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ASSESSING IMPACTS OF OIL-SHALE DEVELOPMENT ON THE PICEANCE BASIN MULE DEER HERD

by

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ABSTRACT--Development of energy resources on big game ranges generally negatively impacts these important wildlife resources. Although habitat disturbance is generally important, this impact is overshadowed by the negative impacts due to an increasing human population in the area. Increased human activities particularly stress animals during winter periods when inadequate nutrition levels may have already severly impacted the population. Increased road traffic and poaching causes additional deaths, with a decline in survival rates expected, or at least changes in the causes of mortality. This paper describes the experimental design to monitor and mitigate the impact of oil shale development in northwestern Colorado on the Piceance Basin mule deer herd. Biotelemetry techniques are used to measure changes through time in movements, habitat utilization, and survival rates between control and treatment areas.

KEYWORDS--Big game, survival rates, biotelemetry, Colorado, competing risks.

Development of a commercial oil shale industry in northwestern Colorado will occur primarily in and around the Piceance Basin, which is also winter range for a large migratory mule deer (Odocoileus hemionus) herd. Size of the herd has fluctuated considerably from year to year and is presently estimated at 20-25,000 animals. This herd is an important economic resource in the area. From 2-5,000 deer are harvested annually in the basin by an average of 5,000 hunters (CDOW 1978). Most expenditures by these hunters go to area businesses and the Colorado Division of Wildlife (Ross et al. 1975). The potential ecological consequences of commercial development of Piceance Basin oil shale deposits on the deer herd are a sensitive political and public concern. In response to this concern, the U.S. Department of Energy has funded a study to assess impacts of oil shale development on the mule deer herd in the Piceance Basin. The goal of this paper is to explain the experimental approach we are taking to measure those impacts.

OBJECTIVES

The major potential impacts we are studying are changes in deer survival. Factors which may directly affect mortality rates are increased hunting, poaching, and auto-deer collisions due to increased use of roads and public lands for recreation. Also increased harassment of deer by human activities when animals are in poor condition due to winter stress may decrease survival rates. Other factors which may indirectly affect deer survival rates are loss of habitat and forage production due to mining activities, air pollution, spent shale disposal and construction of housing, roads, utility corridors and retort facilities. On the other hand, reclamation of mining and spent shale disposal areas may enhance habitat, thus increasing deer survival rates. Therefore the objective of the study is to quantify changes in deer survival rates and cause of death as a function of oil shale development.

METHODS

Deer survival rates are estimated using biotelemetry. Deer fitted with radio transmitters may be located as often as necessary using ground, mobile and aerial tracking techniques. Transmitters are also equipped with a motion sensing device that signals the researcher when the animal has failed to move for a predetermined length of time, allowing mortalities to be quickly detected and investigated. Thus, biotelemetry provides data on both the spatial and temporal movement patterns of collared animals as well as their survival.

RESULTS AND DISCUSSION

The results to date have contributed descriptive baseline information on deer movement patterns and survival before the oil shale industry expands to commercial production. Expansion of the industry will greatly magnify the potential for serious impacts on the deer herd and it is these impacts that our studies must detect. If we limit our investigations to that portion of the deer herd inhabiting areas where intensive development is projected, we may detect changes in deer movement patterns and mortality. However, we could not attribute those changes solely to development activities (cf. Green 1979). If the Piceance ecosystem was static this might be possible, but ecosystems are dynamic and change is inherent. Therefore, temporal changes in deer movements and mortality may be a result of natural variability and/or perturbations caused by development activities. In order to separate natural changes in the ecosystem from those caused by man's activities, one must have a quantitative understanding of the natural phenomena that cause change in ecosystem structure and function. However, our knowledge of ecosystem dynamics is minimal at best, and such distinctions cannot be made (cf. Suter 1981).

We want to use mule deer survival rates to illustrate this problem of delineating between natural temporal variation and impacts of the oil shale industry. Continued monitoring of survival rates of deer occupying areas where intensive development is planned may indicate survival rates remain relatively constant until major development activities are initiated. At that time, survival rates may decrease sharply (Figure 1).

These data would then show a correlation between development and deer mortality, but would not imply a cause-effect relationship. How can we determine if decreased survival resulted from oil shale development? One approach would be to study a second population of deer during the same time interval and subjected to the same environmental influences as the monitored population, but occupying an area isolated from development activities. A decrease in the survival rate of both populations at the time of accelerated development would indicate the decrease was not a result of development but some natural phenomenon such as a severe winter. If, however, the survival rate of the population occupying the development area decreases while the rate remains relatively unchanged in the population isolated from development, then the decreased survival may be attributed to man's activities. The design required to remove the time variable is shown in Figure 2 (Ward 1978, cf. Green 1979).

Figure 2 will be interpreted with an additive effects model, although a multiplicative effects model may be appropriate. The difference between cell y_{11} and cell y_{12} is a measure of how close the geographic control site is to the perturbed site. The difference between cell y_{11} and cell y_{21} is a measure of differences due to time without perturbation. The results of perturbation must be shown indirectly because the difference $y_{21}-y_{22}$ represents both geographic and perturbation differences. Two separate ways of obtaining perturbation differences

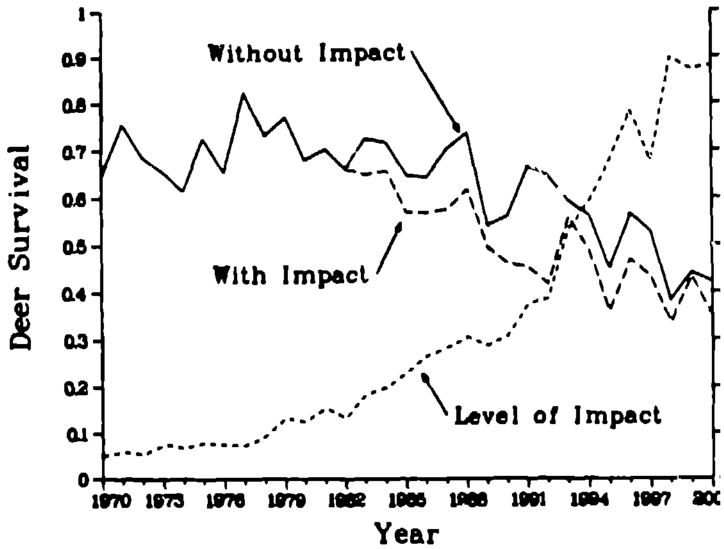

FIGURE 1. Demonstration of the possible wrong conclusions which may be drawn when the system being studied is changing with time and no spatial control area is used to compare with the perturbated area.

	α_1 Geographical Control Site	α_2 Perturbed Site
β_1 Pre-Impact	y_{11}	y_{12}
β_2 Post-Impact	y_{21}	y_{22}

FIGURE 2. Experimental design necessary to measure environmental impact when changes due to time are also expected.

are available. First, $(y_{12}-y_{22}) - (y_{11}-y_{21})$ provides a measure of perturbation effects when time differences are removed. Second, $(y_{21}-y_{22}) - (y_{11}-y_{12})$ is a measure of perturbation effects when geographic differences are removed.

The purpose for including both time and geographic controls in the impact study is to be able to show cause and effect. If either the time control or the geographic control is left out of the design, the resulting confounding of factors would leave the interpretation of results open to question, i.e., the perturbation, per se, may or may not have had an impact. The design in Figure 2 represents a manipulation experiment, where the treatment is the perturbation. Given that the second geographic area is really a control (i.e., $y_{11}-y_{12}$ = a constant), conclusive results can be reached.

This control-treatment experimental design provides the optimal approach to assessing impacts of oil shale development on the Piceance deer herd. But where can we find a control for this population? Obviously there is none, but the problem of distinguishing between natural fluctuations and man-caused changes dictates that we attempt to design our study as close to a control-treatment experiment as biologically possible. Studying two subpopulations of the Piceance deer herd provides the best solution to this problem.

Banding studies conducted by the Colorado Division of Wildlife during the 1970's indicate that deer wintering in the Piceance Basin may be divided into two subpopulations based on wintering and summering areas (Bartmann and Steinert 1981). Most deer wintering in the northern portion of the Basin migrate eastward and summer in the upper White River drainage. Deer wintering in the southern portion of the Basin, which includes the C-b tract area, migrate southward and summer on the Roan Plateau. Most oil shale development will be concentrated in the central and southern portions of the Basin and the Roan Plateau. Little development is currently planned for the northern portion of the Basin and there are no commercial deposits of oil shale in the upper White River area. The subpopulation of deer that occupies this area may, therefore, act as a quasi-control for the southern subpopulation which will bear the brunt of oil shale development. The subpopulations do not strictly satisfy the requirements for a control-treatment experiment as some development impacts will be regional in scope. The two subpopulations, however, are in close proximity and are subjected to similar climatic conditions, and should be similar genetically. Therefore, banning human intervention, they would be expected to follow the same trend over time (Eberhardt 1976).

Note that it is not critical that the control and treatment populations be identical, only that both respond to the same environmental factors, i.e., the two populations "track" one another. Thus, the expected difference between the two subpopulations is a constant through time if no impact occurs. A change in the difference of the two subpopulations through time indicates that some factor is changing between them. In this case we assume oil shale impacts, either on winter range, summer range, or both.

Eberhardt (1976) proposed this approach for environmental impact assessments, suggesting it be known as a "pseudoexperiment". He uses this term because "classical" experimental designs call for random assignment of the control and treatment groups and replications of each group. Although the ideal approach in terms of quantitative design, random assignment is impossible because the treatment, in this case oil shale development, cannot be controlled and replicate control and treatment groups are essentially nonexistent in natural ecosystems. Hence, the best we can do in field studies is establish one control and treatment group as ecologically similar as possible and collect several years of pre- and post-development data. Technique limitations and the inevitable variability associated with natural populations makes it doubtful that any but major changes can be detected experimentally (Eberhardt 1976). Although we may detect statistically significant changes in measured parameters, determining cause-and-effect relationships will be difficult (Thomas et al. 1981) and will require assumptions based on judgment. When this experimental approach is compared with the alternative of attempting to identify developmental impacts from temporal changes alone, the advantages are clearly evident.

The greatest difficulty with detecting impacts of oil shale development on the mule deer population is the small sample size that can be expected. For the experiment described above, the sample size (n) is years. Each year that the two subpopulations are monitored adds an additional data point, i.e., one more observation of the differences between the two subpopulations is detected. The number of radios put on deer only refines the quality of measurements taken. That is, more radios can be equated to a balance with greater precision or a microscope with a more powerful lens. The number of radio-collared deer in each subpopulation, therefore, does not contribute data points to the estimate of the difference between the two subpopulations. Rather, it provides a more precise measurement of the estimate of the difference between the two subpopulations.

In addition to measuring deer survival rates, we will use a competing risk analysis to detect changes in causes of deer mortality between the quasi-control and treatment areas. Application of the theory of competing risks to the deer population involves detecting shifts in the cause of mortality due to oil shale development. Conceivably, the negative and positive forces on deer survival could balance out, i.e., more deer may be killed by poachers and on the highways, but fewer deer are killed by coyotes because of increased hunting and trapping pressure on predators. A competing risk analysis on the fate of radio collared deer could detect these changes through time and between the quasi-control and treatment areas, even though the overall deer survival rate remained constant.

The major contribution of a competing risk analysis is quantification of the actual impact of an increase in a particular source of mortality. For example, an increase of 500 deer per year killed by poachers does not mean 500 fewer deer. Rather, some of the 500 deer would have died of other causes shortly after the time they were poached. Therefore, even though an individual animal is killed due to an oil shale impact, the actual impact on the deer population may not be as high as the data would first suggest.

We believe it essential to measure survival rates in the two subpopulations to detect impacts of oil shale development. Changes in movement patterns of mule deer will reflect some impact, but the importance of the impact cannot be documented based only on changes in movements. Such changes may not lead to a decline in the deer population, the ultimate potential impact of oil shale development. In contrast, a drop in the annual survival rate without compensation will lead to a lowered deer population, and hence indicate a substantial impact.

CONCLUSIONS

From the information we collected to date, we feel that a control-treatment experimental design is practical for assessing oil shale industry impacts on the Piceance Basin mule deer herd and we have implemented this design. Pre-development movement and mortality data will be collected for several years and an attempt made to maximize sample sizes to increase our ability to detect changes. Development of a commercial oil shale industry will then provide the perturbations to be measured.

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