POTENTIAL EFFECTS OF OIL AND GAS DEVELOPMENT ON MULE DEER AND PRONGHORN POPULATIONS IN WESTERN WYOMING

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Abstract

We documented distribution and seasonal movement patterns of radio-collared mule deer (Odocoileus hemionus) and pronghorn (Antilocapra americana) that used winter ranges in and adjacent to the Pinedale Anticline Project Area (PAPA). The PAPA is a 308 square-mile (798 km^2) area located in western Wyoming proposed for extensive natural gas development. Both mule deer and pronghorn exhibited seasonal migrations that were among the longest recorded for either species. Mule deer moved 40-100 miles (64-161 km) between seasonal ranges and wintered throughout the northern half of the PAPA, with distribution influenced primarily by snow depths. Most pronghorn wintered in the central portion of the PAPA and seasonally migrated 100-150 miles (160-241 km). Similar to other mule deer and pronghorn populations in the west, each relied on relatively distinct winter, summer, and transition ranges during the annual cycle. Summer ranges appeared relatively secure because of their size and land status, but transition and winter ranges of both species are threatened by energy development and subdivision expansion. The 4,000-6,000 mule deer and 2,000-3,000 pronghorn that depend on these winter ranges also require transition ranges that provide migration routes to their summer ranges. Bottlenecks in several areas along their migration routes already restrict movements to narrow corridors < 0.25 miles (400 m)- wide. Slight changes that further restrict animal movements in these areas could effectively sever migration corridors of mule deer and pronghorn. Energy development on the PAPA will likely influence the winter distribution of pronghorn and mule deer and the capacity of these ranges to support the two species.

This manuscript describes results of the pre-development phase of a long-term project where scheduled energy development was intended to provide the second or experimental phase. Results have identified threats to migration routes that need immediate attention, and distribution and movement patterns of these species that will assist agencies and industry with minimizing impacts to mule deer and pronghorn. However, documenting population level effects of energy development activities on these species will require interagency cooperation, adequate funding, and properly designed monitoring during development of the PAPA.

Introduction

Western Wyoming is home to the largest, most diverse ungulate populations in the Rocky Mountain region. Maintenance of these populations and protection of their habitats is a primary concern among public and private sectors. While expansion of subdivisions and decadent shrub communities have contributed to management concerns for ungulate populations, extensive energy development in the Green River Basin is thought to pose the most serious and large-scale threat to mule deer and pronghorn populations. Southwestern Wyoming is rich with oil and gas resources and has consistently produced 10 million barrels of oil each year, with gas production increasing steadily since the early 1980's. A five-county area (Sweetwater, Carbon, Sublette, Lincoln, and Uinta) produced an estimated 13.8 million barrels of oil and 885 million cubic feet of natural gas in 1998. As of 1998, there were an estimated 2,100 producing oil and gas wells in southwestern Wyoming. Between 1984 and 1998 the Bureau of Land Management (BLM) prepared 31 National Environmental Policy Act (NEPA) documents evaluating project proposals for oil and gas development in the area. The cumulative total of approved wells has increased from 238 in 1984 to approximately 8,500 in 1998. While the total number of new wells drilled over this period was lower than the number approved, there is obviously a large potential for further development and much interest in new gas fields. Recently, renewed political and economic support for developing domestic energy reserves has fueled industry interests to extract oil and gas from public lands. In July of 2000, the BLM approved the development of 700 producing well pads in the PAPA, and recognized that this may require as many as 900 well pads to be constructed and drilled. Additionally, 401 (645 km) miles of pipeline and 276 miles (444 km) of access roads were approved for development (USDI-BLM 2000).

Because the PAPA provides winter range for thousands of mule deer and pronghorn, development of this area may have adverse impacts on those populations. Impacts to wildlife species may be defined as the change in a population's reproduction and/or survival caused by some disturbance (Anderson 1999). Determining the impact(s) of energy development on wildlife populations requires long-term manipulative studies, where pre-development data on survival and reproduction are available. Simply documenting a behavioral response (i.e., avoidance, acclimation, dispersal, etc.) to a disturbance does not add to our knowledge of the impact, if it cannot be linked to the survival or reproductive success of the species involved. And conversely, documenting a change in reproduction or survival does not add to our knowledge of the impact if the cause (i.e., weather, development, disease) of the change cannot be determined. Because of the difficulty in designing and funding a long-term experimental study, population-level impacts of energy development on free-ranging ungulate populations are generally unknown. However, both direct and indirect impacts associated with energy development have the potential to affect ungulate population dynamics, particularly when impacts are concentrated on winter ranges, where energetic costs are great and animals occur at high densities. Direct impacts include the loss of habitat to well pads, access roads, and pipelines. Indirect impacts may include changes in distribution, stress, or activity caused by increased human disturbances that result in increased energy expenditures and are ultimately reflected in lower survival and/or reproduction.

The purpose of this study was two-fold: 1) collect pre-development movement and distribution data to assist agencies with management decisions to help minimize potential negative effects of natural gas development on big game winter ranges and migration corridors, and 2) collect pre-development data to facilitate the design and implementation of a long-term study that examines the effects of natural gas development on mule deer and pronghorn populations.

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Study Area

The PAPA is located in west-central Wyoming in Sublette County, near the town of Pinedale (Fig.1). The PAPA is characterized by sagebrush, high desert vegetation, and riparian areas associated with the Green and New Fork Rivers. Elevations range from 6,800 to 7,800 feet (2,702-2,377 m). The 308 square-mile (798 km^2) PAPA consists primarily of federal lands (80%) and minerals (83%) administered by the BLM. All but 7.4 mi^2 (19.2 km^2) of federal minerals in the project area have been leased (USDI-BLM 2000). The state of Wyoming owns 15.2 square miles (39.5 km^2) (5%) and another 46.7 square miles (120.8 km^2) (15%) are private. Aside from the rich natural gas resources, the PAPA is an important area for agriculture and wildlife. The PAPA provides winter range for 4,000-6,000 mule deer, 2,000-3,000 pronghorn, elk (Cervus elaphus), moose (Alces alces), and seasonal range for 3,000-4,000 sage grouse (Centrocercus urophasianus) and at least 12 species of raptors (USDI-BLM 1999). The PAPA is one of two major wintering complexes used by mule deer in the upper Green River Basin (Sawyer and Lindzey 2001).

Methods

Helicopter net-gunning was used to capture and radio-collar adult (>1 year) female pronghorn on summer ranges. Capture work was restricted to early morning hours (0600-1000 hrs) to avoid running pronghorn in hot (>75°F, 24°C) conditions. Radio-collared pronghorn were located from fixed-wing aircraft once a week during the fall migration, October through November. Telemetry flights were

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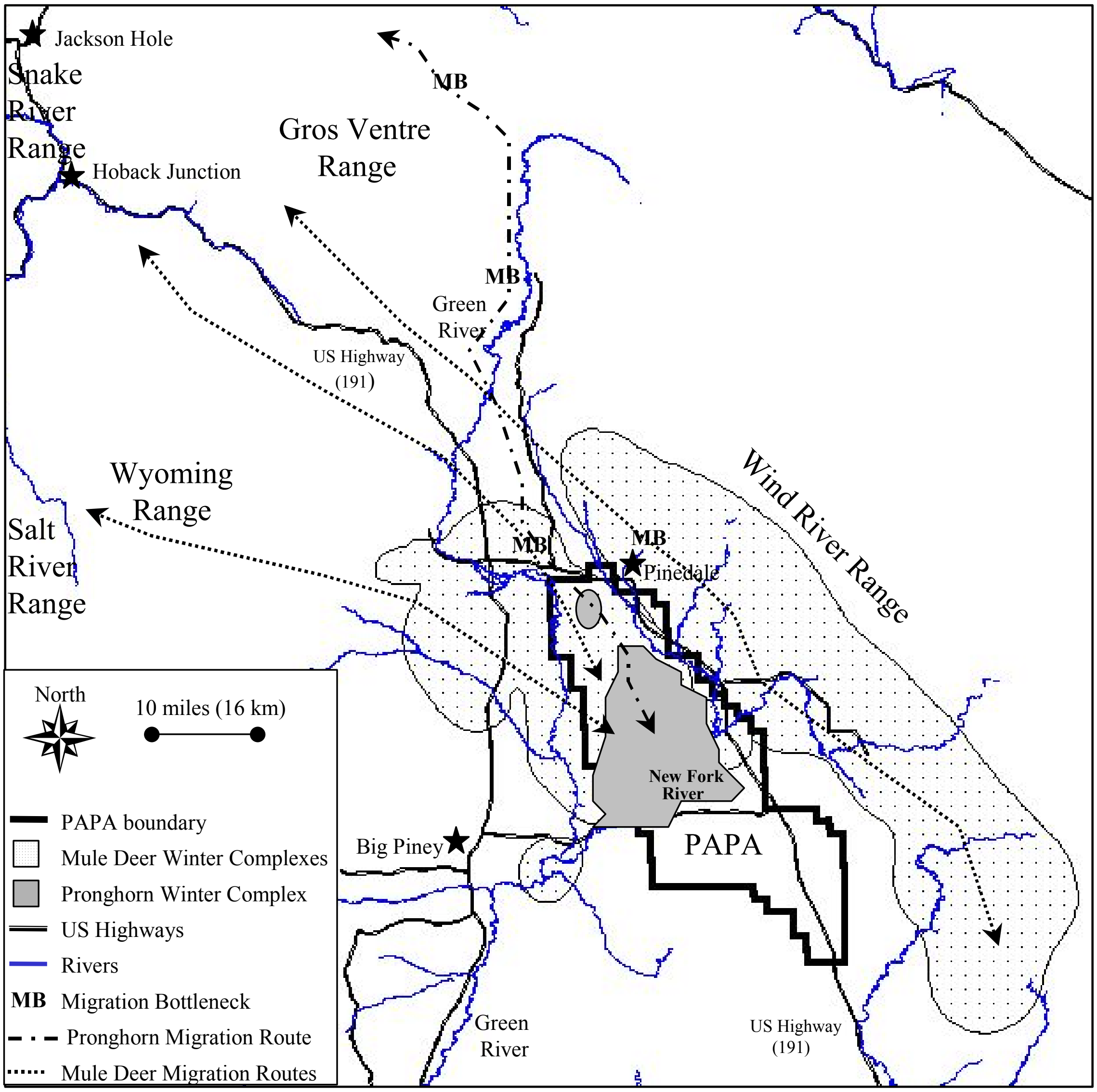

Figure 1. Location of mule deer and pronghorn winter range complexes and migrations routes, in and adjacent to the Pinedale Anticline Project Area (PAPA) in western Wyoming.

reduced to once a month during the winter. Pronghorn were located from the ground and air during the spring migration.

Helicopter net-gunning was also used to capture and radio-collar adult mule deer on winter ranges. Telonics (Generation I and II) radio-collars were equipped with both very high frequency (VHF) transmitters and global positioning systems (GPS). The Generation I GPS units were capable of collecting 700 locations over a 1-year time period and were programmed to obtain locations every 9 hours during migration periods and every 25 hours during summer. The Generation II GPS units stored 2,600 locations and were programmed to collect locations every hour from January 1-April 15. All GPS radio-collars were store-on-board units that had to be retrieved before data could be downloaded. Helicopter net-gunning was used to recapture deer and retrieve Generation I GPS collars. Generation II GPS collars were equipped with remote release mechanisms that were activated at a specified time and date. Radio-collared deer were located from fixed-wing aircraft approximately every 10 days during spring and fall migrations, and once per month during summer. Additionally, radio-collared deer in the PAPA were monitored with ground telemetry during the winters of 1998-1999 and 1999-2000. Monitoring began in February 1998 and ended in October 2000.

ARC-VIEW (Ver.3.2) was used for spatial analysis and mapping distribution data. Winter range boundaries were delineated using a 90% adaptive kernel home range technique on winter (November 15-April 30) locations of deer and pronghorn. Locations obtained from GPS collars and ground monitoring were excluded from estimates of winter dispersion to avoid results biased towards individual deer with many locations. Animals were considered migratory if their summer and winter home ranges did not overlap (Brown 1992). Winter and summer fidelity was examined by comparing locations of individual pronghorn among consecutive years.

Results

Capture

We captured and radio-collared 171 adult mule deer (144 standard VHF collars, 17 GEN I GPS collars, 10 GEN II GPS Collars) across winter ranges in and adjacent to the PAPA between, February 1998 and January 2001. The capture sample included 12 males and 159 females.

We captured and radio-collared 34 adult female and one yearling female pronghorn in July of 1998. The capture sample reflected the proportionate distribution of pronghorn across the summer ranges, with approximately two-thirds (n=23) of the radio-collars distributed in Grand Teton National Park (GTNP) and the other one-third (n=12) in the Gros Ventre River Drainage (GVRD), near Jackson, Wyoming.

Mule Deer Seasonal Movements and Distribution

We collected 34,570 locations from 166 radio-collared deer between February 1998 and April 2001. Approximately 29,844 of these locations (86%) were obtained from the 25 GPS collars (2 others malfunctioned). The other 14% (4,726) of locations were collected from ground and aerial telemetry. Of 166 radio-collared deer we monitored, 96% (n=159) were considered migratory. Most deer from the PAPA seasonally migrated 40-100 miles (64-161 km) north/northwest to summer in portions of four different mountain ranges: the Wyoming Range, Salt River Range, Snake River Range, and the Gros Ventre Range.

Deer from different winter complexes often shared common transition ranges, parturition areas and summer ranges. Transition ranges generally occurred between 7,000 and 8,000 feet (2,134-2,438 m) and were characterized by abundant grass and forb communities intermixed with mountain shrub communities. Deer typically occupied these ranges for 4 to 5 months during the year, usually April, May, early-June, November, and December. Spring migration of mule deer progressed northerly as snow melted and new plant growth provided abundant, high-quality forage. Most deer (70%, n=101) that were monitored through a complete year gave birth on mid-elevation transition ranges before moving onto high-elevation summer ranges. Summer habitats were characterized by rugged terrain and abundant forb communities that occurred between 7,000 and 10,000 feet (2,100-3,048 m).

Data collected from GPS collars indicated deer migrated at a gradual, steady pace rather than moving quickly over long distances. Typical daily movements during spring and fall migrations were 1 to 3 miles (2-5 km). Given GPS location attempts were scheduled every 9 hours, the average distance between each location was usually < 1 mile (1.6 km). Most movement during the spring migration occurred in May, when the average distance increased to 1.1 miles (1.8 km) between GPS locations. Although most deer arrived on summer ranges by late-June, periodic movements of 1-4 miles (2-6 km) were not uncommon during July, August, and September. Mule deer generally remained on summer range July through October, and occasionally through November. Most fall movement occurred in November and December, after the hunting seasons and prior to heavy snow accumulation. Many deer remained on transition ranges north of the PAPA winter ranges during November, December, and occasionally early January when weather conditions allowed.

Mule deer densities in the PAPA were highest January through March. Mule deer were evenly distributed across the northern half of the PAPA when snow depths were < 6-8 inches (15-20 cm). However, as snow depth increased, mule deer generally moved off the higher-elevation areas and into the breaks around the perimeter of the PAPA. Mule deer demonstrated strong fidelity to their seasonal ranges, generally occupying areas 0-5 miles (0-8 km) apart in consecutive seasons. All but two mule deer captured in the PAPA winter range complex returned in subsequent winters and all but one used the same summer ranges during consecutive years.

Pronghorn Seasonal Movements and Distribution

Pronghorn seasonal ranges and migration routes were identified using 918 aerial locations obtained from 33 radio-collared pronghorn. Fieldwork conducted during spring migrations resulted in additional observations of collared and non-collared pronghorn moving between winter and summer ranges. Continuous observation of migrating radio-collared pronghorn was often possible and helped determine specific migration routes (Sawyer and Lindzey 2000a). Pronghorn generally migrated out of GTNP and the GVRD in October and November, crossing the 9,100-foot (2,774 m) hydrographic divide that separates the Gros Ventre and Green River drainages. Pronghorn then migrated southerly 80-100 miles (129-161 km) down the Green River to winter ranges in and adjacent to the PAPA.

An estimated 2,000 pronghorn, including 85% (n=27) of the radio-collars, occupied winter ranges within the PAPA, typically from November through early-April. Although several pronghorn (15%, n=5) spent the majority of winter south of the PAPA, all migrated through the area and used it as a spring transition range, during their 3-month, 100-150 mile (161-241 km) migration back to GTNP and the GVRD. Radio-collared pronghorn were usually distributed among 15-20 distinct herds. Winter (November-April) distribution of GTNP and GVRD pronghorn was similar and mixing of groups common. Pronghorn and mule deer were generally spatially separated December through February, as pronghorn occupied the lower-elevation sagebrush flats and agricultural fields adjacent to the New Fork River. However, when snows began to recede in March, mixing of mule deer and pronghorn in the higher-elevation sagebrush communities of the northern PAPA were common. Deer tended to move off the PAPA earlier (mid-March) than pronghorn in the spring, after which pronghorn shifted into those areas deer occupied for the more severe winter months, until they continued the northerly migration north in April.

Most (86%, n=24) pronghorn monitored through two winters returned to winter ranges within the PAPA and occupied consecutive wintering areas 0-5 miles (0-8 km) apart. Although pronghorn spent most winters in close proximity (0-3 miles) of the New Fork River, they used nearly the entire northern half of the PAPA November through April. Periodic southerly movements of 10-20 miles (16-32 km) were made by eight of the 24, but only for brief time periods. The four (14%) pronghorn that did not use the same winter ranges during consecutive years appeared to be very mobile and never remained in one area for long. It was not uncommon for these pronghorn to move 20-40 miles (32-64 km) at any given time during the winter. All pronghorn captured in the GVRD demonstrated strong site fidelity to summer ranges, while as many as 40% of GTNP pronghorn used summer ranges in different areas.

Migration Bottlenecks

Radio-collared mule deer and pronghorn seasonally migrated 40-150 miles (64-241 km) between winter and summer ranges. Several "bottlenecks" were identified along migratory routes. We defined bottlenecks as those areas along migration routes where topography, vegetation, development and/or other landscape features restricted animal movements to narrow (<0.5 mi, 0.8 km) or limited regions. Some of bottlenecks exceeded 1 mile (1.6 km) in length and were less than 0.25 miles (400 m) in width. Several bottlenecks were used exclusively by pronghorn, while others were used by both mule deer and pronghorn. Telemetry records indicated approximately half of the deer (2,000-3,000) and most of the pronghorn (1,000-1,500) that winter in the PAPA, migrated through at least one, and as many as five bottlenecks twice a year. Pronghorn traveled quickly through bottleneck regions and were observed using opened gates and roads to facilitate movements through fenced areas. For detailed description of migratory bottlenecks used by pronghorn and mule deer from the PAPA refer to Sawyer and Lindzey (2000a) and Sawyer and Lindzey (2001), respectively.

Discussion

Mule deer migrations in western Wyoming were generally much longer than movements of other deer populations in the western states, including Colorado (Garrot et al. 1987), Idaho (Brown 1992, Merrill et al. 1994), Washington (Eberhardt et al. 1984), and California (Nicholson et al. 1997). Although mule deer migrations of ≥ 60 miles (100 km) have been reported in parts of Montana (Mackie et al. 1998) and Idaho (Thomas and Irby 1990), the mule deer herd on and adjacent to the PAPA is likely the most migratory deer population in the western states. The 100-150 mile (161-241 km) seasonal pronghorn migration appears to be the longest of its kind in North America. Mule deer and pronghorn management in western Wyoming is complicated by the long-distance (40-150 mi, 64-241 km) migrations that occur through a variety of habitats and across a mix of land ownership. Because the PAPA provides winter range for mule deer that occupy four different mountain ranges across western Wyoming and pronghorn that summer > 100 miles (161 km) away, conserving seasonal ranges and migration routes will be essential for the long-term maintenance of this population. Additionally, any potential negative effects of oil and gas development will not be localized or exclusively restricted to the PAPA, rather they will be evident across western Wyoming and the summer ranges these animals occupy.

Similar to other studies (Eberhardt et al. 1984, Garrott et al. 1987, Thomas and Irby 1990, Brown 1992, Porter 1999, Sawyer and Lindzey 2000b), mule deer in western Wyoming demonstrated some degree of fidelity to winter and summer ranges. Although traditional use of pronghorn winter ranges has been documented in Alberta (Barret 1980) and Wyoming (Ryder et al. 1984), winter distribution of other pronghorn herds tends to be weather dependent and annually variable (Bruns 1977, Hoskinson and Tester 1980, Mitchell 1980, Raper et al. 1989). Winter range fidelity of pronghorn to the PAPA appeared relatively high at 86%. Consistent, documented use of seasonal ranges should allow agencies to modify seasonal range maps used to assist with management decisions and identify mitigation opportunities. Current range maps used by state and federal agencies in Wyoming underestimate the amount of winter range consistently used by mule deer and pronghorn in the PAPA. Winter range designation is intended to identify areas critical to the survival of a given population. Designated 'crucial' winter ranges receive special protection on public lands and guide management decisions by federal agencies in situations where land-use practices may have adverse impacts. Accurate delineation of 'crucial' ranges will assist state and federal agencies with ungulate management and improve the NEPA process by providing quality data for environmental impact statements (EIS) and environmental assessments (EA). Aside from parturition areas, designated 'crucial' winter ranges are typically the only habitats considered in EIS impact analyses for big game.

The function of winter range is to decrease the rate at which adult and fawn body condition declines by providing forage and thermal cover. Because most native forages available during the winter are often too low in nutritional value to meet the energetic requirements of deer (Wallmo et al. 1977), they must accumulate energy reserves prior to winter, on summer and transition ranges, if they are to survive. Deer cannot maintain body condition on winter ranges because of poor-moderate forage availability combined with the increased cost of thermogenesis (Reeve and Lindzey 1991). Body condition and energy reserves gradually decline over winter as deer expend more energy than they take in (Short 1981). The rate at which body condition declines depends on forage quality/availability, winter severity (temperature, wind speed, snow depth), and age class. Although little can be done to reduce the energetic costs of animals that travel through snow, unnecessary energy expenditures can be reduced by limiting human related disturbances (Parker et al. 1984). The energy balance determining whether a deer will survive the winter is thought to be relatively narrow, especially for fawns (Wood 1988). Overwinter survival of deer, particularly fawns, may decrease in response to human activity or other disturbances (Stephenson et al. 1996). Successful overwinter survival depends on the ability and capacity of the winter range to minimize the rate at which body condition declines. If natural gas development in the PAPA reduces the ability or capacity of the winter range, either by direct habitat loss or indirectly by human disturbances that increase energy expenditures, mule deer and pronghorn populations will suffer.

Unlike some other mule deer populations (Ryder et al. 1985, Gillin and Lindzey 1986, Allen 1995, Porter 1999, Sawyer and Lindzey 2000b), deer from the PAPA utilized a large area of mid-elevation transition range during spring and fall migrations. As a result, rate of movement (0-3 mi, 0-5 km per day) by migrating deer was substantially slower than travel rates in Idaho, where mule deer migrations were characterized by rapid movements of 3-12 miles (5-20 km) with periodic breaks in between (Thomas and Irby 1990). Seasonal migrations of mule deer captured in the PAPA took as long as 60-90 days to complete, depending on weather conditions. The relatively gradual rate of movement and extended periods of time spent on transition range demonstrated the importance of this habitat component to the PAPA mule deer herd. In the absence of high quality forage on winter range, the most appropriate migratory behavior for deer is to remain on higher-elevation ranges where vegetation is typically of better quality (Garrott et al. 1987). Small improvements in body condition during late-fall or early-winter may substantially reduce overwinter mortality (Hobbs 1989).

Generally, transition ranges provide deer with better foraging opportunities than those often available on winter ranges, allowing them to recover body condition earlier in the spring and maintain body condition later in the fall, before entering winter (Short 1981). Effective transition ranges alleviate pressure on winter ranges and minimize the amount of time deer must spend on winter range. Thus, maintenance of effective transition ranges not only increases mule deer survival and productivity, but also contributes to the health and vigor of winter range forage by minimizing its use. The ability to alter their rates of movements, even to retrace their movements if weather dictates, to change their pathways as needed and to hesitate before moving onto summer or winter ranges are behaviors that allow mule deer to best exploit transition ranges. Energy development, housing subdivisions, road networks, fences, increased human activity, and other changes on transition ranges that reduce options available to mule deer will reduce the effectiveness of these ranges, just as they will on winter ranges within the PAPA. As oil and gas development within the PAPA increases, active management and conservation of transition ranges will be key in attempting to maintain healthy mule deer herds in western Wyoming.

Summer, transition, and winter ranges are equally important components to the PAPA mule deer population. The relative importance of each will likely change annually, but loss or degradation of one will not be compensated for by the others, and the mule deer population will suffer in the long-run. Managers should recognize the importance of all seasonal ranges form maintaining healthy and productive mule deer populations (Short 1981, Clements and Young 1997). Currently, summer ranges appear most secure because of their large size, productivity, and land-status in the Bridger-Teton National Forest. The smaller transition and winter ranges however, are threatened by extensive energy development on BLM lands and subdivision expansion on private parcels. The importance of seasonal ranges to mule deer or pronghorn is of little consequence if migration routes to and from these ranges are not maintained. Bottlenecks create management concerns because the potential to disrupt or threaten established migratory routes are much greater in these areas. Misguided development or other land use practices may easily fragment and further restrict wildlife access through these naturally occurring bottlenecks. Archaeological records suggest ungulates have migrated through at least one of the identified bottlenecks for thousands of years (Miller et al. 1999). A recent dig conducted by the Office of the Wyoming State Archaeologist documented a 6,000 year-old pronghorn kill site in the core of the Trapper's Point bottleneck. Prehistoric hunters took advantage of the natural bottleneck and killed migrating pronghorn with primitive stone-tipped weapons. Small amounts of mule deer remains were also revealed. The development of fetal bones found at the site indicated the kills occurred in late-March or early-April, corresponding with the timing of modern-day pronghorn migrations through this corridor. Focusing conservation efforts on bottleneck areas may provide a sound, objective method to prioritize management concerns and direct proactive measures towards maintaining long-distance migrations.

Oil and gas development on the PAPA will result in additional roads (276 mi, 444 km), pipelines (401 mi, 645 km), habitat loss (700-900 well pads), fences, and increased human disturbance on winter ranges used by thousands of mule deer and pronghorn in western Wyoming. How, when, and to what degree mule deer and pronghorn populations will be impacted is unknown. However, reduction in effective winter range size, as potentially brought about by extensive natural gas development in the PAPA, may increase deer density on remaining winter ranges, reducing forage quality, fawn survival, and overwinter carrying capacity. Overwinter fawn survival decreases as densities approach carrying capacity (White et al. 1987, Bartmann et al. 1992), and low overwinter fawn survival may be interpreted as density-dependent population regulation (Bartmann et al. 1992). A reduction in winter range capacity also increases the probability of deer moving onto poorer quality ranges, where adult survival is further decreased. Additionally, any reduction in the ability of mule deer or pronghorn to move about freely on winter ranges reduces their options for coping with a variety of environmental conditions (i.e., snow depth) and human disturbances. Flexibility in movement across ranges is ultimately reflected in the survival and productivity of the deer population and likely enhances their ability to recover from population declines. Brown (1992) suggested that winter movement flexibility also reduced mule deer density and competition for available resources.

The acquisition of GPS and geographic information system (GIS) technologies now allow visualization, analysis, and recognition of land use patterns of radio-collared animals across large spatial scales. The combination of intensive telemetry study (funded by industry) and GIS capabilities identified potential concerns for managers of the mule deer and pronghorn populations that winter on the PAPA. Migration routes where natural and man-made features funnel movements of many mule deer and pronghorn through narrow corridors (bottlenecks) are examples of situations where the need for actions is obvious and the lack of action will be detrimental mule deer and pronghorn in western Wyoming. These same data may form the basis for guiding the development of energy resources and housing subdivisions, with conservation of mule deer and pronghorn populations in mind.

The major shortcoming of efforts to evaluate the effect(s) of disturbances on wildlife populations is that they seldom are addressed in an experimental framework, but rather tend to be short-term and observational in nature. Ideally, these pre-development data will be used to design an experimental study, with the cooperation of industry and agencies, that examines the long-term effects of oil and gas development on mule deer and pronghorn distribution, reproduction, and survival.

References

Allen, J.A. 1995. Seasonal distribution and winter habitat use of female mule deer in the Copper Mountain Region, Wyoming. MS Thesis, University of Wyoming, Laramie. 126 pp.

Anderson, S.H. 1999. Managing our wildlife resources. Prentice Hall, Upper Saddle River, New Jersey. 540 pp.

Barrett, M.W. 1980. Seasonal habitat associations of pronghorns in Alberta. Proc. Pronghorn Antelope Workshop 9:174-195.

Bartmann, R.M., G.C. White, and L.H. Carpenter. 1992. Compensatory mortality in a Colorado mule deer population. Wildlife Monographs 121:1-39.

Brown, C.G. 1992. Movement and migration patterns of mule deer in southeastern Idaho. Journal of Wildlife Management 56:246-253.

Bruns, E.H. 1977. Winter behavior of pronghorns in relation to habitat. Journal of Wildlife Management 41:560-571.

Clements, C.D. and J.A. Young. 1997. A viewpoint: Rangeland health and mule deer habitat. Journal of Range Management 50:129-138.

Eberhardt, L.E., E.E. Hanson, and L.L. Cadwell. 1984. Movement and activity patterns of mule deer in the sagebrush-steppe region. Journal of Mammalogy 65:404-409.

Garrott, R.A., G.C. White, R.M. Bartmann, L.H. Carpenter, and A.W. Alldredge. 1987. Movements of female mule deer in northwest Colorado. Journal of Wildlife Management 51:634-643.

Gillin, C.M. and F.G. Lindzey. 1986. Meeteetse mule deer study. Prog. Rep. Wyoming Cooperative Fish and Wildlife Research Unit, Laramie. 58 pp.

Hobbs, N.T. 1989. Linking energy balance to survival in mule deer: development and test of a simulation model. Wildlife Monograph 101:1-39.

Hoskinson, R.L. and J.R. Tester. 1980. Migration behavior of pronghorn in southeastern Idaho. Journal of Wildlife Management 44:132-144.

Mackie, R.J., D.F. Pac, K.L. Hamlin, and G.L. Dusek. 1998. Ecology and management of mule deer and white-tailed deer in Montana. Montana Fish Wildlife and Parks. 180 pp.

Merrill, E.H., T.P. Hemker, K.P. Woodruff, and L. Kuck. 1994. Impacts of mining facilities on fall migration of mule deer. Wildlife Society Bulletin 22:68-73.

Miller, M.E., P.H. Sanders, and J.E. Francis, eds. 1999. The Trappers Point Site (48SU1006): Early archaic adaptations in the upper Green River Basin, Wyoming. Office of the State Archaeologist, University of Wyoming, Laramie. 530 pp.

Mitchell, G.J. 1980. The pronghorn antelope in Alberta. University of Regina, Saskatchewan, Canada. 165 pp.

Nicholson, M.C., R.T. Bowyer, and J.G. Kie. 1997. Habitat selection and survival of mule deer: tradeoffs associated with migration. Journal of Mammalogy 78:483-504.

Parker, K.L., C.T. Robbins, and T.A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48:474-488.

Porter, M.A. 1999. Spatial relationships between sympatric mule deer and elk in south-central Wyoming. MS Thesis, University of Wyoming, Laramie. 73 pp.

Raper, E., T. Christiansen, and B. Petch. 1989. Sublette antelope study: final report. Annual Big Game Herd Unit Report, Wyoming Game and Fish Department, 124-169.

Reeve, A.F. and F.G. Lindzey. 1991. Evaluation of mule deer winter mortality in south-central Wyoming. Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, WY. 147 pp.

Ryder, T.J., L.L. Irwin, and D.S. Moody. 1984. Wyoming's Red Rim pronghorn controversy: history and current status. Proc. Pronghorn Antelope Workshop 11:195-206.

Ryder, T.J., J.M. Emmerich, and S.H. Anderson. 1985. Winter ecology and seasonal movements of mule deer in the Hall Creek Herd Unit. Final Report. Wyoming Cooperative Fish and Wildlife Research Unit, Laramie. 89 pp.

Sawyer, H. and F. Lindzey. 2000a. The Jackson Hole pronghorn study. Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie. 57 pp.

______ and ______. 2000b. Ecology of sympatric mule deer and white-tailed deer in riparian communities of southeast Wyoming. Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie. 49 pp.

______ and ______. 2001. The Sublette mule deer study. Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, WY. 54 pp.

Short, H.L. 1981. Nutrition and metabolism. Pages 99-127 *in* O.C. Wallmo, ed., Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln, NE.

Stephenson, T.R., M.R. Vaughan, and D.E. Andersen. 1996. Mule deer movements in response to military activity in southeast Colorado. Journal of Wildlife Management 60:777-787.

Thomas, T. and L. Irby. 1990. Habitat use and movement patterns by migrating mule deer in southeastern Idaho. Northwest Science 64:19-27.

USDI- Bureau of Land Management. 1999. Draft environmental impact statement for the Pinedale Anticline natural gas field exploration and development project prepared for Pinedale Field Office, Wyoming.

USDI- Bureau of Land Management. 2000. Record of Decision: Environmental impact statement for the Pinedale Anticline natural gas field exploration and development project prepared for Pinedale Field Office, Wyoming.

Wallmo, O.C., L.H. Carpenter, W.L. Reglin, R.B. Gill, and D.L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. Journal of Range Management 30:122-127.

White, G.C., R.A. Garrott, R.M. Bartmann, L.H. Carpenter, and A.W. Alldredge. 1987. Survival of mule deer in northwest Colorado. Journal of Wildlife Management 51:852-589.

Wood, A.K. 1988. Use of shelter by mule deer during winter. Prairie Naturalist 20:15-22.