismic lines no more than 3 m (9.8 ft) wide. Ovenbirds include narrow seismic lines in their territories, indicating that energy sector beneficial practices can reduce some impacts.

Energy developers suggest native prairie can be restored quickly and easily, but, unlike natural disturbance such as fire or grazing, energy-related disturbance is linear and long-lasting. Some sites may not fully re-vegetate. Bare soil was higher on prairie well pads and pipelines (up to 30 years old) at Canadian Forces Base Suffield in Alberta than on reference sites (J. Rowland, Canadian Department of Defense, unpublished report). Bird communities will not recover, given native grasslands support a higher frequency and abundance of endemic grassland birds than planted grasslands or bare ground (Johnson and Schwartz 1993, McMaster and Davis 2001). More studies are needed to document the success of methods for restoring habitat for grassland birds.

RECOMMENDATIONS

Ungulates

Operational-Phase Mitigation.— The following list briefly summarizes those recommendations provided by the WGFD (2010). This list provides guidance for mule deer, pronghorn, and elk. (Readers are advised to review the previous sections regarding impacts to each of the 3 species.) Some mitigation techniques might be more applicable for 1 species in an affected habitat than another species. This list is to be used at the fine scale of final development design and operation.

1. Directional and phased drilling, moving methodically across the landscape, can do much to minimize impacts to wildlife. Unitized field development (developing and using common facilities such as roads or pipelines within an oil and gas area) minimizes the industrial footprint with a concomitant reduction in habitat disturbance and should be used whenever possible.
2. Development should be constructed in clustered configurations to minimize habitat impacts. To the extent technologically practicable, well pads, facilities, and roads should be located in clustered configurations within the least-sensitive habitats.
3. Liquid gathering systems significantly reduce disturbances to wildlife by piping condensate rather than trucking liquids offsite. Each truck trip and activity associated with pumping has the potential to displace animals from suitable winter habitat for up to several days.
4. To the extent technologically feasible, install telemetry to remotely monitor instrumentation and reduce or eliminate travel and human visits required to manually inspect and read instruments.
5. A travel plan should be developed and implemented to minimize frequency of trips on well-field roads and thereby reduce impacts to ungulates. The road plan should include provisions in subcontractor agreements requiring adherence to the same travel plan provisions observed in company operations.

6. All newly constructed roads should be gated and closed to public travel during sensitive times of year. The purpose of these roads is to access and maintain well sites, not to provide additional public access.
7. Implement an adequate wildlife monitoring program (with sufficient sample size to reveal a 5%-10% change in survival) to detect and evaluate ongoing effects such as mortalities, avoidance responses, distribution shifts, habituation, evidence of movement and migration barriers, and depressed productivity (e.g., low fawn ratios), and to assess the effectiveness of mitigation. Vegetation utilization within and outside the well field should be monitored. Each company or consultant representing the company should annually prepare a wildlife monitoring report for review by land and wildlife management agencies. Companies should agree to conduct or fund monitoring and environmental studies as 1 component of an integrated mitigation program, but the BLM also should commit adequate budget and staff to complete and evaluate the necessary monitoring.
8. Design and implement land or vegetation treatments sufficient to maintain habitat functions within or immediately adjacent to the well field. This includes control of invasive weeds and reclamation with appropriate native forage and cover plants as soon as possible.
9. If it is not possible to maintain habitat functions within or immediately adjacent to the well field, off-site and off-lease mitigation is an option. The primary emphasis of off-site or off-lease mitigation is to maintain habitat functions for the affected population or herd as close to the impacted site as possible and within the same landscape unit. Off-site and off-lease mitigation should be considered only when feasible mitigation options are not available within or immediately adjacent to the impacted area, or when the off-site or off-lease location would provide more effective mitigation than can be achieved on-site.
10. Migration corridors demand special mitigation attention when proposed for oil and gas development. Within narrow migration corridors or "bottlenecks" of less than 0.8 km (0.5 mile) wide (Sawyer et al. 2005, 2006, 2008), the management prescription for oil and gas development should be no surface occupancy (NSO). Within migration corridors that exceed 0.8 km (0.5 mile) wide, the recommended management prescription is to maintain options for animal movement along the corridor and avoid further constricting the corridor to the point that a bottleneck is created. Well-field developments should not exceed 4 well-pad locations or 60 acres of disturbance per mi^2. Fences, expansive field developments, and other potential impediments to migration should not be constructed.

Sage-Grouse

1. Core areas containing clumped distributions of populations should be utilized by decision makers to assist in prioritizing conservation targets. The use of core areas will help foster industry partnerships and allow the forecasting of development scenarios to be used as a tool for conservation design.
2. Continuing research in sage-grouse genetics and in using GPS technology to monitor sage-grouse movements is needed for a better understanding of connectivity between and among sage-grouse populations. This research will help indicate limitations that may be required of the oil and gas industry to protect sage-grouse populations.
3. Using birds as the currency in combination with landscape-level conservation planning can improve mitigation of energy development impacts on sage-grouse.

Waterfowl

The FWS recommends the following measures be used to reduce or prevent the negative impacts on waterfowl and other wildlife from the toxic effects of produced water (Ramirez 2002):

1. Closed containment systems (e.g., closed-topped tanks), which are low maintenance and can be moved to new sites when the wells are shut in, should be used. Closed containment systems also eliminate soil contamination and remediation expense.
2. Storage of contaminated produced water should be eliminated. A fail-safe solution is to remove

pits, ponds, and tanks. Immediate clean-up of oil spilled into open pits, ponds, or tanks is critical to prevent wildlife mortalities. The efficiency of oil and water separation before produced water is stored in pits, ponds, or tanks should be maximized.
3. Effective and proven wildlife deterrents or exclusionary devices should be used. Netting appears to be the most effective method of excluding birds and other wildlife from entering facilities containing produced water.
4. The amount of oil discharged into lakes, rivers, streams, and wetlands should be minimized. Proper maintenance and operation of equipment used to separate oil from the produced water will minimize the amount of oil entering the lakes, rivers, streams, and wetlands used by fish and wildlife.
5. Secondary or tertiary containment ponds or tanks should be installed to capture any oil leaving the primary or secondary pits, ponds, or tanks.

Songbirds

WGFD (2010) recommendations are an example of beneficial practices that will reduce impacts. Importantly, many of these recommendations were developed by leading energy-sector companies and have been adopted by industry. Whether beneficial practices are enough to conserve all birds of concern is debatable. The recommendations provided for ungulates for the operations phase are for the most part appropriate for songbirds. Exceptions and additional recommendations are listed below.

1. Additional restriction on any activities generating noise more than 10 dB above background levels during the breeding season, which extends from April through August, should be employed. This would limit activities such as drilling and fracturing. The timing of restrictions for grassland birds largely will be in conflict with those suggested for ungulates. That is, mitigation for birds would require activities occurring largely in fall and winter, which would disturb ungulates during a time when they are energetically vulnerable.
2. The recommendation, under ungulates, to cluster wells in less sensitive habitats is problematic for grassland songbirds, because oil and gas reserves overlap extensively with remaining stretches of native grassland cover. In the more fragmented grasslands, directional drilling from adjacent cropland could avoid sensitive habitats, but where grassland occurs in large blocks, it is not possible to use less sensitive habitats. One is left with directional drilling from existing well pads and limiting installation of new pipelines and other linear development. More consideration should be given to the justification to add more wells. In instances where in-fill drilling occurs mainly to accelerate gas recovery and not to access new reserves, consideration should be given to denying applications for additional wells, particularly on federal land.
3. All newly constructed roads should be gated and closed to general public travel during sensitive times of year. Such restrictions for songbirds in addition to those mentioned above for ungulates may necessitate year-round closures. However, much of the linear development in oil and gas fields may be two-track trails rather than roads and, therefore, it may not be feasible to control access to many miles of road and trail for each section of land that is drilled.
4. Removing direct mortality as a result of haying or spraying is as simple as delaying haying or shrub removal until after the breeding season. (Bollinger et al. 1990, Dale et al. 1997, Nocera et al. 2005).
5. Mitigation for vehicle collisions is difficult because it may require severe speed reductions or manipulation of ditch width, vegetation height, or sound to discourage bird crossings and, therefore, collisions; but diminished crossing rates may decrease connectivity between other habitats and populations.
6. Beneficial practices used by the energy sector to make features smaller and regenerate faster will create less change in bird communities. Unfortunately, no research has been done on the territorial behavior of boreal songbirds near wider linear features such as pipelines, power lines, or roads to identify critical thresholds in widths of features that birds will use. The value of energy-sector sites for early-successional bird species should be improved by putting more effort into retaining some habitat structure on disturbed sites (Yahner 2008).

For example, industry should adopt beneficial practices to encourage tree growth.

7. Noise suppression should be encouraged on all energy-sector disturbances. Retrofitting compressor stations and certain types of wells is far more expensive than building them to minimize noise in the first place.

CONCLUSIONS

Ungulates

Oil and gas development in western North America is widespread and currently occurring with incredible speed and intensity (Weller et al. 2002). For ungulates, a variety of seasonal ranges and movement corridors are being impacted. Individual herds are challenged by development in summer and winter, and in transitional ranges and the corridors that connect them. The ability of native ungulates to adjust to such rapid and wide-ranging impacts is severely limited (Western Governors' Association 2008). The federal processes currently used to assess and mitigate impacts often take place at the individual project level (Zimmerman 2008), but many impacts are occurring at the landscape level. For native ungulates and other native wildlife, western landscapes are being fragmented into islands of habitat that may or may not be capable of providing sufficient food, cover, and space at the appropriate time of year.

To assure viable and recreationally available ungulate populations into the future, land and management agencies must cease conducting impact assessment and mitigation on a project-by-project, piecemeal basis. Western ungulates and other native wildlife have evolved seasonal movements at the landscape level to assure survival. The severe fragmentation of western landscapes cuts the habitat into many small segments that may not be biologically valuable to ungulates. A new paradigm of landscape-level conservation design that includes refugia for seasonal ranges and the corridors that connect them will be needed to maintain viable ungulate populations for the public's use and enjoyment and as the biological seed to re-populate the West after fossil fuel reserves are drained.

Sage-Grouse

The severity of impacts on sage-grouse populations from various types of energy development dictates the need to shift from local to landscape conservation. This shift should transcend state and other political boundaries to develop and implement a plan for conservation of sage-grouse populations across the western U.S. and Canada. Tools are available that overlay the best known areas for sage-grouse with the extent of current and projected development for all of Sage-Grouse Management Zones I and II (Doherty et al. 2011), and range-wide core areas for conservation planning are publicly accessible (Doherty et al. 2010a). Maps depicting locations of the largest remaining sage-grouse populations and their relative risk of loss provide decision makers with the information they need to implement community-based landscape conservation. Ultimately, multiple stressors—not just energy development—must be managed collectively to maintain populations over time in priority landscapes.

A scientifically-defensible strategy can be constructed, but the most reliable measure of success will be long-term maintenance of robust sage-grouse populations in their natural habitats. Forgoing development in priority landscapes is the obvious approach necessary to conserve large populations. The challenge will be for governments, industries, and communities to implement solutions at a sufficiently large scale across multiple jurisdictions to meet the biological needs of sage-grouse. New best management practices can be applied and rigorously tested in landscapes less critical to conservation. The capability and opportunity is available to reduce future losses of sage-grouse to energy development, yet populations continue to decline as energy production increases, so the need for inter-jurisdictional cooperation is paramount. Political wrangling, lawsuits, regulatory uncertainty, and repeated attempts to list the species as federally threatened or endangered will continue until demonstrated success is achieved in collaborative landscape planning and on-the-ground actions that benefit sage-grouse populations.

Waterfowl

Responses of waterfowl to disturbances caused by oil and gas development vary by species, situation, and season. If industrial-scale oil and gas developments impact the region's wetlands and riparian areas with a spider web of roads, fences, pipelines, drilling pads, gravel pits, airstrips, and other facilities, waterfowl and other aquatic birds will experience greatly increased disturbance, predation, pollution, contamination, fragmentation, and loss of habitats. A key concern in the Rocky Mountain Region is the potential for toxicity effects on aquatic organisms resulting from produced water discharges to lakes, rivers, and wetland systems. Produced water can have different potential impacts on waterfowl depending on where it is discharged. The key to the future is that any development of the region's oil and gas resources must be planned and carried out carefully and must be balanced with protection of key hotspots for waterfowl and other birds. Only then will Rocky Mountain wetland and riparian systems remain available and productive as habitat for waterfowl in the future.

Songbirds

Energy development activities broadly overlap the tundra, boreal forest, grasslands, and shrub-steppe of North America. Unfortunately, little is known about its population-level effects on songbirds, and whether these impacts are additive or synergistic with effects of other human land uses. To date, there has been no or poor testing of beneficial practices that focus on restoration or minimization of the size and duration of energy extraction. Identifying key areas where urgent conservation protection is required, such as excluding development, may be the only way to ensure that energy-sector activities do not affect sensitive bird populations.

Monitoring and research need to be conducted more effectively. At a local scale, behavioral avoidance caused by development often is subtle, so avian sampling must be extremely accurate and precise to fully elucidate impacts. More vital-rate research is necessary to determine if birds are affected by energy-sector development and to estimate how population dynamics will be influenced by future development. The results from different studies need to be combined to estimate the synergistic effects of all the different energy-sector activities on songbirds and how energy effects contribute to cumulative impacts. Monitoring populations and cumulative-impact research at large spatial scales are needed to yield landscape-level estimates for broad-scale conservation planning.

Priorities must be set to facilitate effective research and conservation. It stands to reason that each management action will increase some species while decreasing others. It is critical that the losers can afford to lose (species that are widespread and abundant). In grasslands, this is not the case — all of the species with documented negative effects from energy (Sprague's pipit, Baird's sparrows, chestnut-collared longspur) are declining and ranked as being of above-average conservation concern by Partners in Flight and State Wildlife Action Plans.

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