GREATER SAGE-GROUSE POPULATIONS AND ENERGY DEVELOPMENT IN WYOMING

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SYNOPSIS

Understanding how energy development affects greater sage-grouse populations is a management priority in Wyoming. There is broad interest in determining whether viable sage grouse populations and energy development can coexist and, if so, under what specific conditions. Some biologists have contended that oil and gas development at a density of more than one well per square mile will cause the extirpation of local sage-grouse populations, and that the standard protective stipulations applied by the Bureau of Land Management (BLM) on energy development activities are insufficient for maintaining viable populations in development areas. This has prompted State and Federal land and wildlife management agencies to apply significantly more stringent restrictions on energy development activities in sage-grouse habitat. We examined sage-grouse populations in several oil and gas fields in Wyoming to characterize population trends and to better understand the specific development scenarios under which impacts to sage-grouse populations are observed. We used publicly available databases from the Wyoming Game and Fish Department (WGFD) and the Wyoming Oil and Gas Conservation Commission (WOGCC).

We analyzed six oil and gas development areas with various degrees and ages of activity to determine population trends relative to the timing and intensity of oil and gas development in those areas. We compared these trends to trends in an area in which oil and gas activity is minimal and to trends state-wide.

The results show that: 1) sage-grouse population trends are consistent among populations regardless of the scope or age of the energy development field, and that population trends in the six development areas mirror trends state-wide; 2) application of the BLM standard sage-grouse stipulations appears to be effective in reducing the impact of oil and gas development on male-lek attendance; 3) male-lek attendance in areas that are not impacted by oil and gas development is generally better than in areas that are impacted (see below for definitions of impacted versus non-impacted leks); 4) displacement from impacted leks to non-impacted leks may be occurring; research is needed to assess displacement and its implications for developing conservation strategies; 5) lek abandonment was most often associated with two conditions including high density well development at forty acre spacing (sixteen wells per square mile) and, regardless of well spacing, when development activity occurred within the quarter mile lek buffer; 6) extirpation of sage-grouse populations has not occurred in any of the study areas; and 7) like many wildlife populations, long-term fluctuations in sage-grouse population trends in Wyoming likely reflect long-term processes such as precipitation regimes rather than energy development activity; however, energy development can exacerbate fluctuations in sage-grouse population trends over the short-term.

BACKGROUND

Energy development can negatively impact greater sage-grouse populations through direct loss of habitat, habitat fragmentation due to road and pipeline construction, overhead electric lines, noise interference with courtship behaviors and brood rearing, and support of predator populations through augmentation of food sources and perch sites. (Doherty et al. 20XX, Lyon

2000, Holloran 2005, Kaiser 2006, Walker et al. 20XX). In Wyoming there is broad interest in maintaining viable sage-grouse populations while assuring productive oil and gas fields. Some research has suggested that extirpation of sage-grouse populations is imminent in areas affected by oil and gas development, and that BLM stipulations are ineffective in conserving populations (Aldridge 2005, Doherty et al. 20XX, Holloran and Anderson 2006, Walker et al. 20XX).

Clearly, no wildlife population can persist if habitat is altered to an extent that exceeds the capacity of individuals to adapt. But critical questions remain about whether viable sage-grouse populations and energy development can coexist and, if so, at what thresholds would development exceed the capacity for population persistence. Further, the assertion that BLM stipulations have limited conservation value is premised on the notion that any impact to sage-grouse is evidence that the stipulations are ineffective.

The Council for Environmental Quality (CEQ) regulations (2007) state there are various expectations of applied mitigation measures; these are avoidance of impact and reduction of impact. The Bureau of Land Management spatial and temporal stipulations for greater sage-grouse are intended to reduce the impact of the activity, not to eliminate impacts altogether; this clarification is found in the CEQ National Environmental Policy Act (NEPA) regulations at 40 CFR 1508.20,mitigation may include one or more of the following:

> *(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.."*

The objective of this report is to characterize sage-grouse population trends in Wyoming qualitatively in an effort to advance our understanding of whether there may be conditions of development under which the coexistence of viable sage-grouse populations and productive oil and gas fields would be feasible.

METHODS

DATABASES – We used publicly available databases in the analysis. Sage-grouse observation and location data were from the Wyoming Game and Fish Department (WGFD 2006), and spatial and temporal information on oil and gas development was from the Wyoming Oil and Gas Conservation Commission database (WOGCC 2006).

After assessing the WGFD and WOGCC data we developed criteria for including leks or wells in the analysis that were intended to facilitate reliable interpretation of the results:

- in many cases leks appear in the WGFD database even though there are no records of sage-grouse having been observed on them; we included only those leks at which sage-grouse have been observed
- among leks at which sage-grouse have been observed, we retained for the analysis only those for which sage-grouse were observed during the period 1980 to 2006.
- we considered cells in the WGFD database containing the number zero to represent a lek count that was conducted but for which no male was observed. This is a highly conservative measure; it is known that zeros in the database may also indicate that the lek count did not occur (i.e., zero was used as a placeholder; T. Christensen, WGFD, 2006, pers. com).
- we limited inclusion of wells in the analysis to those actually drilled through 2006; we excluded those with pending or expired permits.

LEK DEFINITIONS - We classified leks into five types and made qualitative comparisons among them. The metric used in the comparisons was the WGFD “average peak males in attendance”.

- *Impacted leks* are those with more than 10 wells drilled within a two mile radius (slightly less than 1 well per square mile). Ten wells within the two mile radius corresponds with the condition identified by Holloran (2005) and Doherty et al. (20XX) as the maximum level of development that would allow the continued occupation of the area by sage-grouse,
- *Non-impacted leks* are those leks with 10 or fewer wells drilled within the two mile radius (i.e. those identified by previous authors as outside of development)
- *Field leks* are the combination of impacted and non-impacted leks in each study area,
- *Area leks* are all leks within the Game and Fish management area(s) surrounding and including the study area, and
- *State leks* are all leks known within the State of Wyoming and represent the statewide population.

In addition to examining individual leks, we examined impacted and non-impacted lek complexes in each study area. We used total males observed as the metric in this analysis. Population trends using average males or total males followed similar patterns. Lek complex definitions generally follow the WGFD nomenclature.

STUDY AREAS – We selected study areas that were representative of the variation that characterizes energy development in Wyoming. These areas differed in terms of the longevity of development, density and intensity of development, and production type (e.g., oil, gas or coal bed natural gas). Six development areas and a "control" area were selected (Figure 1):

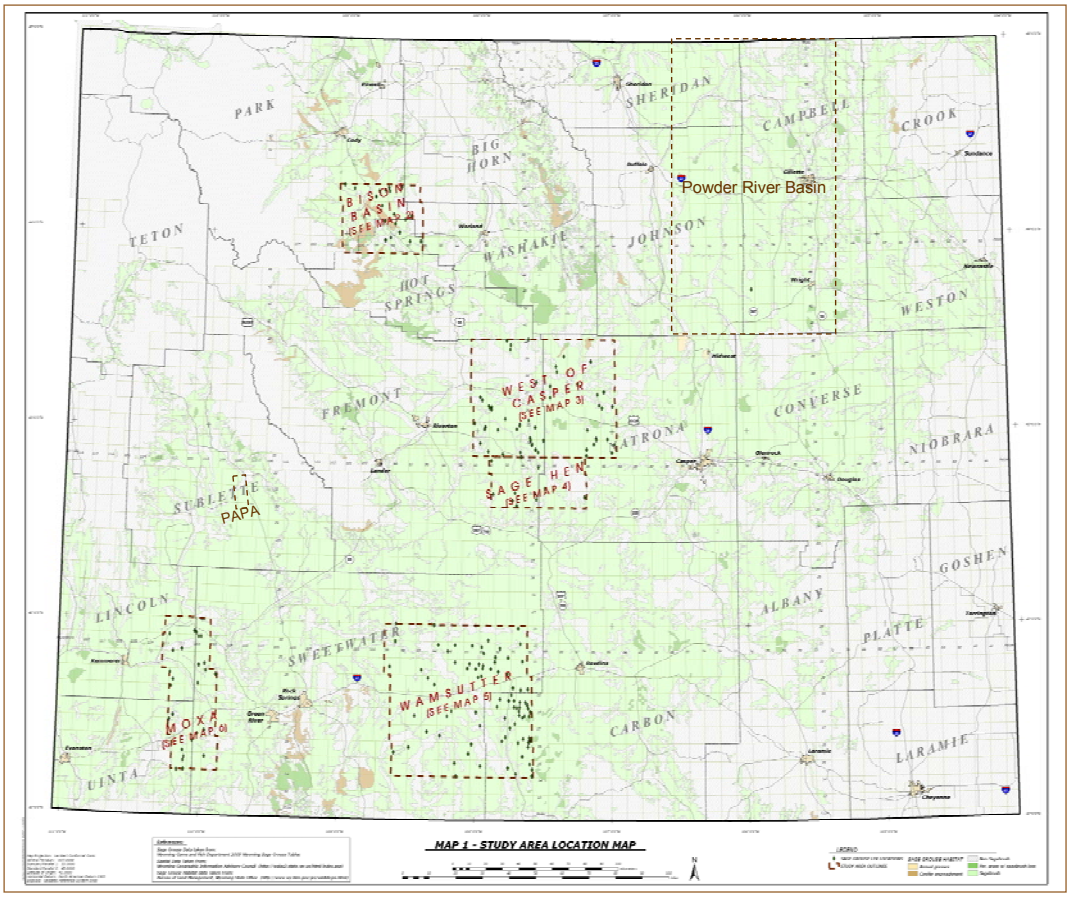
- *Powder River Basin (PRB)*: Coalbed natural gas (CBNG) is in development and production stages throughout a large geographic area.
- *West of Casper:* This area includes a wide variety of field development areas.
- *Sagehen Creek:* This is the study "control" area; few oil wells (~60) have been drilled in the area making it a reasonable site for comparisons.
- *Wamsutter:* Initial development in the area began circa 1946 with renewed interest in the late 1970's.
- *Moxa Arch:* Development of the Moxa Arch natural gas field also began circa 1946 with renewed interest beginning around 1980.
- *Pinedale Anticline Participating Area (PAPA):* This area has been the focus of significant interest since development was renewed in 1998.
- *Bison Basin:* This is an old oil field area located northwest Wyoming.

VEGETATION BASE MAPS – We used the BLM sagebrush habitat map (BLM 2006) to characterize vegetation types in each study area except for PRB. In PRB, we used the Wyoming GAP analysis vegetation map (WY GAP 2006), given the extent of private land in PRB and the consequent lack of ground truthing in this area, the GAP data probably were more accurate than the BLM data.

LEK MAP SYMBOLS – We based lek map symbols on male attendance during the period 2004 through 2006. We used this three year period to reflect efforts by WGFD to survey each lek at least once every three years. The lek characteristics are illustrated on the maps as follows:

- The lek center is indicated by a ¼ mile radius circle illustrating the BLM lek buffer (breeding habitat) avoidance requirement.
- The size of the colored dot within the lek center indicates the relative size of the lek in terms of the peak male-lek attendance.
- A green dot in the lek center indicates that no sage-grouse was observed on the lek.
- An open circle in the lek center indicates that no count or survey was conducted.

Figure 1 - Statewide over view map of study areas



A 2-mile radius circle around the lek center represents the area of greatest concern for the protection of nesting and early brood rearing habitats as managed by the BLM through the use of seasonal (temporal) timing restrictions on surface disturbing activities.

WELL SYMBOLS - Well symbols are as follows:

- Black dots represent active wells,
- Grey dots represent plugged and abandoned wells,
- Well symbols in PRB are different; red dots indicate wells drilled on the federal mineral estate and blue dots indicate wells on state or private minerals (non-federal).

DATA SUITE COMPARISONS – We conducted the following qualitative analyses for each study area:

1. We determined average peak male lek attendance for each year using only those leks counted in that year; therefore, the sample size changed annually.
2. We made comparisons of average male-lek attendance among the following lek classifications: impacted, non-impacted, the defined study area, the affected WGFD management areas, and the State.
3. We did not make comparisons among study areas (i.e. PRB impacted leks are not compared to PAPA impacted leks) because each area differs in vegetation, topography, and

precipitation regimes, as well as in the density of residential housing. Livestock grazing, recreation, and hunting are generally consistent in all areas.

4. We also provide observations on the impact of the density of well development within the two mile radius of a lek.
5. In addition to evaluating individual leks, we examined impacted and non-impacted lek complexes to better understand the threshold at which development appears to negatively impact leks or lek complexes.

RESULTS AND DISCUSSION

POWDER RIVER BASIN (PRB)

Coal bed natural gas (CBNG) development in the PRB began in the early 1990's with significant development starting in 1997. Currently, CBNG is in the production stage in the eastern and central portions of the Basin with development occurring in the western portion. The CBNG activity occurs throughout a large geographic area; the largest coal producing basin in the United States. Early in the development of the PRB portions of the east side of the basin were drilled on 40-acre spacing (16 wells per square mile); subsequently, the majority of the basin has been drilled on 80-acre spacing, or 8 wells per square mile. By the end of 2006 there were approximately 25,000 wells drilled and producing gas. The size of the geologic structure and the intensity of activity make this a unique development area. Our analysis of the PRB included 195 impacted and 94 non-impacted leks; there are 493 leks in the northeast Wyoming management area. The study area is illustrated in Figure 2 .

The PRB, unlike most of the state of Wyoming and the other study areas included in this paper, is comprised primarily of private land (86%) underlain by federal minerals (63%). This land and mineral ownership pattern (commonly referred to as "split estate") leads to the inconsistent application of the standard BLM protective stipulations for greater sage-grouse. Early in the development of the PRB CBNG field, BLM underwent an extended period of field development planning, as required by NEPA. This long period of analysis prohibited development on federal minerals which resulted in the disproportional development of private and State of Wyoming owned minerals where wildlife protection stipulations are not applied. This early drilling activity was performed primarily on 40-acre spacing and occurred on the eastern edge of the Basin. Figure 2 also illustrates clearly that leks imbedded in CBNG development areas continue to be active even after upwards of ten years of gas development activity in the PRB.

As seen in Figure 3, declines in average male-lek attendance occurred in the PRB from 1989 to 1995 and from 2000 to 2002. These population declines are also observed range-wide (Figure 4; Connelly et al. 2004). It appears that the population in the PRB has not recovered fully from the population crash of 1989 to 1995 but that population growth, as indicated by male lek attendance, is occurring.

Figure 2: Powder River Basin study area

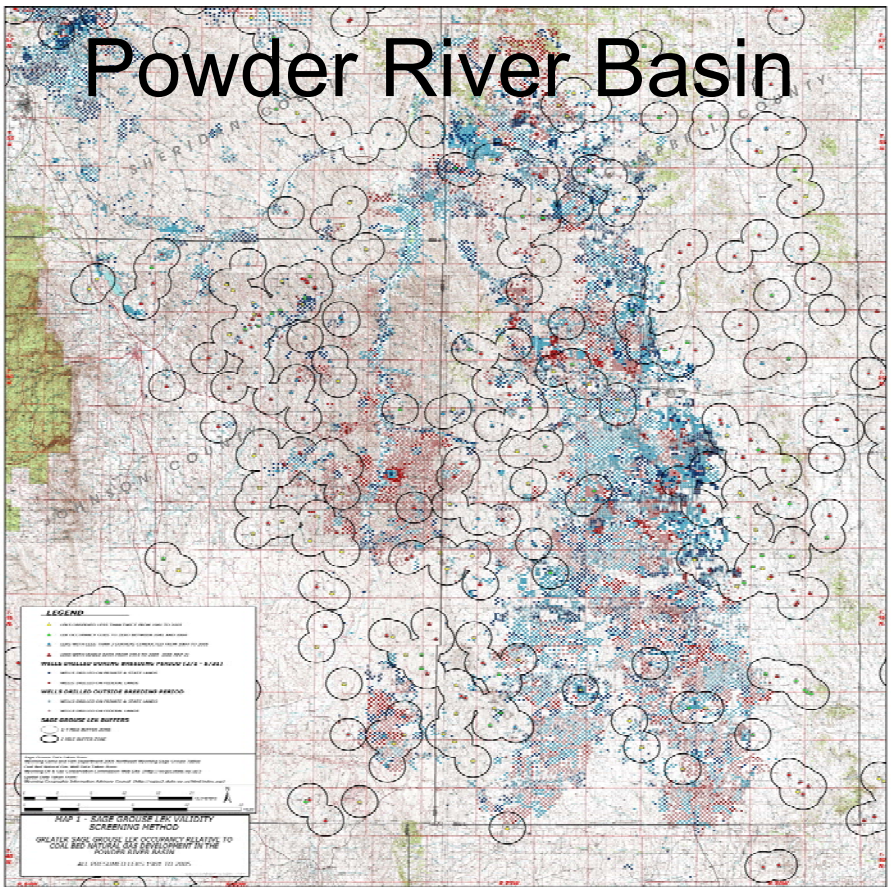


Figure 3: Average male-lek attendance in the PRB 1980 to 2006

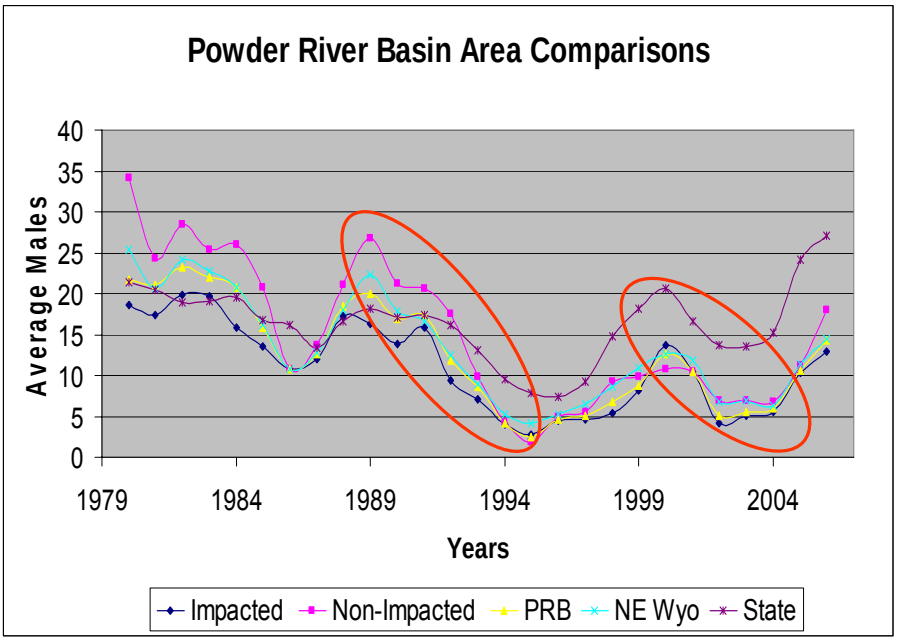


Figure 4: Connelly et al. 2004 Range-wide change in population index

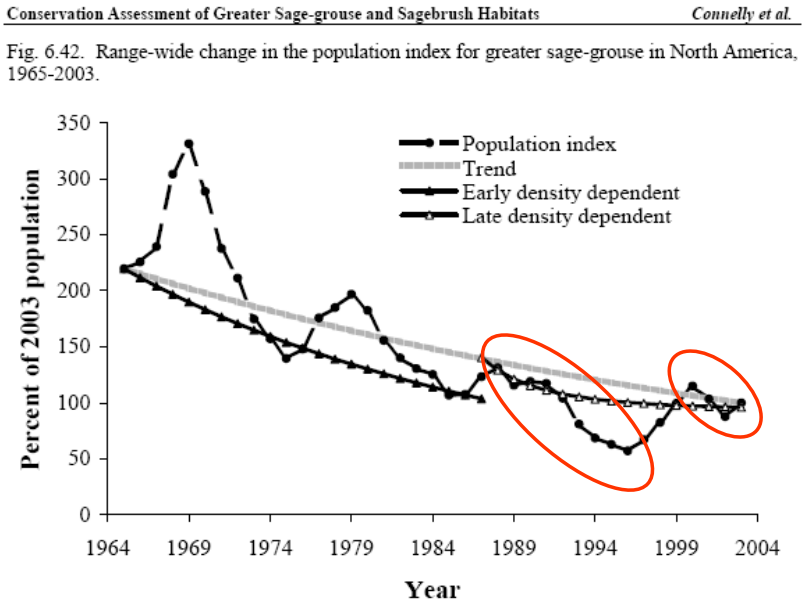


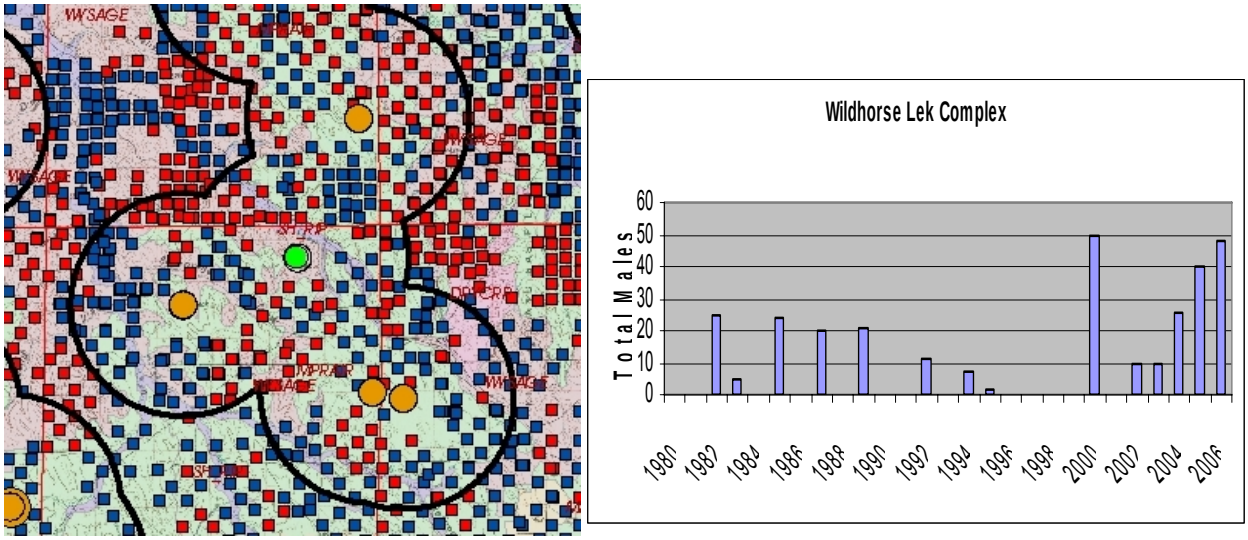
Figure 3 shows that impacted leks continue to be attended by male grouse in the PRB. The differential between impacted and non-impacted in male lek attendance is slightly larger in 2006 (1.9 males) than was evident before CBNG development began in 1997 (0.6 males), however both groups of leks continue to follow the same growth trends as seen for the state wide population.

For purposes of the analysis, determining the response of greater sage-grouse to energy development in the PRB, we investigated the status of the 89 leks in the WGFD data base currently identified as inactive. Sixty six of these leks became inactive during the 1989-1995 decline; that is, before significant CBNG development began in 1997. Twenty three of the 89 currently inactive leks in the PRB became inactive after the 1989-1995 decline; these leks might shed light on impacts of energy development. Of these 23 leks, 5 were eliminated by surface coal mining activity, 13 were impacted by CBNG development and 5 had no readily discernible impacting agent. Of the 13 leks impacted by CBNG, 9 were developed on 40-acre spacing, with as many as 200 wells drilled within the two mile standard stipulation radius, in addition to development activity within the BLM ¼ mile radius lek buffer. It is likely due to the private and state mineral ownership that the protective stipulations were not applied. It appears that this level of habitat modification from energy development exceeded the tolerance of sage-grouse and may have caused lek abandonment. In contrast, lek attendance in PRB was maintained, albeit at reduced numbers, under conditions in which wells were drilled on 80-acre spacing, 100 or fewer wells were drilled within the 2 mile radius, and development activity did not occur within ¼ mile of the lek.

We examined six lek complexes in a variety of development scenarios in the PRB CBNG field to better understand the impacts of 40- vs. 80-acre spacing; these complexes are discussed below.

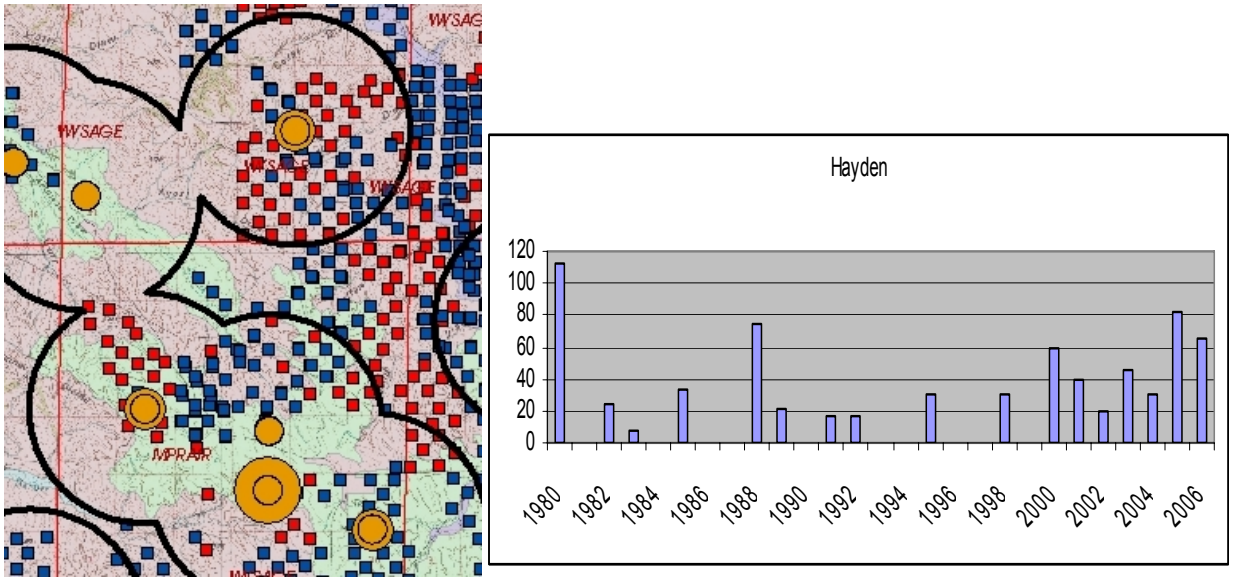
WILDHORSE COMPLEX - Since the year 2000, over 700 wells have been drilled on 40- and 80-acre spacing in the area surrounding the Wildhorse complex (Figure 5). As can be seen in the accompanying graph, the complex leks continue to be attended each spring, with the numbers of males observed increasing since 2002. Over 100 wells have been drilled within the two mile radius of each of the leks in the complex but the leks continue to be active.

Figure 5: Wildhorse complex



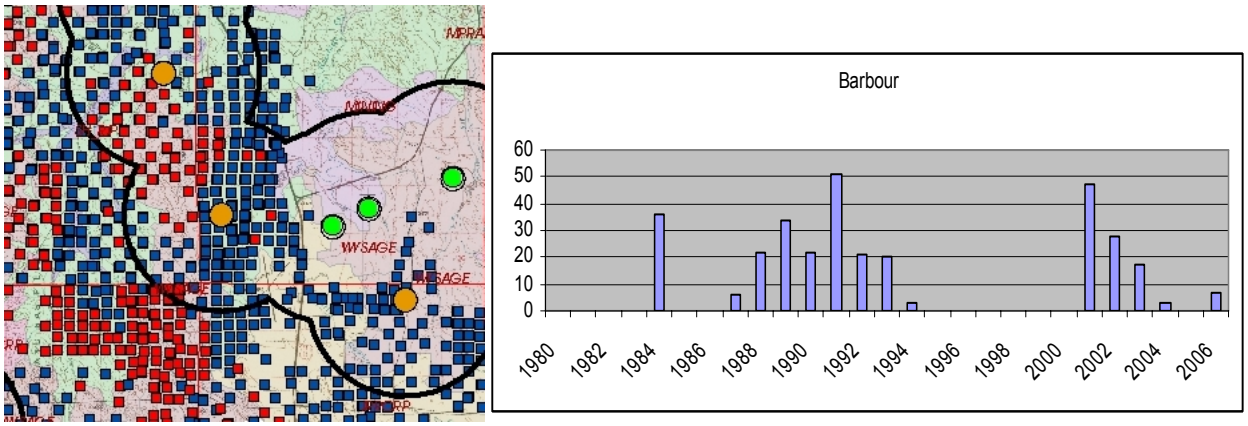
HAYDEN COMPLEX - The Hayden complex (Figure 6) lies west of the Wildhorse complex and is surrounded by CBNG development drilled primarily on 80-acre spacing. Development and production in this area has been ongoing since 1999 with over 200 wells drilled in the township. Again, the complex leks are active and male attendance has increased since 2002.

Figure 6: Hayden complex detail



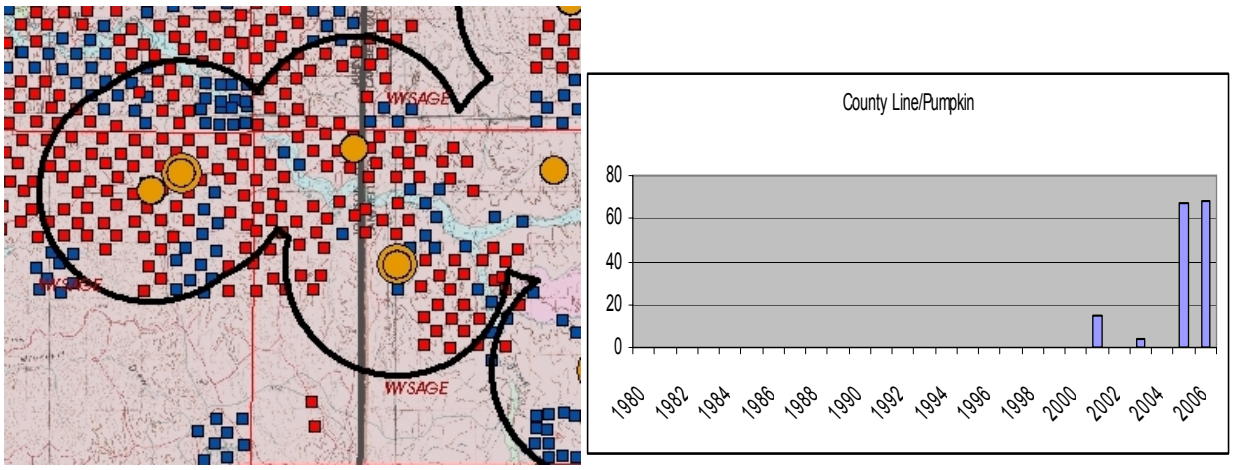
BARBOUR COMPLEX - The Barbour complex (Figure 7) is located on the eastern edge of the CBNG area of the PRB. This area was drilled primarily on 40-acre spacing beginning in 1999. Almost 600 wells have been drilled and are producing gas in the township surrounding this complex. The abandoned leks (green dots) to the east were destroyed by surface coal mining activity. The leks within the CBNG development areas continue to attract males but at very low numbers.

Figure 7: Barbour complex detail



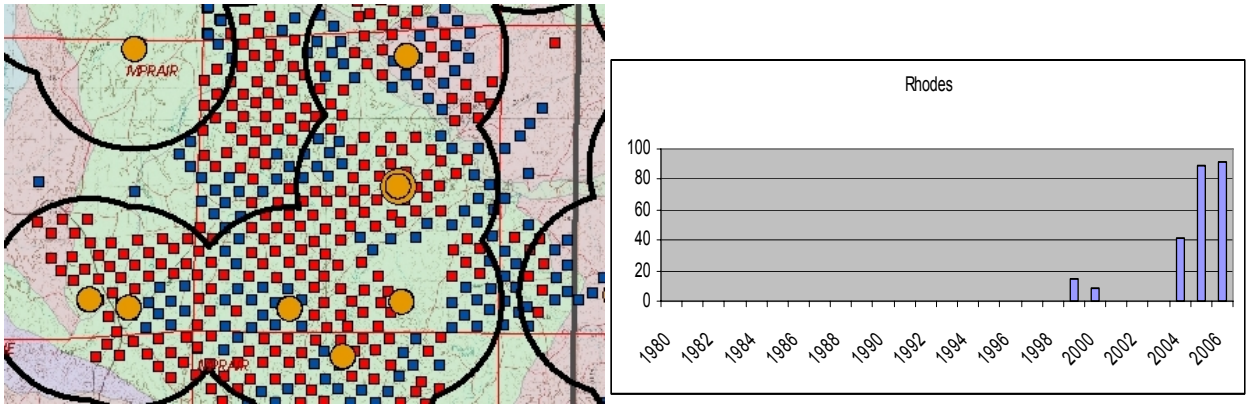
COUNTY LINE/PUMPKIN COMPLEX - The County Line/Pumpkin complex (Figure 8) is located in the south-central portion of the PRB. This area has been producing since 2004 although some initial exploratory work occurred as early as 2000. Approximately 240 wells have been drilled in the two townships surrounding this complex. Data are limited for this area because these leks were generally unknown before development began. Male attendance is currently robust.

Figure 8: County Line/Pumpkin complex detail



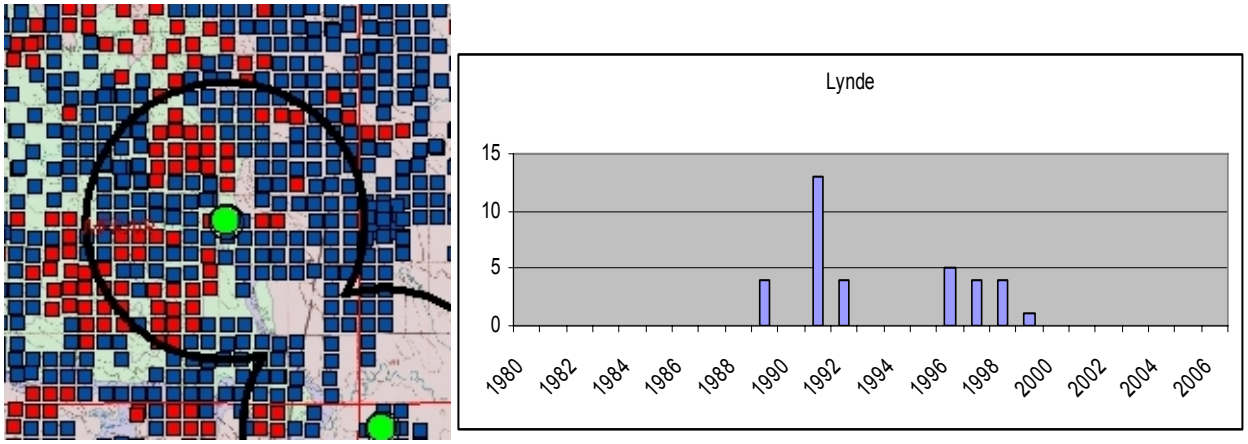
RHODES COMPLEX - The Rhodes complex (Figure 9) is located in what is currently the southwestern edge of CBNG development in the PRB. The complex is surrounded by approximately 300 CBNG wells drilled since 2004. In 1999 one lek in the area was surveyed; in 2006 seven leks were counted. In the three years since development began male attendance has increased. An important consideration is whether this increase simply reflects increased survey effort. Alternatively the increase could reflect improving habitat conditions from increased precipitation in the area over the same period of time.

Figure 9: Rhodes complex detail



LYNDE LEK - The Lynde lek (Figure10) is located on the eastern edge of the CBNG field in the PRB. CBNG development in the PRB began in this area in 1997 with approximately 480 wells drilled in the township surrounding the lek. This area was drilled on 40 acre spacing, averaging 13 wells per square mile. Wells in this portion of the field are now being plugged and abandoned with many more abandonments planned as the gas resource in this area is depleted. The Lynde lek became inactive in 2000; three years after intensive, high density development began.

Figure 10: Lynde lek detail



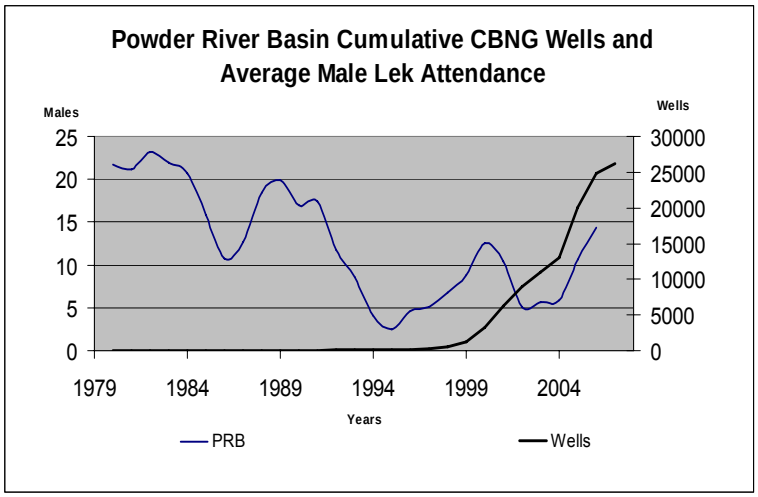
SUMMARY OF PRB FINDINGS - The Hayden and Wildhorse complexes demonstrate the continuation of male-lek attendance in areas of 80-acre spacing even after seven to eight years of development and gas production activity. The Lynde lek and Barbour complex analyses demonstrate that leks become inactive when surrounded by hundreds of wells drilled on 40-acre spacing. After three to four years of 80-acre development activity, the Rhodes and County Line/Pumpkin lek complexes show continuing growth of male attendance as opposed to the declines demonstrated by the leks impacted by 40-acre development. These findings suggest that lek abandonment is related to intensive development on 40-acre spacing whereas "buffered" leks surrounded by 80 acre development continue to be attended by males. Data from the Wildhorse and Hayden lek complexes show that 80-acre well spacing has not caused reduced male lek attendance over time and suggest that well spacing in an important component of development scenarios that could be managed to facilitate persistence of leks and local populations. Overall, trends in the PRB population call into question any assertion that lek abandonment and local extirpation are imminent consequences of energy development, and suggest that the relationship between development and population persistence is more complex than previous research has indicated.

Figures 3, 4 and 11 illustrate the following:

- The population decline of 1989 to 1995 occurred before the onset of CBNG development rendering any conclusion that this decline was a direct consequence of CBNG unsupported.
- Population declines from 2000 to 2002 are consistent with those seen state and range wide.
- The sage-grouse population in the PRB exhibits an increasing trend that is consistent with trends statewide

The PRB represents an important population in terms of sage-grouse conservation range-wide. However, this population accounts for less than 10% of sage-grouse in the state of Wyoming. Given differences in habitat and development conditions throughout the state, any contention that a single population such as PRB has a disproportionate influence on population trends state- or range-wide would be unsupported. Recent data (Thiele 2007) show that average male lek attendance in Northeast Wyoming was 18.8 males or 0.5 males per lek lower than the 2006 average. Of 517 leks surveyed, 38 or 7% were found to be inactive. Twenty newly identified leks were documented in the spring of 2007.

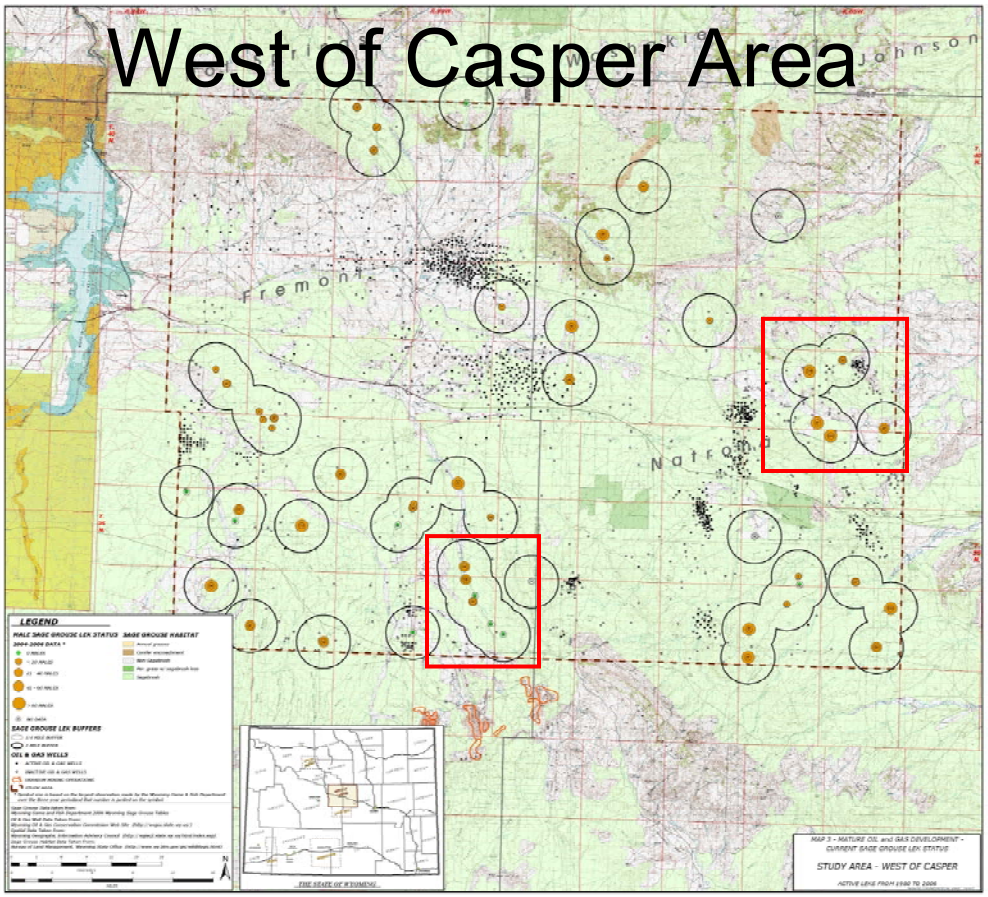
Figure 11: Average male-lek attendance contrasted with the cumulative number of CBNG wells drilled in the PRB



WEST OF CASPER

As illustrated in Figure 12, the area west of the City of Casper includes a number of field development areas, all relatively small in size, the largest encompassing a few townships. There is some gas, some oil, and fields range from almost 100 years of age to currently in development. Spacing is highly variable. The lek complexes in this analysis are indicated on the map by the red boxes. Our analysis of this area included 6 impacted and 48 non-impacted leks out of the 224 leks identified in the WGFD management area.

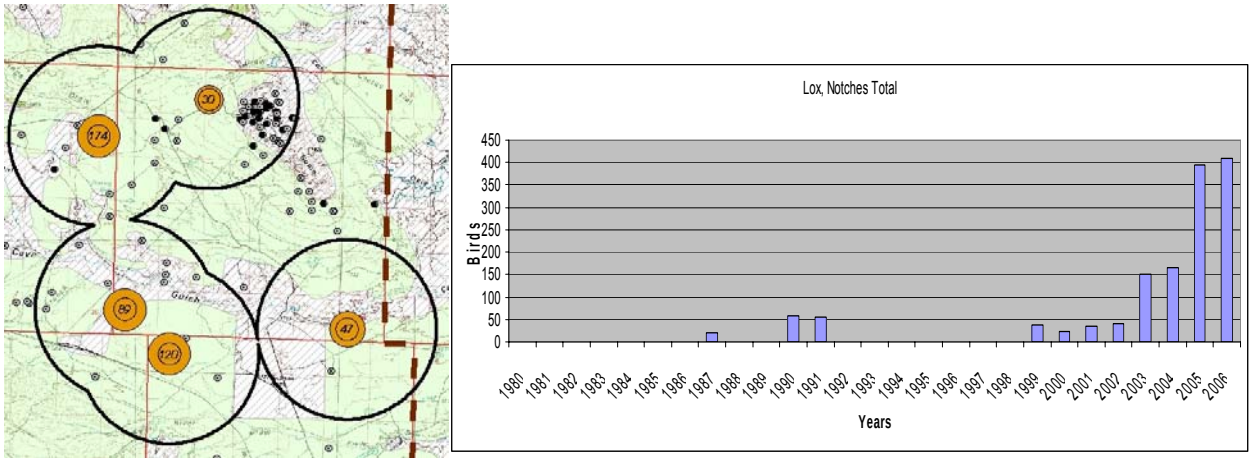
Figure 12: Leks locations and oil and gas development west of Casper



The area west of Casper is popular with sage-grouse hunters because there are many large leks (<75 males in attendance) which translates into excellent hunter success. A close evaluation of the two indicated lek complexes offers an appreciation for the population of grouse in the area.

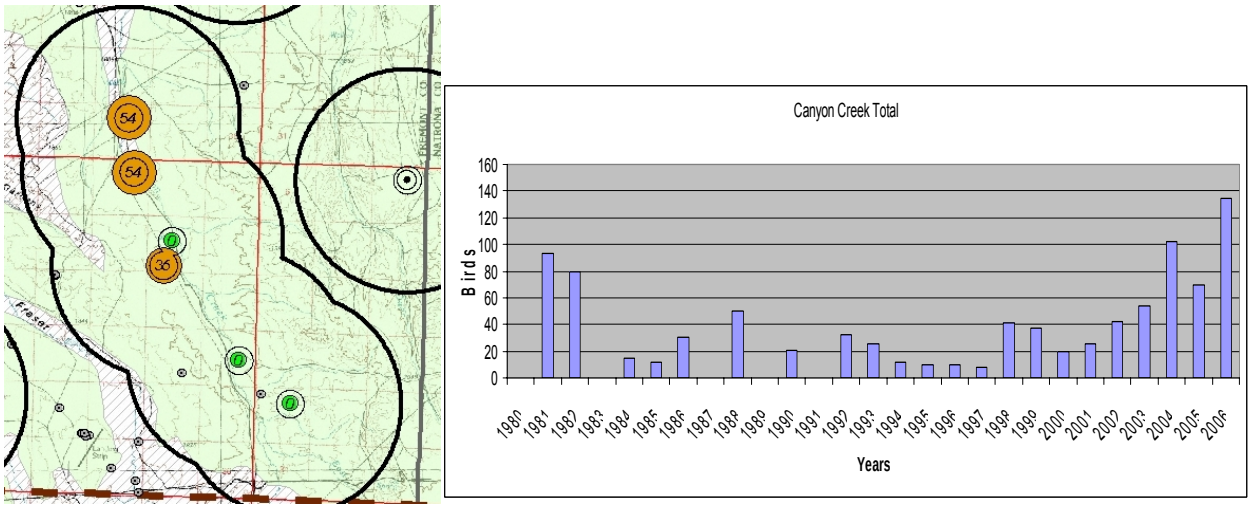
LOX NOTCHES COMPLEX - The Lox Notches complex (Figure 13) is located in the north eastern portion of the study area and is the location of the Notches oil field which has been producing oil since 1917 and pre-dates WOGCC spacing regulations. Steady growth in male-lek attendance from 1999 to current is seen.

Figure 13: Lox Notches lek complex



CANYON CREEK COMPLEX - The Canyon Creek complex (Figure 14) is located in the south central portion of the study area, the leks are scattered along a county road in eastern Fremont County and are just north of the Gas Hills uranium district. Three wells have been drilled and plugged in the area surrounded by the two-mile lek buffer of this complex. This non-impacted complex has seen a pattern of growth similar to the impacted Lox Notches complex.

Figure 14: Canyon Creek lek complex



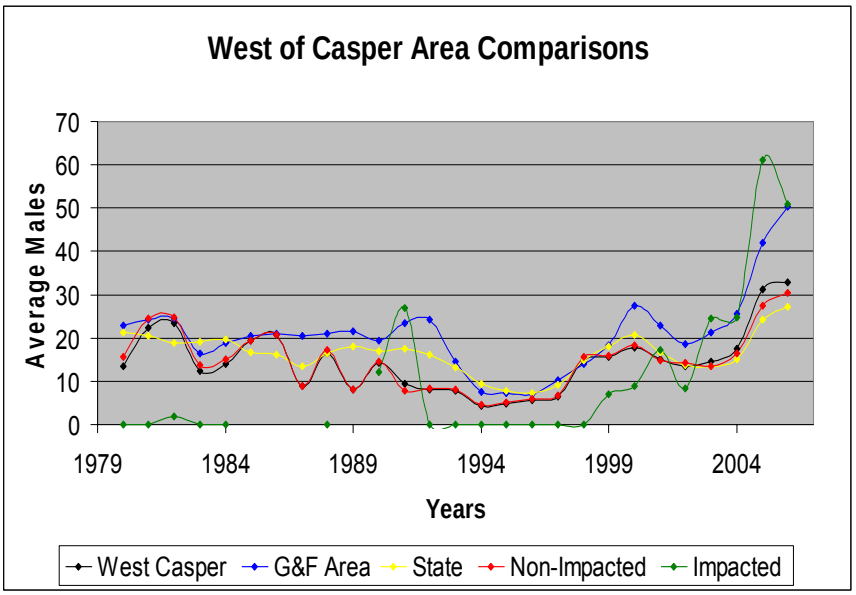
SUMMARY OF WEST OF CASPER FINDINGS - Analysis of the eight currently inactive leks in the West of Casper study area show the following:

- Seven have little or no energy development activity within the 2 mile radius,
- Seven are located immediately adjacent to county roads,
- One appears to have been drilled on or is located on a well site.
- Only one of the eight inactive leks has producing and plugged wells within the two mile radius.

The 2 leks in the study area with more than 10 wells drilled within the 2 mile radius continue to be active and show stable and increasing male-lek attendance.

Figure 15 supports these observations and illustrates that despite almost 1400 wells being drilled in the study area, male-lek attendance is increasing and impacted leks have increased the most in recent years.

Figure 15: West of Casper lek comparisons

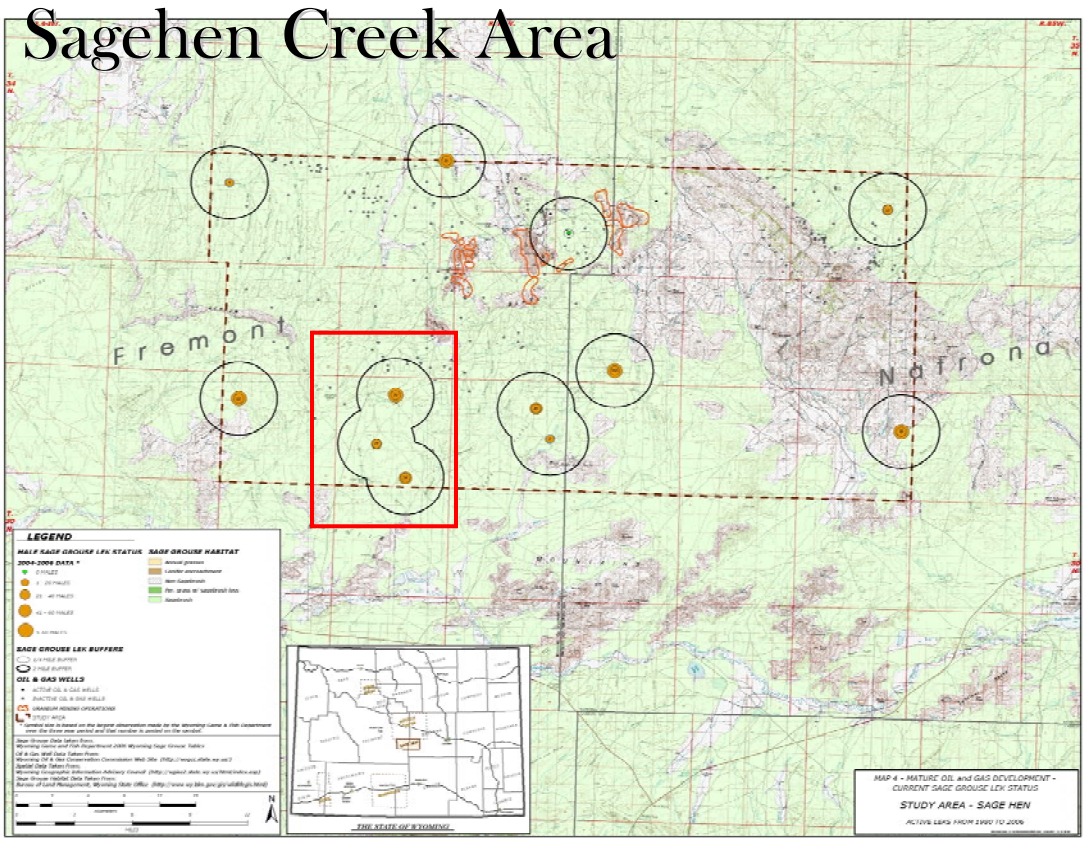


SAGEHEN CREEK

For purposes of this study Sagehen Creek represents the “control” area; few oil wells (~60) have been drilled in the area, most of which have been plugged and abandoned. As seen on Figure 16, the area has been impacted by the development of three major uranium mines (red polygons) all of which have been abandoned and reclaimed. Otherwise the area contains no towns and has extremely limited human habitation. Sagehen Creek is historically popular with sage-grouse hunters as it is known for excellent grouse productivity. Our analysis of this area included 12 leks, one of which was impacted by energy development; the WGFD management area includes 191 leks.

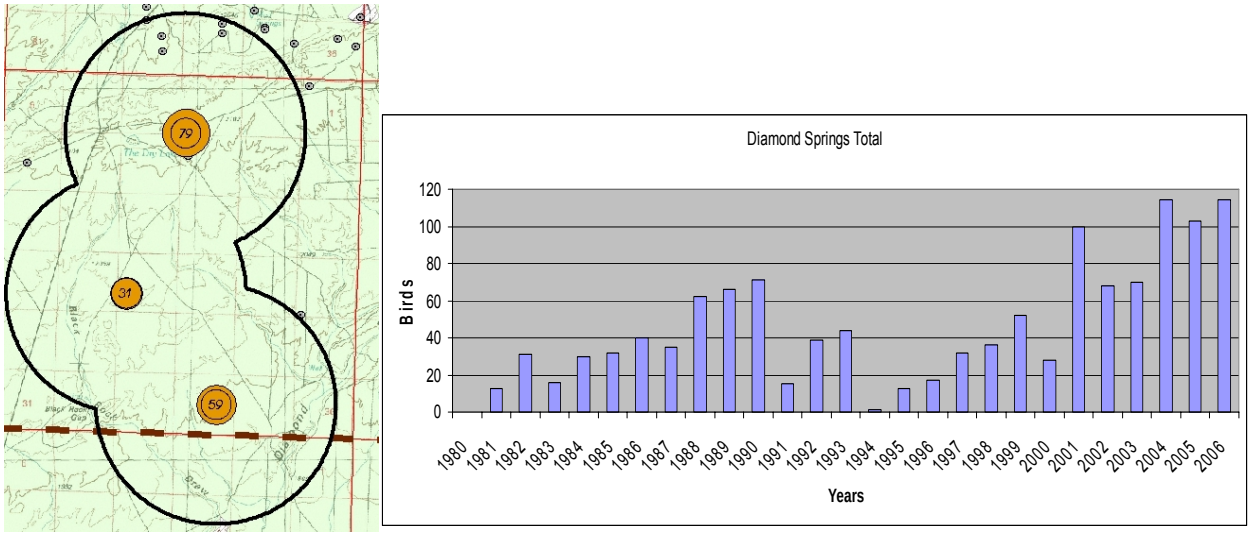
One lek in the area is currently inactive and is located between two reclaimed uranium mines. Reclamation activity in the area has been ongoing for many years and is now complete.

Figure 16: Sagehen Creek study area



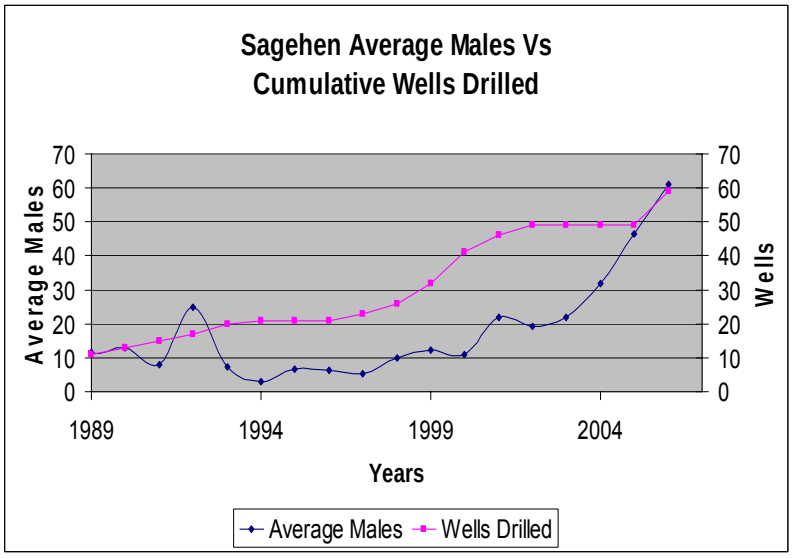
DIAMOND SPRINGS COMPLEX - The Diamond Springs lek complex (Figure 17) graph clearly illustrates the population decline of 1990 to 1994 and the growth of the population subsequent to that event, as does Figure 18 (average male-lek attendance for the entire area).

Figure 17: Diamond Springs Lek Complex



SUMMARY OF SAGEHEN CREEK FINDINGS - Figure 18 demonstrates the population of Sagehen Creek, using average male-lek attendance as a surrogate, has increased steadily since 1995. Sagehen Creek represents not only the "control" for this study but also an area perceived to represent extremely high quality sage-grouse habitat. No other area or sub-population analyzed shows such strong population growth.

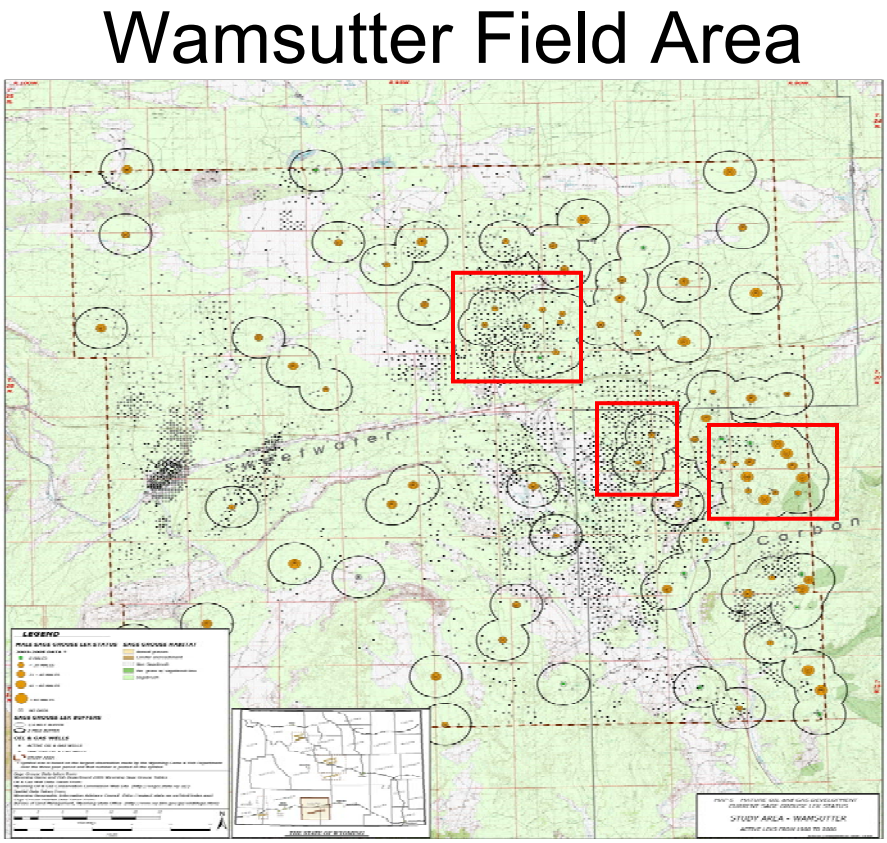
Figure 18: Sagehen Creek male-lek attendance and cumulative wells drilled



WAMSUTTER

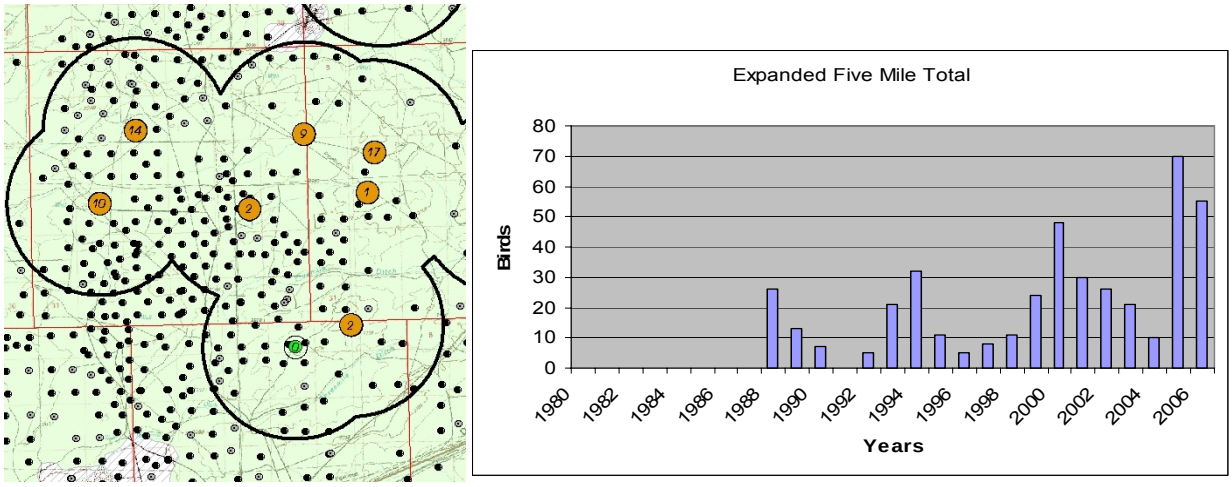
Limited development in the Wamsutter area of south-central Wyoming began in the 1940's. In the late 1970's development was re-initiated at a higher intensity. Development, gas production, and infill drilling have taken place in the area for the last thirty years. NEPA documents for the project (BLM 2000) indicate approved well spacing between 1 and 8 wells per section depending on the character of the gas reservoir being developed. The May 2000 NEPA analysis and Record of Decision completed for the Wamsutter field required the development and implementation of a sage-grouse impact mitigation plan. Additional NEPA environmental impact analysis is currently in progress, the proponent-suggested alternative proposes additional infill drilling to occur primarily from existing well pads. Figure 19 illustrates the location of the existing wells and sage-grouse leks within the study area as well as three lek complexes that are discussed in greater detail. Our analysis of the Wamsutter area included 47 impacted and 38 non-impacted leks; the WDGF management area includes 503 leks.

Figure 19: Wamsutter study area



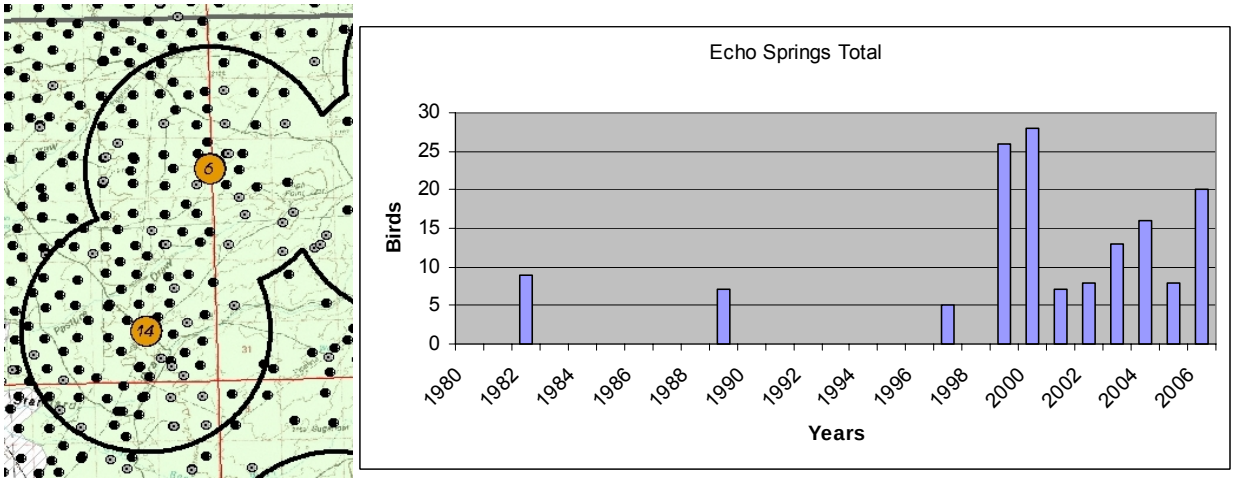
EXPANDED FIVE MILE COMPLEX - The Expanded Five Mile complex (Figure 20) represents an area of continued development and production from 1978 to 2006. Two hundred thirty one wells have been drilled in the townships surrounding the leks in the Expanded Five Mile complex. These wells were drilled on 80 acre spacing which represents 8 wells per square mile. While data on these leks are limited before 1989, they show a steady increase over time interspersed with moderate declines.

Figure 20: Expanded Five Mile complex detail



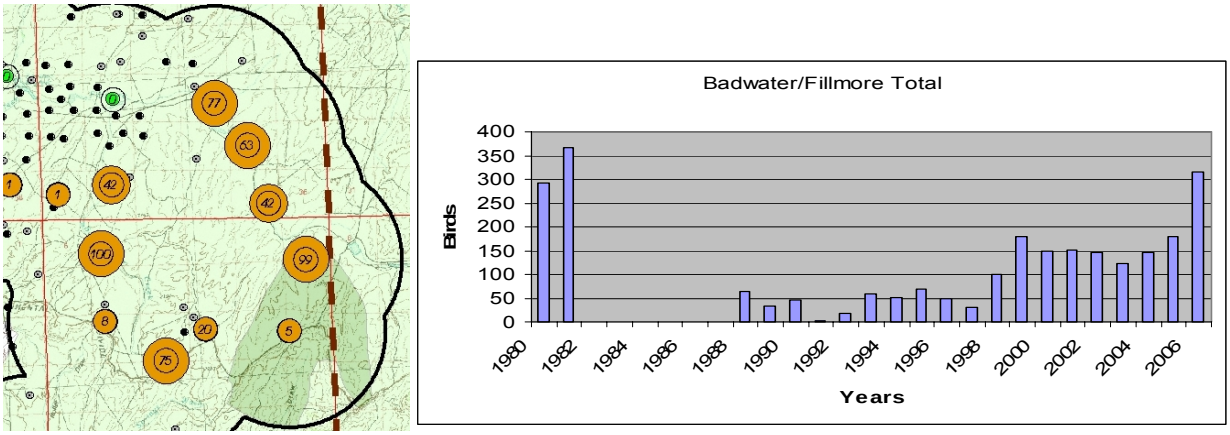
ECHO SPRINGS COMPLEX - The Echo Springs complex (Figure 21) also represents an area of continued development and production from 1978 to 2006 with 8 wells drilled per section. Approximately 250 wells have been drilled in this township since 1979 with activity continuing into 2006, some of the wells have been plugged but most are still producing gas. The graph indicates that even with the large number of wells drilled within the two mile radius of the leks within the complex the number of males in attendance shows a pattern of recent increase and long term stability.

Figure 21: Echo Springs complex detail



BADWATER/FILLMORE COMPLEX - We combined the Badwater/Fillmore complexes (Figure 22) due to the amount of overlap between the 2 mile lek radii. There are eleven leks within the two townships that encompass the complex; approximately 40 wells have been drilled within the area since late 1960's. In 1981 367 males were counted in this non-impacted lek complex while 316 were counted in 2006.

Figure 22: Badwater/Fillmore complex detail

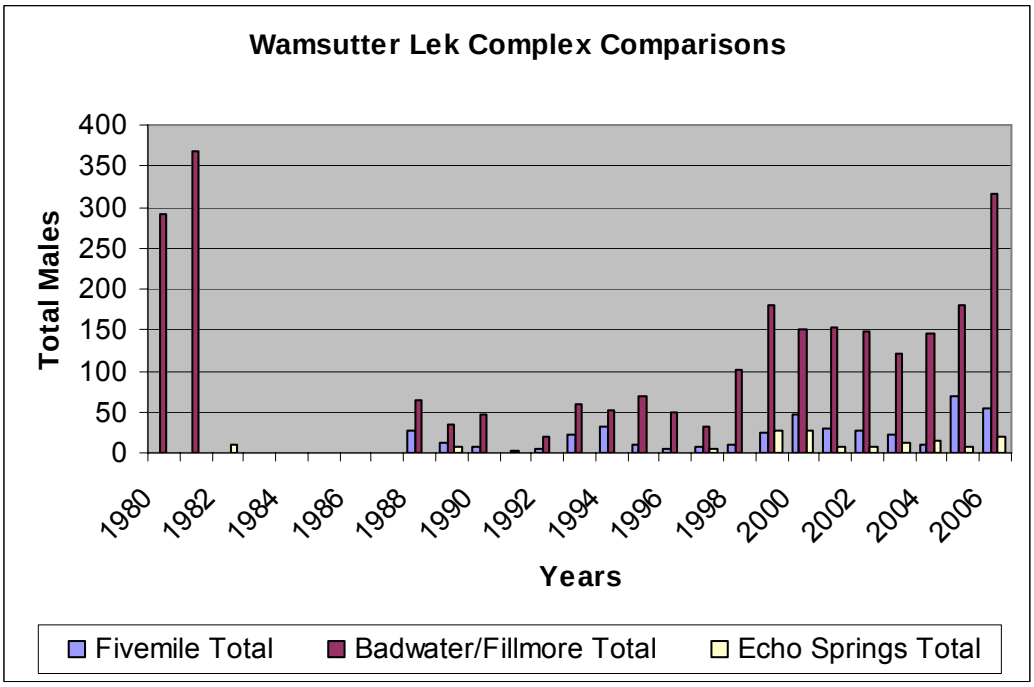


SUMMARY OF WAMSUTTER FINDINGS - Among these complexes we see similar trends of higher numbers of males in attendance in the 1980s than seen in the 1990s with an increase in males occurring again in the 2000s. The periods of decline seen in 1990, 1996 and 2002 at the Badwater/Fillmore complex are similar to those seen for the Expanded Five Mile complex. These are the same trends that are seen state-wide and may be more closely aligned with climatic influences such as precipitation than with energy development activity.

Does the Wamsutter study area map (Figure 19) suggest displacement of sage-grouse from impacted to non-impacted leks as illustrated by the size of the lek dot? Large lek indicators are generally located on the periphery of the field while smaller lek indicators are found within the field. An observation of displacement would be consistent with the findings of Kaiser (2006). In the Pinedale Anticline field Kaiser (2006) found displacement of young males from the development areas and overall low rates of mortality. While the displacement hypothesis would require research, the observable trends show long term stability with cyclical variation over time. It is not unreasonable to hypothesize that these fluctuations reflect the combined influences of several factors including development and precipitation. It is clear that after 30 years of development and production activity (10 generations of grouse), male sage-grouse continue to attend leks imbedded in the Wamsutter natural gas field. It can be assumed that males would not continue this activity if females were absent, or if suitable nesting and early brood rearing habitats were not available.

When we compare the lek complexes on the same graph (Figure 23) we see, as we do in Figure 24, the differential between impacted and non-impacted lek attendance was in place before development at Wamsutter began. The Badwater/Fillmore lek complex has traditionally had greater male attendance than either the Echo Springs or Five Mile complexes. This differential is also illustrated in Figure 25.

Figure 23: Wamsutter lek complex comparisons



In Figure 24, we included data starting in 1980 in an effort to view grouse response to activity in the early days of field development. This effort, though highly erratic before 1985, illustrates consistent trends in sage-grouse populations regardless of the influence of energy development activity. The field wide population (black line), based on average male-lek attendance, in 2006 is comparable to that seen in 1985.

Figure 24: Wamsutter area male-lek attendance comparisons

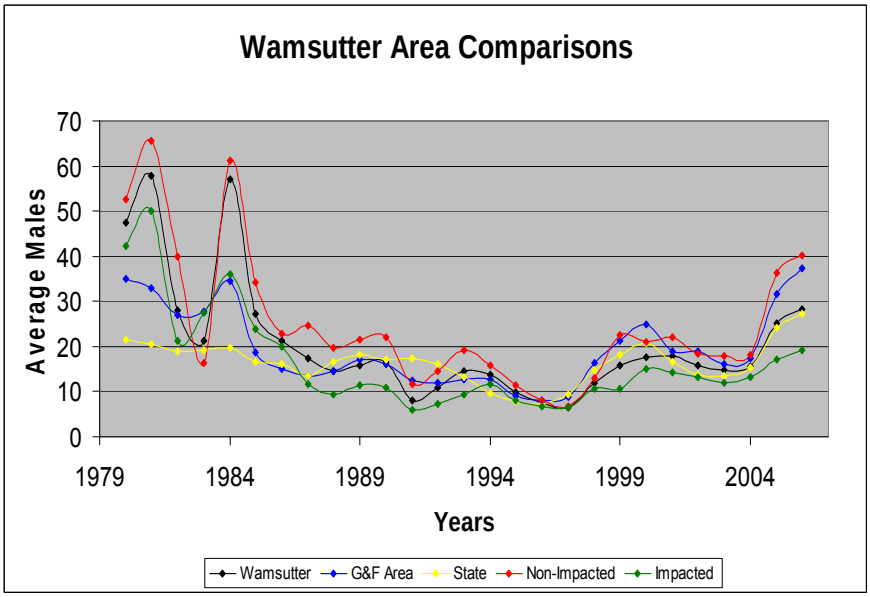
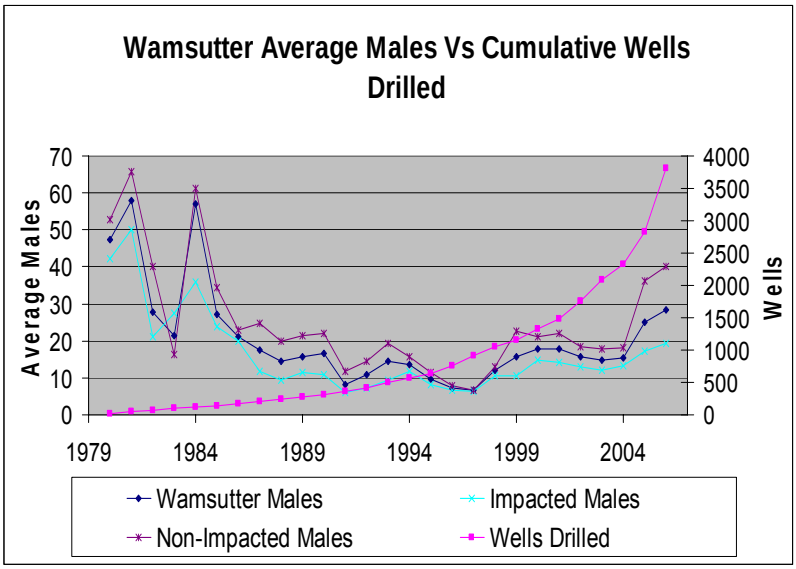


Figure 25 also shows that the suite of leks identified as impacted and non-impacted, based on 2006 well data, have had differential male-lek attendance dating back to the beginning of field development. The differential stays consistent with impacted leks having approximately 50% of the average male-lek attendance of non-impacted leks. It is this differential that raises questions about displacement and about the influences of habitat quality and lek survey protocols. Since 1980, approximately 3800 wells have been drilled in the Wamsutter natural gas field.

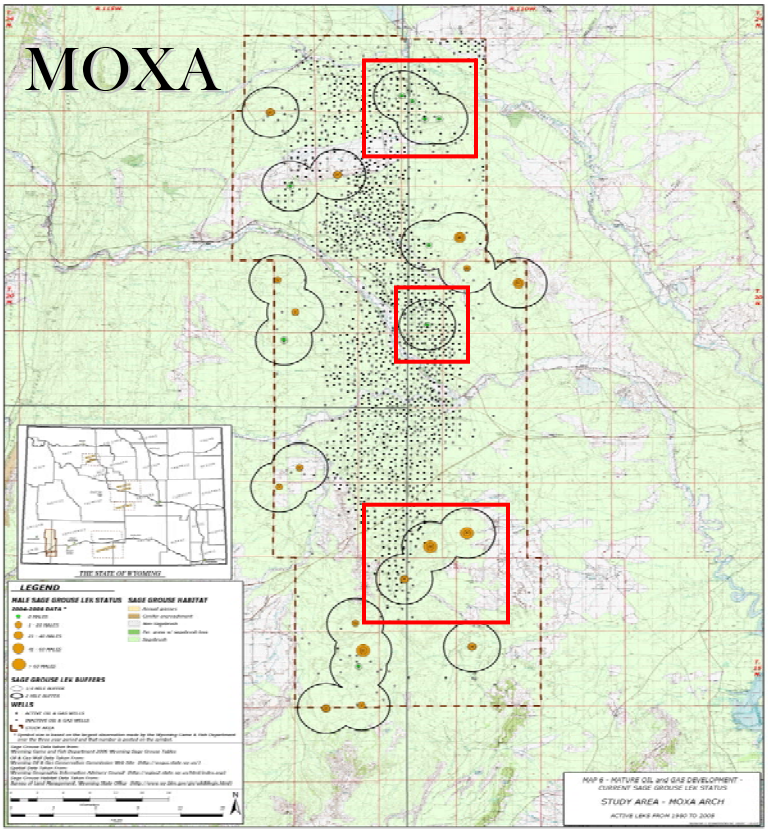
Figure 25: Wamsutter lek comparisons and wells drilled



MOXA ARCH (MOXA)

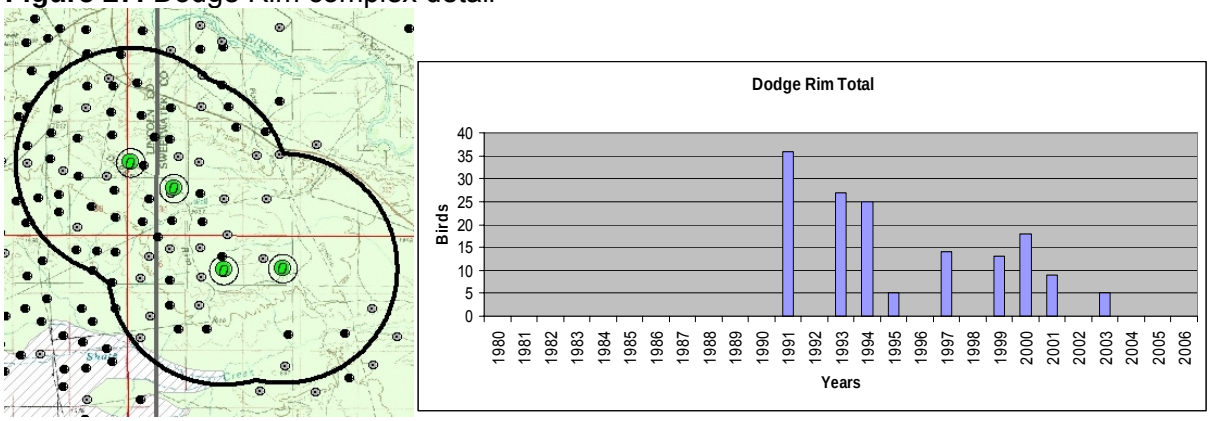
As with Wamsutter, development of the Moxa Arch natural gas field began circa 1980, Figure 26. This field was permitted at 80-acre spacing with some areas being drilled on 160's (4 wells per square mile). Development in Moxa is concentrated on a very well defined geologic structure. Infill development continues today with additional NEPA analysis currently underway. Unlike Wamsutter, Moxa did not have a large number of leks within the field development area before development. We see from Figure 26 that leks imbedded within the development area have significantly lower male-lek attendance when compared to non-impacted leks; in some cases lek abandonment has occurred. The WGFD management areas surrounding Moxa contain 241 leks; our analysis of the study area included 11 impacted and 15 non-impacted leks.

Figure 26: Moxa Arch natural gas field



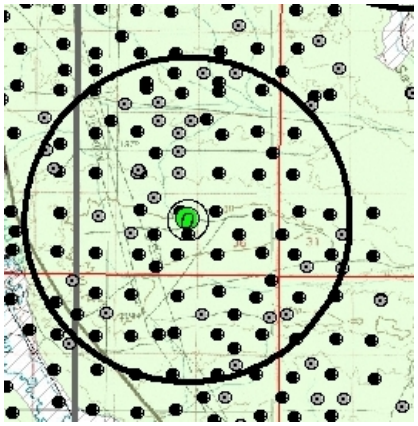
DODGE RIM COMPLEX - The Dodge Rim lek complex (Figure 27) is the northern most lek complex in the Moxa field. Approximately 250 wells have been drilled in the area surrounding this complex. Consistent lek surveys indicate the leks have become inactive since 2003. Three of the four inactive leks in the complex have wells drilled on or immediately adjacent to them. The fourth lek has a well drilled immediately outside the ¼ mile lek buffer. Information found in Holloran (2005) indicates noise and direction of the prevailing wind, in addition to road traffic are factors impacting sage-grouse lek attendance. Moreover, these findings have implications for the importance of stringent application of the BLM sage-grouse stipulations, specifically the ¼ mile lek buffer. The Dodge Rim complex might represent a good example of the conservation benefit of the BLM stipulations.

Figure 27: Dodge Rim complex detail



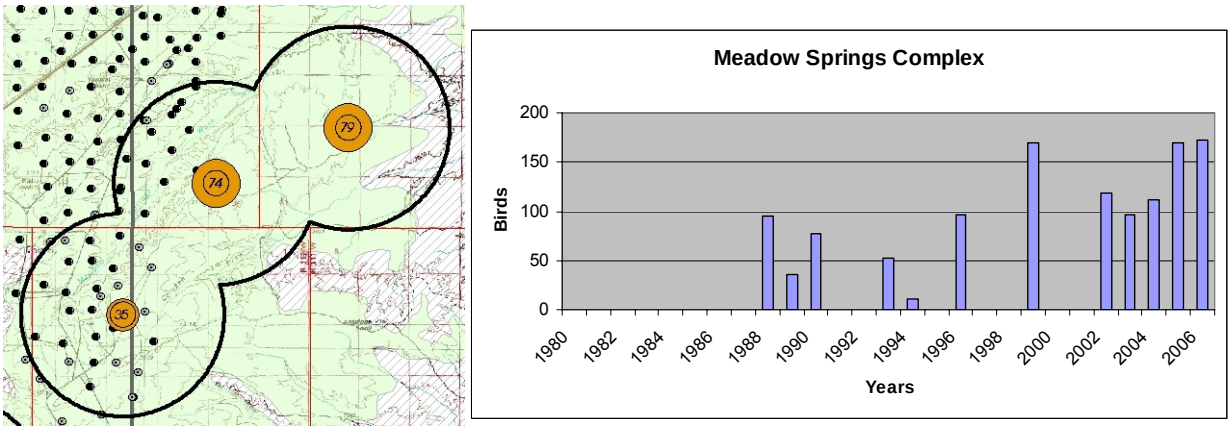
SEVEN MILE GULCH LEK - Seven Mile Gulch lek (Figure 28), located in the middle of the analysis area, appears to have been abandoned. Data are poor for this lek with only two surveys having been conducted, but this lek is heavily impacted by 80-acre spacing and the ¼ mile lek buffer has been directly impacted by two wells.

Figure 28: Seven Mile Gulch lek detail



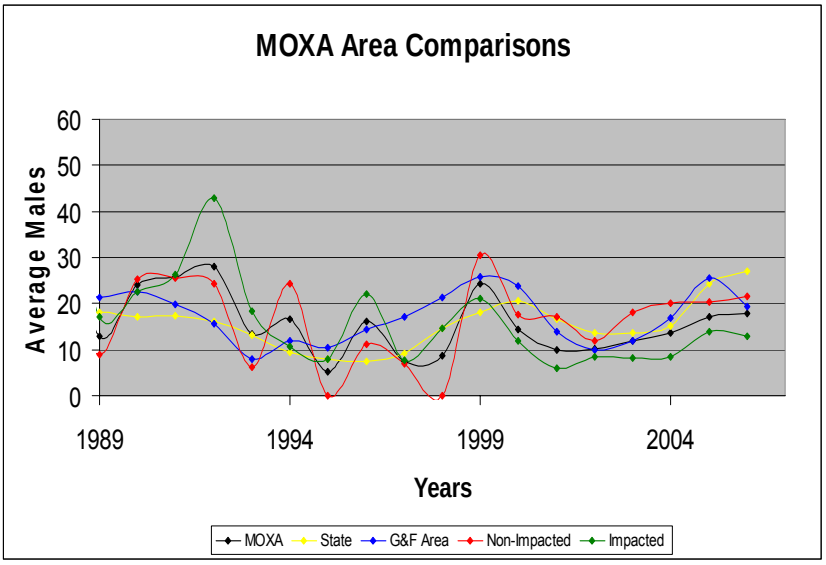
MEADOW SPRINGS COMPLEX - Only 43 wells have been drilled in the area west of the Meadow Springs complex (Figure 29), these wells are generally drilled on 160 acre spacing and none of the lek buffers are impacted by development. The leks continue to be active with attendance increasing over time.

Figure 29: Meadow Springs complex detail



SUMMARY OF MOXA ARCH FINDINGS - As seen in Figure 30**,** Moxa lek counts and surveys were erratic before 1999. While development appears to have significantly impacted individual leks within heavily developed areas of the field, the Moxa Arch sage-grouse population remains steady after more than 30 years of development and 1700 producing wells.

Figure 30: Moxa area lek comparisons



PINEDALE (PAPA)

The Pinedale Anticline natural gas field (Pinedale Anticline Project Area or PAPA) is currently in an intense drilling phase. Gas was initially discovered in this area in 1939 but not in quantities that justified additional development. Renewed interest in the area in 1997 was spurred by the prolific Jonah Gas Field, immediately to the south. The PAPA is a unique geologic feature that contains a number of tight natural gas formations. Development of this area must take place on close spacing to accomplish efficient recovery of the gas resource. A desire to minimize environmental impacts has spurred the development of new drilling and reservoir stimulation techniques. The successful use of directional drilling has made multiple well-pad drilling in the area possible with upwards of 30 wells per pad being proposed.

Concern about the impacts of high-density, high-intensity development on wildlife has prompted the initiation of ongoing research in the area (Lyon 2000, Holloran 2005, Kaiser 2006). Because nearly the entire PAPA overlies federal minerals, the opportunity to study sage-grouse under strict BLM control was afforded.

As a result of issues identified in Lyon (2000), the BLM Pinedale Field Office, industry partners, and the University of Wyoming initiated cooperative research on the effectiveness of the BLM standard sage-grouse stipulations. To test the effectiveness of the stipulations, BLM manipulated the impacts of gas development as follows:

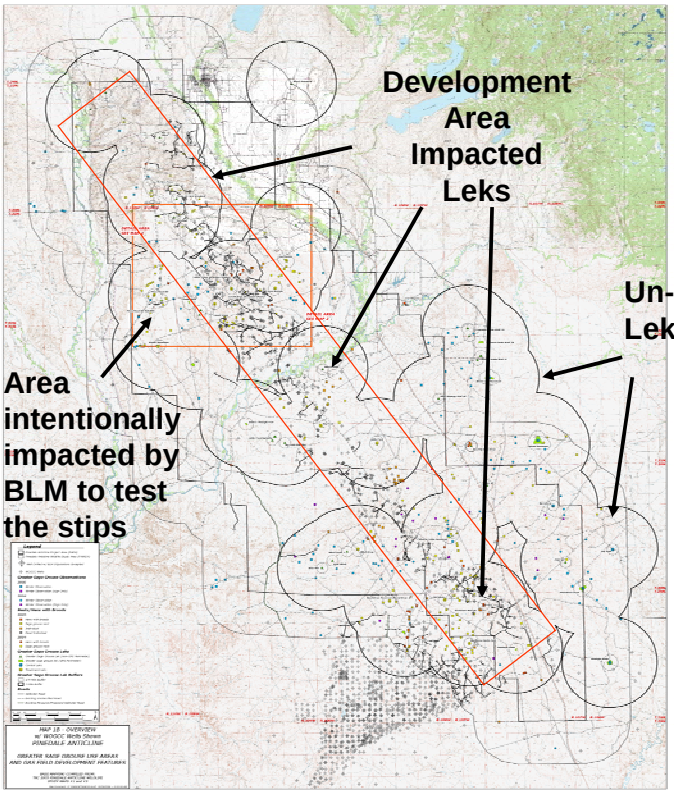
- Two leks (Lovatt Draw Reservoir and Mesa Springs in the Mesa complex) were provided no protection from year round development activity,
- Leks in the remainder of the field were protected through the stringent application of the standard protective stipulations, and
- Leks located outside the study area were not impacted by gas development activity and served as the control.

The intent of the study was to determine the effectiveness of the stipulations in an applied setting.

The base map used in Figure 31 is taken directly from the TRC Mariah (2006) wildlife report which is provided annually to the BLM by the PAPA operators. The red rectangle represents the 4 mile wide swath along crest of the Pinedale Mesa that we analyzed as the impacted development area. The leks intentionally impacted by BLM are located within the smaller red rectangle indicated on the map. In this smaller area the standard sage-grouse stipulations were waived, providing no spatial or temporal protection to these leks for a period of two years. Other leks within the developed area were protected by the stringent application of the stipulations. The leks impacted by vacating the stipulations were abandoned in a few years (Holloran 2005); the other leks, those protected by the application of the stipulations, continue to have males in attendance. This experiment provided evidence that the stipulations appear to be effective in reducing the impact of development on sage-grouse. On the PAPA maps well locations are identified by circles with crosses through them (A). The Upper Green management area contains 124 leks; 21 were included in our analysis as impacted and 32 as non-impacted leks.

Figure 31: Pinedale Anticline field development area

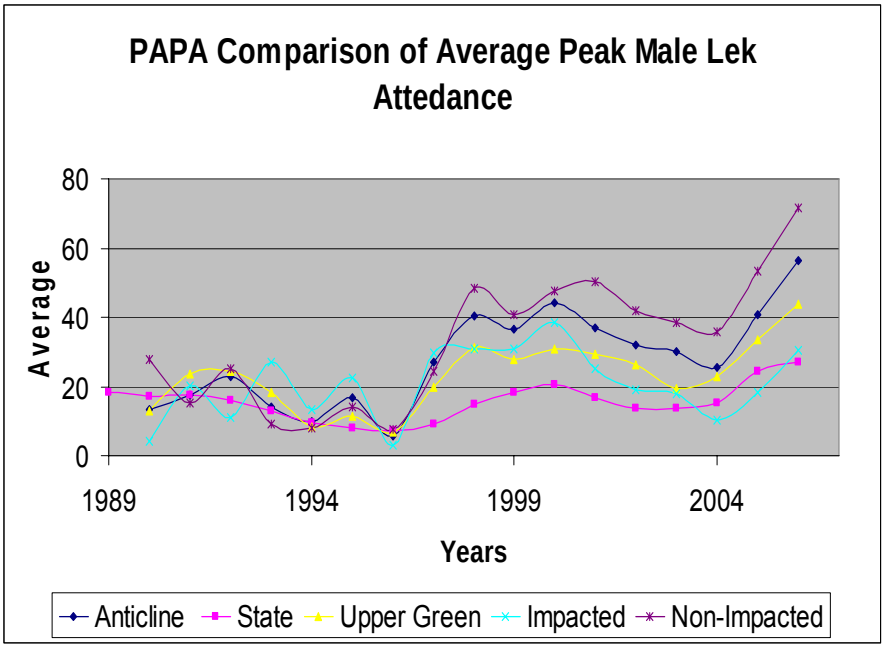
PAPA Field Development Area



The "impacted" leks in this analysis include those leks intentionally impacted by BLM. Holloran (2005) used these BLM-impacted leks, which ultimately became inactive during the course of his study, in deriving model-based estimates of population persistence. The exercise predicted localized extirpation of leks impacted by gas development at densities greater than 1 well per square mile. This work was completed in 2004 in the wake of a general state-wide decline. As

illustrated in Figure 32, predictions made at that time indicated extirpation of grouse was inevitable, not only for the development area but throughout the Upper Green. Since 2004 populations have increased. Given the long-term population fluctuations that sage-grouse exhibit range-wide, the results of any short-term modeling exercise must be interpreted with due circumspection.

Figure 32: Pinedale Anticline average male-lek attendance comparisons

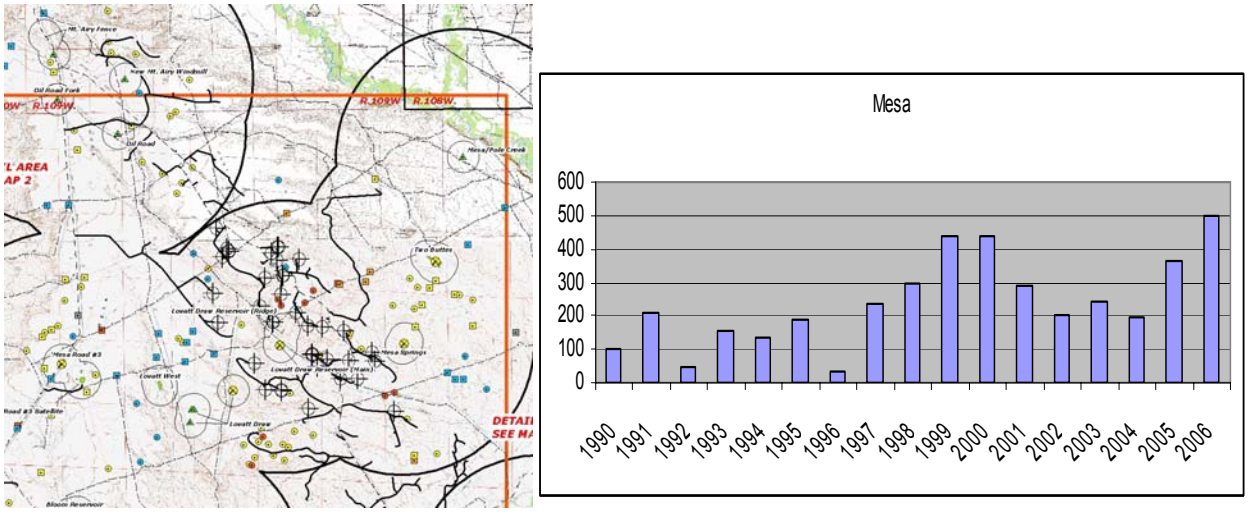


The WGFD data base contains limited data for the area before 1998, since that time lek counts have been consistently conducted with additional leks being identified annually.

The analysis of lek complexes in the area demonstrates that leks continue to be occupied even when impacted by the intensive natural gas development. The following analysis looks closely at three impacted and two non-impacted complexes.

MESA COMPLEX - The Mesa complex (Figure 33) includes the leks purposely impacted by the BLM to benefit the Holloran (2005) study of the effectiveness of the BLM standard sage-grouse stipulations. The BLM impacted leks (Lovatt Draw Reservoir and Mesa Spring) were further impacted by the activity taking place in Section 16, located immediately to the north. No stipulations or conditions of approval are placed on state mineral leases resulting in continued year round development activity. The Cat, Cora and Mesa/Pole Cat leks were removed from the analysis of this complex because they are un-impacted by gas development activity. This complex has been impacted by intensive year-round gas development operations since 1998 and remains active.

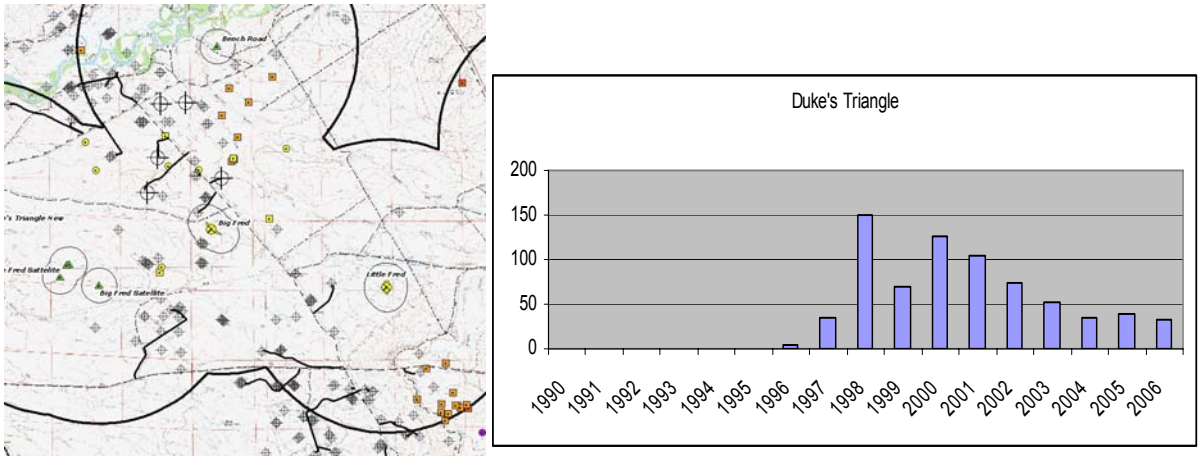
Figure 33: Mesa complex detail



DUKE'S TRIANGLE COMPLEX - The Duke's Triangle complex (Figure 34) consists of six leks, of which only two are regularly attended. Of the two significant leks in the complex, one (Big Fred) has declined steadily over the last five years. Development activity has occurred around these leks since 1998.

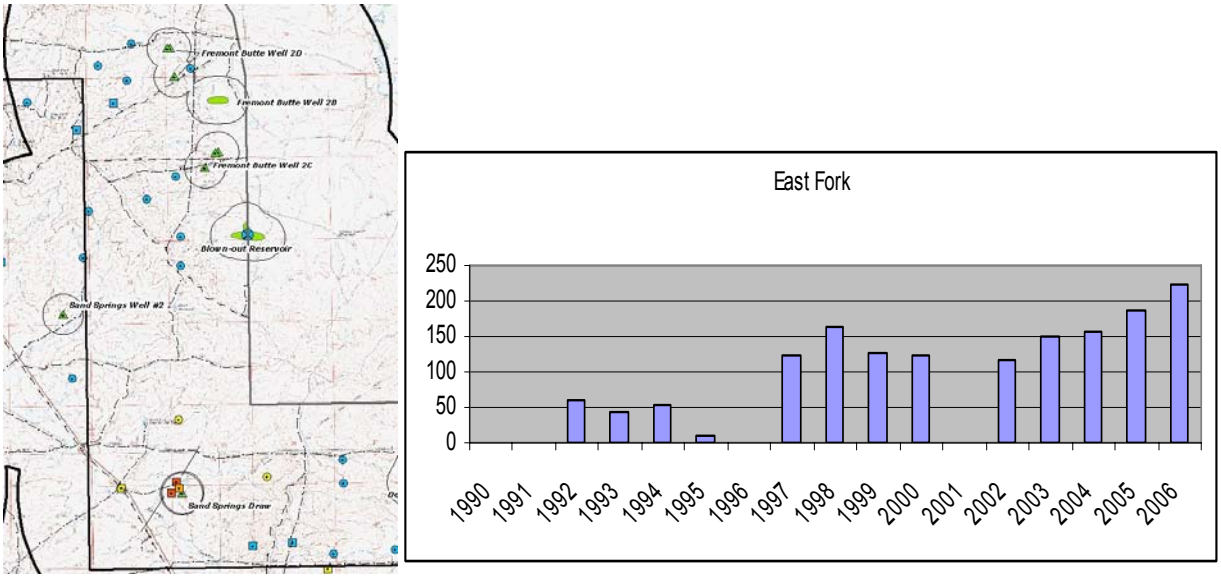
Big Fred is located approximately one mile northeast, directly down wind, of Section 36, a section of state owned minerals. State leases (Sections 16 and 36) are not encumbered by spatial and temporal stipulations and conditions of approval as are federal wells. Activity on federal leases on the Pinedale Mesa is generally shut down through the winter for the protection of crucial mule deer and antelope winter range, followed by the sage-grouse breeding and nesting/brood rearing period of March 1 to July 15. During this period of extremely limited activity on federal leases, drilling and completion activity continues on state leased areas. The Big Fred lek has been impacted by development activity throughout the breeding and brood rearing season since 2001 with increased activity levels from 2004 through 2006, a similar situation as was seen relative to the Mesa Springs and Lovatt Draw Reservoir leks.

Figure 34: Duke's Triangle complex detail



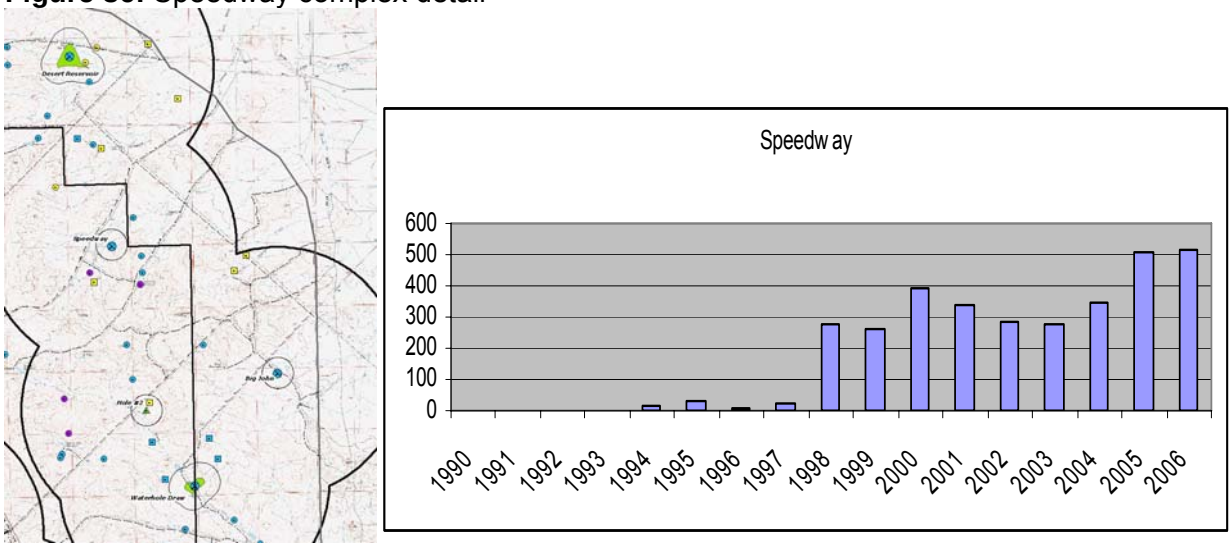
EAST FORK COMPLEX - The East Fork complex (Figure 35) is located east of the PAPA and is not impacted by gas development activity and shows generally the same trends as the impacted Mesa complex.

Figure 35: East Fork complex detail



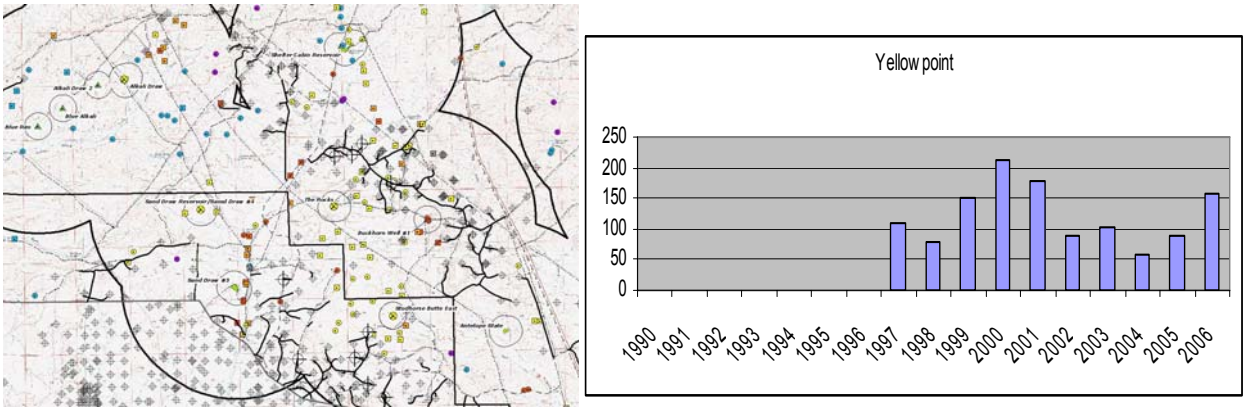
SPEEDWAY COMPLEX - The Speedway lek complex (Figure 36) is located to the south and east of the PAPA. As with the East Fork complex this group of leks is not impacted by gas development activity and trends are similar to the Mesa and East Fork complexes.

Figure 36: Speedway complex detail



YELLOWPOINT COMPLEX - The Yellowpoint complex (Figure 37) located at the south end of the PAPA geologic structure is impacted by that development activity as well as that which is occurring in the Jonah Field located southwest of the complex. Despite this level of development activity the Yellowpoint complex continues to be attended and trends are comparable to Mesa and the two non-impacted complexes.

Figure 37: Yellowpoint complex detail



SUMMARY OF PINEDALE ANTICLINE FINDINGS - A comparison of all five complexes (Figure 38) indicates that, with the exception of Duke's Triangle, the population trend for sage-grouse in the area of the Pinedale Anticline is similar regardless of the influence of natural gas development.

Figure 38: PAPA lek complex comparison

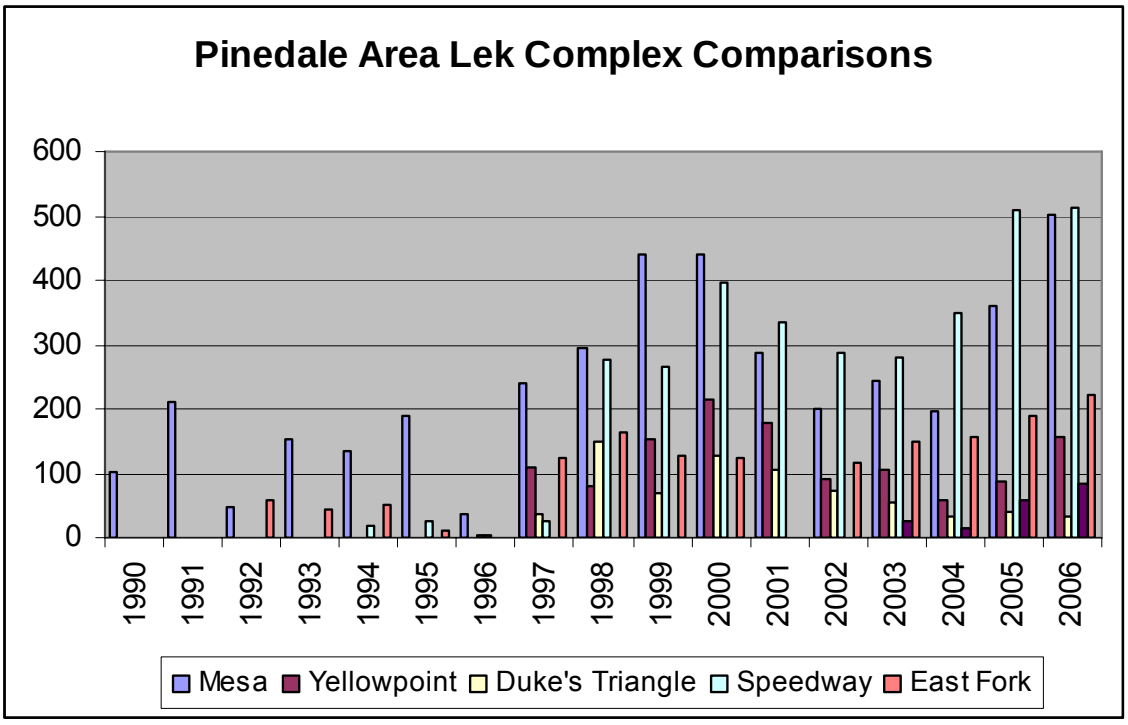
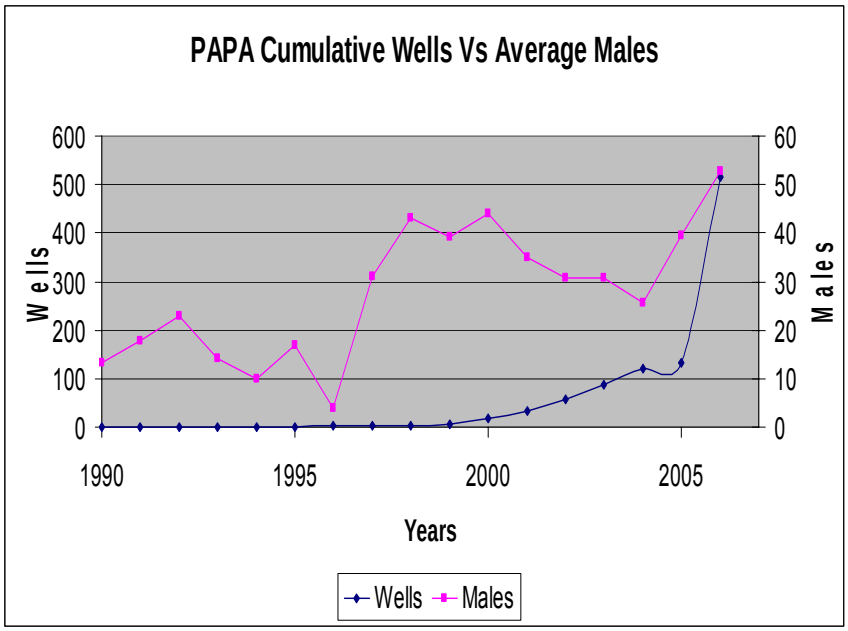


Figure 39 illustrates the cumulative number of wells drilled within the study area. The significant increase in the number of wells drilled from 2005 to 2006 represents the approval by BLM of multi-well pad drilling and year round activity. Pad drilling limits the surface disturbance and concentrates development activity thereby disturbing fewer leks. While this development scenario will limit surface disturbance and duration of development activity, it will enhance development intensity and possibly result in localized impacts to sage-grouse similar to those documented by Holloran (2005) at Lovatt Draw Reservoir and Mesa Springs leks, and to those we have demonstrated at the Big Fred lek.

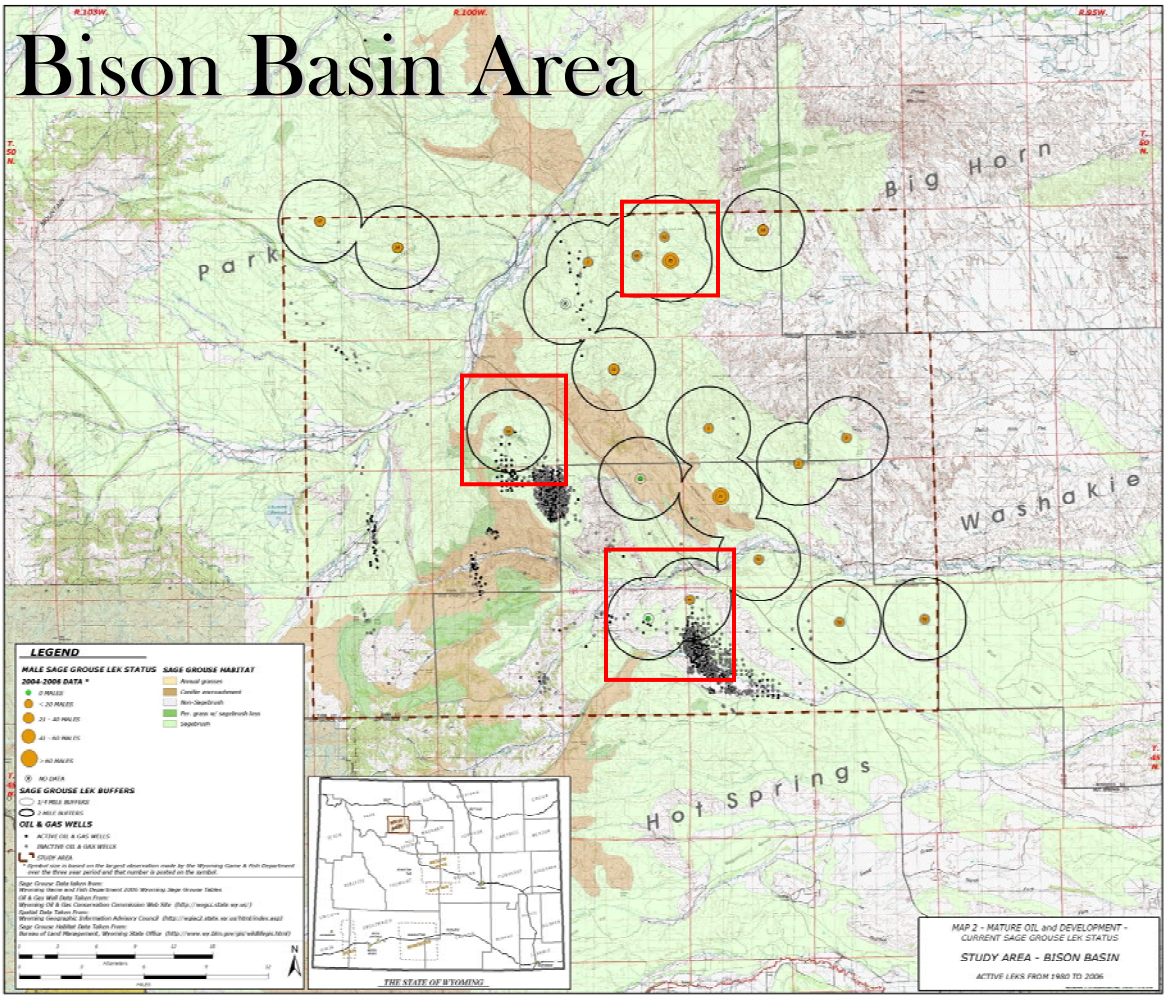
Figure 39: Pinedale Anticline comparison of male-lek attendance and wells drilled



BISON BASIN

The Bison Basin is an old oil field area located in the Big Horn Basin of northwest Wyoming (Figure 40). The small fields are densely developed, as they pre-dated WOGCC spacing regulations, with some being over 100-years old. Sage-grouse mitigation would not have been applied to the development of these fields. There is renewed interest in this resource area, additional geophysical exploration is in progress. We analyzed 5 impacted and 15 non-impacted leks out of the 96 leks identified in the WGFD management area.

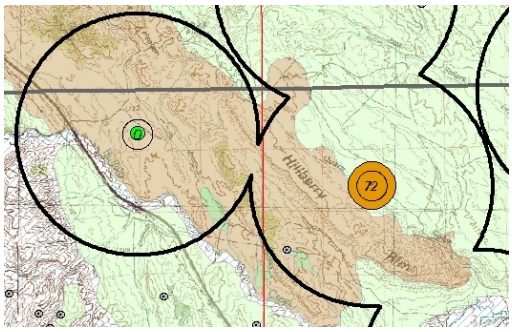
Figure 40: Bison Basin study area

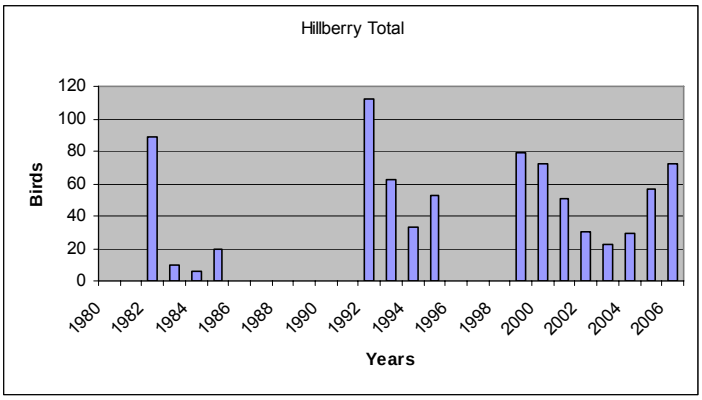


A lack of consistent data for the area limits the comparisons that can be made between impacted and non-impacted leks and lek complexes but an attempt to evaluate three areas from north to south across the study area was made.

HILLBERRY COMPLEX - The Hillberry lek complex (Figure 41) is not impacted by oil and gas development and demonstrates the same oscillations seen in other complexes.

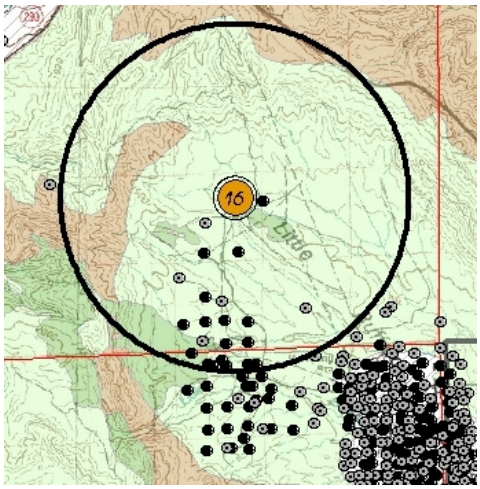
Figure 41: Hillberry complex detail

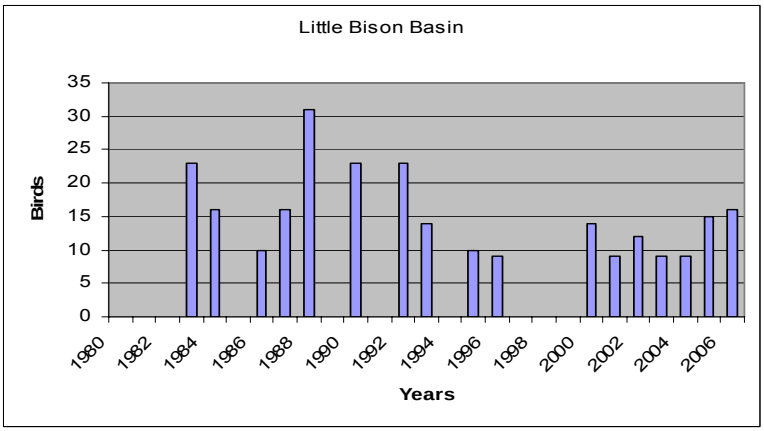




LITTLE BISON BASIN LEK - The Little Bison Basin lek (Figure 42) has had 23 wells drilled within the two mile radius of the lek and hundreds of wells drilled within a four mile radius. This field has been actively producing oil since 1915; sage-grouse continue to attend this impacted lek.

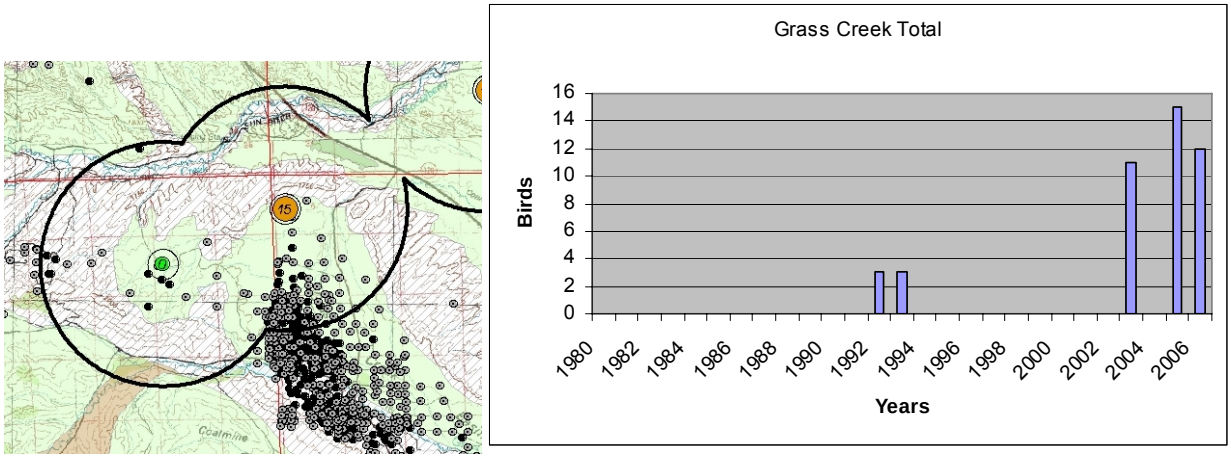
Figure 42: Little Bison Basin lek detail:





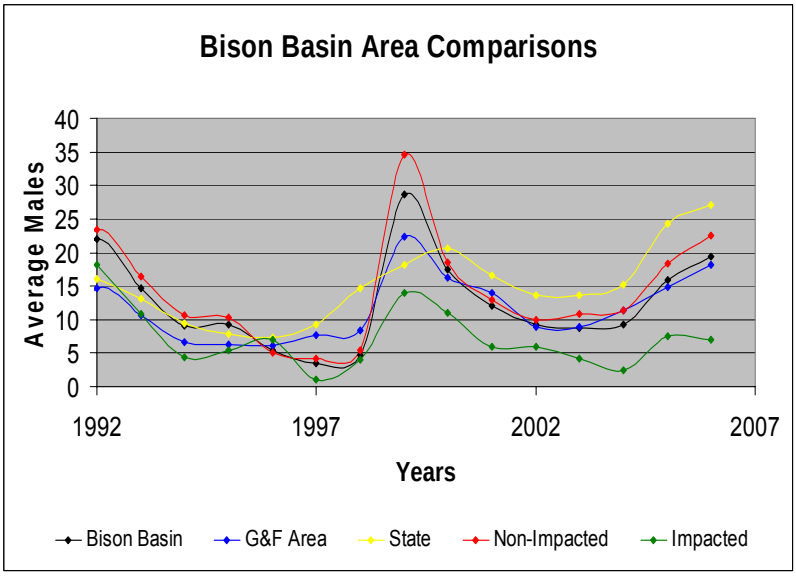
GRASS CREEK COMPLEX - Data are poor for the Grass Creek complex (Figure 43) but surveys conducted in the last four years indicate that the leks are occupied and stable. The complex is located in the Grass Greek oil field where almost 900 oil wells have been drilled since 1910. The Grass Creek oil field continues to be active today as does the sage-grouse complex of the same name.

Figure 43: Grass Creek complex detail



SUMMARY OF BISON BASIN FINDINGS - The comparison of the five lek categories for the Bison Basin study area (Figure 44) indicates that, even in this very old development area where no protective stipulations or spacing restrictions would have been applied, trends in this sage-grouse population are consistent with other populations and with state-wide trends. The only deviation seen is a slight decline in male attendance on impacted leks which is explained by the loss of three males attending the Grass Creek complex in 2006.

Figure 44: Bison Basin area comparisons



CONCLUSIONS

Five general conclusions emerge from this analysis.

1. Density of development is an important factor affecting male lek attendance

Sage-grouse continue to inhabit energy development areas characterized by a variety of well density scenarios. However, well density appears to affect lek activity. In both the PRB and Moxa, sage-grouse leks with more than 10 producing wells within the 2-mile lek radius continue to be attended by males during the breeding season, but leks with wells drilled within the ¼ mile lek-buffer or with more than 100 wells drilled within the 2-mile radius appear to become inactive. In the PAPA, the data show that year round drilling and completion activity within the ¼-mile and 2-mile radii (i.e. BLM granting exceptions to the sage-grouse protection stipulations or leks proximal to state leases) may lead to lek abandonment in a relatively short period of time.

Previous research has suggested that ≤1 well per 283 ha (approximately 1 well per section) within 3 km of a lek would reduce the negative consequences of gas field development (i.e. Holloran 2005, Walker et al. 20XX). There is no doubt that less than 1 well/square mile would reduce impact to sage-grouse but yet again we are left with the question about thresholds of development that no previous research has addressed. We have initiated research that will attempt to address this question.

It is likely that habitat quality plays a role in determining the level of development that impacts lek activity. Sage-grouse within relatively poor or marginal habitat (i.e. Moxa, PRB) appear to be less tolerant of increased well density than sage-grouse in areas of high quality habitat (i.e. PAPA, Wamsutter).

The conditions under which energy development impacts sage-grouse populations are more complex than has been previously suggested. Impacts appear to reflect an interaction of several factors including development density, the intensity of development activities, the life-history stage of the sage-grouse (i.e., brood rearing, lekking), and habitat quality. Some impacts are minimal while others pose a serious concern; the degree of impact seems to be related to the quality of the habitat affected by energy development, but this relationship is not always straightforward. Are the impacts of habitat fragmentation/conversion more severe when habitat is less-than-optimal, such as may be the case in PRB and Moxa? It cannot be stated that 80-acre spacing will facilitate population persistence in all instances; Moxa illustrates that this is not the case. But Moxa also illustrates the ¼ mile buffer caveat; leks that were abandoned in Moxa had development activity within this buffer. It is clear that 40-acre spacing will not support sage-grouse, but questions remain about the respective roles that increased human activity and habitat fragmentation/conversion play and whether some type of mitigation may be effective in areas impacted by 40-acre spacing. The implication for managing sage-grouse in energy development areas is that strategies will be most effective if they are developed on a population-specific basis. This will require site-specific research and activity planning.

2. BLM standard stipulations for reducing impacts to sage-grouse appear to be effective.

The stringent application of the current BLM lek and nesting habitat protection stipulations in the Pinedale Anticline reduced the impact of drilling and completion activities on lek attendance when compared to those leks where the stipulations were not applied. This comparison provides evidence that the BLM standard stipulations appear to be effective in reducing the impact of development activity on sage-grouse populations. Although we caution against extrapolating the results of a single short-term study to other populations or sage-grouse in

general, the evidence suggests that any statement that BLM stipulations are ineffective is unsupported.

While reviewing the existing body of research regarding the effectiveness of the standard BLM stipulations for mitigating the impacts of drilling operations on sage-grouse it became evident that the base assumption for the conclusion that these stipulations were ineffective was incorrect. Holloran (2005) states “My results suggest that current development stipulations are inadequate to maintain greater sage-grouse breeding populations in natural gas fields”, Walker (20XX) agrees stating “Current lease stipulations that prohibit development within the 0.4 km of sage-grouse leks on federal lands are inadequate to ensure lek persistence and may result in impacts to breeding populations over larger areas”. Also, in Braun et al. (2002), “We believe it is the responsibility of the oil and gas industry to demonstrate their activities have no negative impacts initially, short-term, or over the long term.” We have demonstrated that, while energy development can negatively impact sage grouse, populations persist in oil and gas fields through decades and, indeed, centuries of oil and gas activity. It is unreasonable to expect an absence of any negative impact because any activity that modifies habitat directly or indirectly will have consequences for wildlife populations. The question is, at what threshold of development can we maintain viable sage-grouse populations and productive oil and gas fields? To date, previous research has aimed to determine whether energy development affects sage-grouse populations. This is what has been referred to as gratuitous testing, that is, research based on questions for which we almost certainly already know the answer. Research aimed at finding feasible solutions is needed.

The BLM standard sage-grouse stipulations were intended to reduce the impact of the activity, not to eliminate impact altogether; this clarification is found in the CEQ NEPA regulations at 40 CFR 1508.20, "mitigation may include one or more of the following:

> (b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.”

BLM stipulations intended to mitigate impacts to sage-grouse on the Pinedale Anticline (BLM 2006) are spatial and temporal, and include:

- no surface disturbance within ¼ mile of a lek to protect the integrity of the lek site, including a specific prohibition of high profile structures within the ¼ mile if BLM does not apply the stipulation and allows activity within the ¼ mile,
- no surface disturbing activity within 1 mile of a lek from March 1 to May 15 to avoid disturbing breeding birds, and
- no activity within 2 miles of a lek from April 1 to July 31 to protect nesting hens and early brood rearing.

All BLM offices in Wyoming that manage sage-grouse habitat have similar stipulations in place, the two mile no surface activity restriction is applied, with slight variation, from March 1 to July 15. When the effectiveness of the stipulation is evaluated in accordance with the CEQ regulations the results are significantly different. For example, on the PAPA, sage-grouse leks that were protected using the BLM standard stipulations continue to have males in attendance; leks at which these stipulations were waived (Lovatt Draw Reservoir and Mesa Springs) for research purposes were impacted and no longer have males in attendance.

Clarification of the intended purpose and potential effectiveness of the existing BLM stipulations is essential as research outlined above is routinely cited as the evidence to compel BLM to change their sage-grouse management strategies. For example the draft Big Horn Basin Conservation Area Sage-grouse Conservation Plan (2007) states “Researchers concluded existing stipulations were inadequate to maintain sage-grouse breeding populations.” We have

cast doubt on this contention and provide evidence that existing stipulations may in fact reduce the impact of energy development on sage grouse populations.

Table 1 shows that well density and application of the BLM standard stipulations are important for maintaining lek attendance over the long term. Well densities at about 100 wells within the two mile radius were generally associated with persistence of sage-grouse populations. As well density exceeded 100 wells/2 mile radius, negative impacts on sage-grouse populations such as lek abandonment became apparent.

Table 1: Development Impact Summary

Development Scenario	Lek Status (1/4 mile lek buffer)	Development within 2 mile radius	Attendance Status
PRB 40 acre spacing	compromised	200 wells	abandoned
PRB 80 acre spacing	intact	100 wells	reduced and stable
Notches, un-spaced; an example of cluster development?	intact	40 wells in a one mi^2 area w/in the 2 mi radius	stable and increasing
Wamsutter, modified 80's	intact	50 to 60 wells	increasing
Wamsutter, modified 80's	intact, but close	+80 wells	increasing
Moxa 80 acre spacing	compromised	approaching 100 wells	abandoned
Moxa 80 acre spacing	compromised	between 50 and 100 wells	abandoned
Moxa 80 acre spacing	intact	between 50 and 100 wells	reduced and stable
Moxa 160 acre spacing	intact, but close	30 wells	increasing
PAPA	compromised	year round pad drilling	abandoned
PAPA	intact	year round pad drilling	increasing
PAPA 40 acre spacing	intact	between 100 and 200 wells	stable and increasing
Bison Basin, un-spaced	intact, but close	23 wells in 2 miles and hundreds w/in 4 miles	stable and increasing
Bison Basin, un-spaced	intact	hundreds of wells w/in 2 miles	stable and increasing
Bison Basin, un-spaced	compromised	28 wells in 2 miles and hundreds w/in 4 miles	abandoned

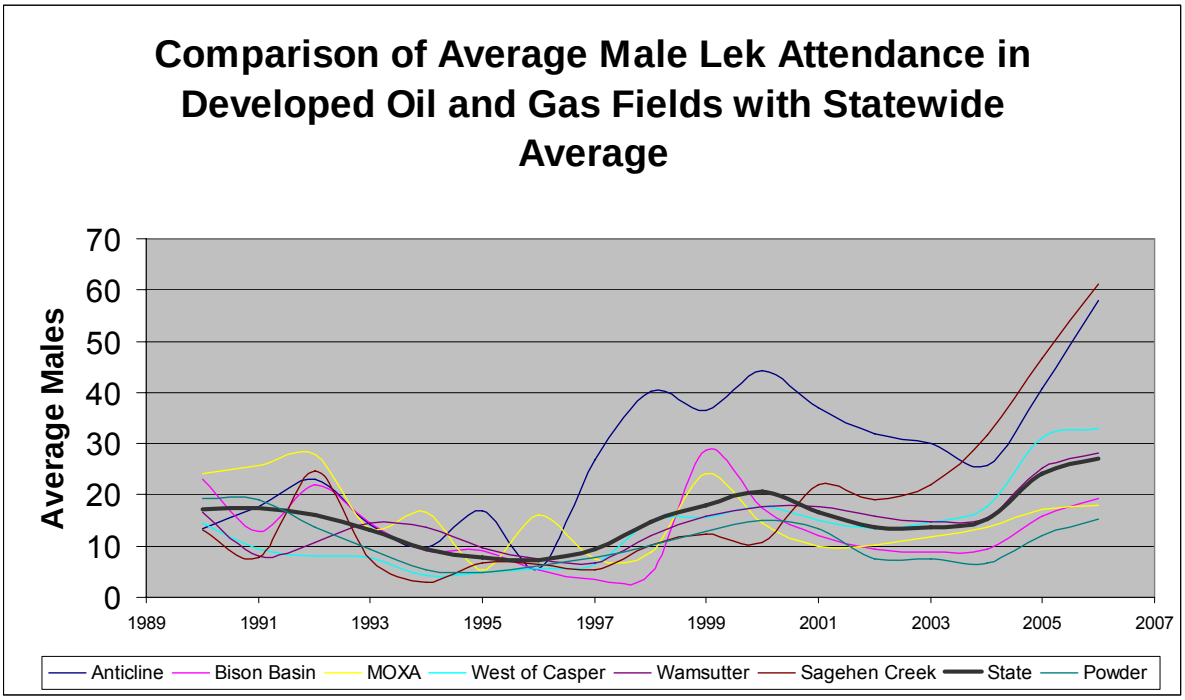
3. Extirpation has not occurred in any study area with either new or old development.
The data show that sage-grouse populations have persisted in energy development areas. Any contention that energy development will result in population extirpation must be qualified with statements on development density and intensity. However, there is concern about the effects of continued rapid expansion of energy development because we have yet to quantify the extent to which viable sage-grouse populations will tolerate habitat modification.

4. Impacted leks show varying rates of reduced male attendance compared to non-impacted leks.
Average male-lek attendance and population-growth rates are lower on impacted leks when compared to non-impacted leks.

PAPA development activity, which accelerated in 1998, appears to have decreased average male-lek attendance on impacted leks. We can see from the graph (Figure 32) that there was no divergence between the impacted and non-impacted lek averages prior to 1996. While there is now a significant difference in average male-lek attendance numbers on impacted vs. non-impacted leks, male attendance has increased in recent years on leks within the development areas and impacted leks continue to support males. However, in Wamsutter (Figures 24 and 25) the differential between impacted and non-impacted leks was in place before development activity began and may be due, in part, to the variation in habitat quality in the area. In the PRB (Figure 4) the differential between impacted and non-impacted leks was small before CBNG development (<0.6 males) and is only slightly higher today (<1.9 males).

5. All Greater Sage-Grouse populations studied showed synchronous fluctuations in male-lek attendance. The analysis presented in this report found that, regardless of the population in question, the male-lek attendance trend is the same throughout the State (Figure 45). Population increases and declines occur at approximately the same time and are generally of the same magnitude regardless of the specific population being evaluated. A similar observation was made by Braun et al. (2002) relative to the sage-grouse in the McCallum Oil Field in North Park, Colorado, "During the 1973 to 2001 interval, number of male sage-grouse counted and active leks in this area fluctuated in synchrony with the entire sage-grouse population in North Park." These same fluctuations are seen range wide; see Figure 4 taken from the WAFWA Greater Sage-grouse Conservation Assessment (Connelly et al. 2004). Greater sage-grouse populations, like many wildlife populations, show periodic fluctuation in abundance and distribution. These fluctuations are likely the result of a suite of factors including climatic trends and anthropogenic influences.

Figure 45: Comparison of average male-lek attendance in developed oil and gas fields with statewide average



Summary and implications

a) Strict application of the BLM protective stipulations reduces impact to sage-grouse populations in development areas. These stipulations should be implemented with further testing.
    i) It should be anticipated that multi year-round drilling and completion activity within 2 miles of a lek will negatively impact lek attendance and associated nesting and brood rearing activity.
b) Consider well density and removal of habitat, for example
    i) cluster 40 acre spaced wells (if geologically applicable, see the Lox Notches and Grass Creek complex discussions as examples) in marginal habitat, this is preferred over full scale 40 acre spacing that removes good quality habitat,
    ii) drilling multiple wells from a single location,
    iii) use the fewest number of surface well sites possible to extract the resource,
c) Leave undisturbed patches of habitat scattered throughout the field development area, for example map the habitat, the resource and create habitat set aside areas.
d) Application of management practices to reduce direct impacts to sagebrush habitats should assist in reducing the differential between impacted and non-impacted male-lek attendance and the likely displacement of grouse from development areas.
    i) Avoid impacting lek buffers.
    ii) Avoid impacting high quality nesting and early brood rearing habitats.
    iii) Reestablish or enhance sage-grouse habitat as quickly as possible using locally selected forb and sagebrush species.

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Spatial data: Wyoming Geographic Information Advisory Council
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Oil and Gas Well Data: Wyoming Oil and Gas Conservation Commission
http://wogcc.state.wy.us/)

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