STUDY IMPLEMENTATION PLAN

Title: Elk and bison grazing ecology and management in Great Sand Dunes National Park and Preserve

Project PMIS #: 95762

National Park strategic plan goal #: 1b1

Date of the plan: 7-25-04

Organizations jointly involved in the project:
National Park Service
U.S. Geological Survey
The Nature Conservancy
U.S. Forest Service
U.S. Fish and Wildlife Service

Organizations assisting the project through cooperation:
Colorado Division of Wildlife

Principal Investigators:

Francis J. Singer, Research Ecologist, USGS ________________________________ Date__________

Kathryn A. Schoenecker, Ecologist, USGS____________________________________Date__________

Park Unit Lead:

Steve Chaney, Superintendent /Fred Bunch, Resources Management

Others who helped develop the project plan:
Chris Pague, The Nature Conservancy, Boulder, CO
Chuck Wagner, Colorado Division of Wildlife, Monte Vista, CO
Ron Rivale, Colorado Division of Wildlife, Monte Vista, CO
Brent Woodward, Colorado Division of Wildlife, Monte Vista, CO
Bruce Watkins, Colorado Division of Wildlife, Montrose, CO
Mike Artman, USFWS
Lamar Taylor, USFS

Natural Resources Program Center Project Coordinator:

Mike Coffey, NPS ____ Date_________

Table of Contents:

Abstract: In 2000 the U.S. Congress authorized the expansion of the former Great Sand Dunes National Monument by establishing a new Great Sand Dunes National Park and Preserve in its place, and establishing the Baca National Wildlife Refuge. A new ungulate management plan to address the challenges brought about by the new land designations needs to be developed. The new land areas have different management requirements, and the situation is predicted to result in elk seeking out the park and other protected areas as refugia. Elk are currently far in excess of agency goals and heavily impact fragile dune grasslands and sensitive riparian habitats in the national park, refuge, Nature Conservancy lands, and private lands. In addition, about 1,500 bison graze the Medano-Zapata Ranch, owned by The Nature Conservancy (TNC). TNC seeks to increase bison numbers to represent a genetically viable unit and a representative, semi-wild and migratory population. Opinions vary as to the numbers of bison needed to accomplish that goal. Elk move freely across all elements of the new land designations (park, preserve, refuge, TNC ranches) and elk and bison share the Medano-Zapata Ranch. Thus this plan proposes to gather information in order to manage the entire land complex as one ecosystem. The plan also proposes to convene a steering committee to coordinate the needs and actions of the various management participants. The study will ultimately guide managers by providing the information needed to develop a predictive model to be used for grazing management of both elk and bison.

Problem Statement:

The establishment of Great Sand Dunes National Park and Preserve and the new Baca National Wildlife Refuge in the San Luis Valley of Colorado was one of the most significant land conservation actions in the U.S. west in recent years. The action was a result of cooperation between the National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), Bureau of Land Management (BLM), U.S. Forest Service (USFS), and TNC. The new national park will consist of 107,265 acres, the new national preserve, 41,872 acres, and the new national wildlife refuge (USFWS lands) 92,180 acres. The area encompassed by this designation protects a number of natural wonders and features including a unique ecosystem of natural sand dunes, the entire watershed of surface and ground waters that are necessary to preserve and recharge the dunes and adjacent wetlands, a unique stunted forest, and other valuable riparian vegetation communities that support a host of associated wildlife and bird species.

The Nature Conservancy acquired the Baca Ranch for national wildlife refuge designation and also acquired and manages the Medano-Zapata Ranch to protect its rich natural resources. TNC manages about 1,500 bison on the Medano-Zapata Ranch, which is located within the core of the protected lands. The bison population is not supplementally fed any hay or grain. The herd's growth is controlled by the round-up and sale of bison calves and yearlings each year. TNC seeks to eventually maintain a larger, semi-wild population of perhaps 1,800-3,000 bison on the Medano-Zapata Ranch and adjacent NPS and NWR lands, although there are currently no plans to allow bison on NPS lands. The boundaries of the bison use area are currently fenced to keep the bison in. The bison management goals of the TNC include taking down large portions of this fence to encourage a more natural annual movement of the bison, encouraging (through opening/closure of water holes, and driving) a natural tendency of the bison to migrate to the north end of the ranch each summer and to the south end each winter, in order to rest the vegetation for part of each year. A recent ecoregional planning effort identified this area as the best site in the southern Rockies to support a semi-wild, self-sustaining population of bison (Chris Pague, pers. commun., 1 March 2002, TNC). Three-hundred-thousand acres of grazing land was recommended by the planning group as necessary to support such a bison population. TNC has estimated that the Medano-Zapata Ranch alone should not hold more than 1,800 animal units. Thus, there is a challenge to both increase the current size of the bison herd, yet not exceed the limits of the range. The impact of herbivory from such a large bison herd on local plant communities is currently not known.

The goals of TNC are to support a nearly intact herd of bison, one that is genetically viable, in which genetic input from outside herds is not necessary. They also seek to mange a herd that is nearly wild. Bison would move between seasonal ranges, and an annual migration, although abbreviated, would occur within the ranch. This objective is not unrealistic, as the bison already have adapted a general north-south annual movement pattern (they move to the north end of the ranch in summer and drift back to southern areas in winter). TNC and the USFWS are interested in the natural grazing effects that bison have on the ecosystem. Is there an acceleration (or perhaps deceleration) in nutrients, do bison move nutrients around the system, do bison alter the vegetation communities by their activity, how do the effects on vegetation of year-round versus seasonal grazing differ? TNC and USFWS are also interested in how the herd will break up into groups based on age and sex, and what parts of the ecosystem these demographic units will use, as more natural conditions are allowed to return. Several agencies will be faced with the decision to retain bison on their lands, or not, when the final land designations take place. Thus information on the role of bison in the ecosystem is essential. Are the bison doing any damage to the system, or is their grazing compatible with agency goals?

Bison currently graze many sectors of the ranch year-round. For example, some wet meadows are grazed on and off all year. Year-round grazing of the same areas is not a recommended range management technique, nor does it typically occur in natural bison grazing systems. In addition, elk forage seasonally in some of the same areas as the bison. Both elk and bison use cottonwood and willow patches for loafing, bedding, and feeding habitat. Concentrations of large ungulates in these woody patches for extended periods has resulted in barking of trees and shrub stems and high browse levels. A general trend toward dune deposition is burying many willow and younger cottonwood individuals, thus reducing their growth potential and making them even more vulnerable to heavy browsing. The potential exists for rapid death and loss, likely within the next 5 years, of many of the younger patches of these unique and rare woody riparian vegetation communities that are interspersed throughout the dune complex. The older cottonwood stands will persist longer, but they too will disappear with no recruitment of new stems. The cottonwood stands are the only forested component of the dunes complex, and the stands provide nesting habitat for raptors and many other birds that otherwise would not use the dunes complex.

Ungulates have been observed to accelerate nitrogen processes through their conversion of less decomposable forage into labile feces or urine and through their acceleration of the nitrogen mineralization process (Frank et al. 1998, Singer and Schoenecker 2003). Alternatively, ungulate grazing may result in a deceleration of nitrogen processes through declines in high quality, more decomposable forage due to excess herbivory (Schoenecker et al. 2004). Managers seek to know how bison grazing on the Medano-Zapata ranch influences soil nutrient processes and nutrient pools.

Background:
To date there has been no formal research on the ecology, forage relations, corrected estimates of elk population size, population dynamics, nor habitat relations of elk in the Great Sand Dunes-Sangre de Cristo-Baca area. The elk population has grown dramatically over the previous 15-20 years at an average annual rate of increase of 8-9% per year and elk currently number 4,000-5,000 animals. Recent harvests have been limited to only about 100 animals per year (~2% annual harvest of the population), far below the 8-12% annual harvest that would be needed to limit or reduce the growth of the elk population.

The annual migration of bison, if it could be encouraged, would rest plant communities during some seasons, and would be the basis for a new and much more successful grazing program. However, any large increase in bison numbers to accomplish genetic goals (one estimated projection is to double current numbers, another projection is to support 500 breeding cows), combined with the recent increase in elk numbers, demands a new population and grazing assessment for both species of large ungulates. The management parties desire to have this study explore the quantitative effects of a variety of management actions. They seek the ecology of the potential management actions to be laid out in clear-cut potential scenarios. This would provide the mangers with a tool box to draw upon for later management actions and plans. Some new management treatments and experiments will occur during the course of the project, and this study will evaluate the effects of those actions. However, the management participants project a new ungulate management plan would require a full 5 years from the initiation of this study, when all the results of this study can be assimilated, evaluated and discussed. These new management plans are beyond the scope of this initial study, but the plans may be based upon this study to a large extent.

When the National Park was initially established, there were concerns about over-concentrations and impacts of the unhunted segments of a large and growing elk population to rare native plant communities. This led to the designation of the Preserve as a compromise solution, where the elk could be harvested. The Preserve Unit, however, will not resolve all the ungulate management problems. In order to curtail the current elk population expansion, harvests of elk need to be aggressive. But aggressive special hunts of elk to achieve large population reductions can result in elk avoidance of certain areas, in elk seeking refuge in areas where they cannot be hunted, while removals of whole herd segments and abandonment or alterations of migration routes can occur (Smith and Robbins 1994; Boyce et al. 1991). Elk may seek refuge from hunting in the newly expanded Park Unit and TNC lands where they might over-concentrate and impact rare vegetation communities. In these sites of refugia, or preferred loafing sites, elk and bison could be accelerating a decline in woody riparian shrubs and trees. This decline may also be due to changes in hydrology, climatic, or dunal processes, but the ungulates might exacerbate the effects of those processes. This study needs to evaluate the potential for multiple causes.

The valley floor and dunes ecosystem is a dry land area where water sources, often from snow melt and springs, is rare and at a premium. There are basically three unique and irreplaceable vegetation types of the greater sand dunes complex. (1) Active Dunes and Swale Area: grasses such as blowout grass (*Redfieldia flexuosa*) grow in low densities on the dunes. The swales are flooded ephemerally during spring from snowmelt off the mountains, and support a more dense ground cover of sedges, and wet grasses. Water sources in this complex include the Sand Creek, Little Springs, and Big Springs. Cottonwood stands that occur along Sand Creek are considered unique for the southern Rockies, since they are pure narrow-leaved cottonwood (*Populus angustifolia*), while most other stands are hybrids of narrow-leaf and broadleaf. (2) Ephemeral Wetlands: these form the western boundary of the complex and are watered from the springs and Sand Creek. The only large population of the endangered slender spider flower (*Claeome multicaulis*) occurs in these meadows. Only a few records for the spider flower exist outside of this population. As a challenge to managers, the plant does not thrive under total protection, but it does best under a regime of annual flooding and some grazing disturbance. (3) The Sand Sheet: this area surrounds the active dunes complex and is dominated by greasewood (*Sarcobatus vermiculatus*) and rabbitbrush (*Chrysothamnus viscidiflorus*). Cottonwoods and willows (Coyote willow-*Salix exigua,* Mountain willow-*Salix monticola,* Interior willow-*Salix interior)* grow on top of some dunes (the dunes may support a pyramid water supply) and along the Sand Creek watercourse and near the springs.

Historically, bison, elk, and pronghorn antelope were native and inhabited the area in numbers, until about the 1840s when both bison and pronghorn were extirpated. Livestock, mostly cattle, were grazed in the area until the 1970s, especially in the Sand Sheet type. The heavy historic cattle grazing has left this vegetation type in poor condition. The wet meadow type was irrigated and hayed to increase cattle production, and is likely larger than it would have been naturally because of man-made flooding. Willow and spider flower populations have flourished from summer irrigation by humans, but neither the NPS nor TNC have any set plans to continue irrigation of the wet meadow, or any other vegetation types. Managers, however, are open to the idea of continued irrigation, but only if the benefits and justifications were laid out.

Another challenge to managers is to retain the cottonwood and willow populations, which are currently declining. The decline appears to be related to reduced water availability and also to recent sand deposition on inter-dunal sites. Elk and bison may be very significantly contributing to the decline. Ungulate browsing, rubbing and thrashing on both cottonwood and willow stems is high in these stressed stands. As an example of the declining trends in theses communities we present the following information:

> In 1937, there were 114 inter-dunal ponds in the Sand Creek drainage, but presently there are only 51 such ponds. Sand Creek has downcut 1.0-1.5m in some areas, thus dewatering local willow patches. Recent sand deposits are burying many inter-dunal willow patches. A brief survey of 24 willow patches on a 1 March 2002 tour (F. Singer, field notes) indicated that two-thirds of the willow patches had extensive willow mortality. Similarly, there was essentially no cottonwood regeneration at 16 cottonwood stands, and recruitment at only 4 other stands of a total of 20 stands visited that day. Elk seem to seek out the willow and cottonwood stands for cover and as loafing areas. We observed elk to browse, break stems, rub and bark the trees, and bull elk to thrash stems with their antlers. Bison feed primarily on graminoids and browse little. However, bison on the study area aggregate and frequently loaf in cottonwood and willow patches. Due to these concentrations, bison may also contribute to the lack of recruitment. Bison rubbed on many stems, dusted and rolled near the stands and seemed to browse some willows.

We seek to understand the interaction of climate with the apparent increase in herbivory and physical damage of willow and cottonwood by ungulates. A dry period of several decades resulted in a decline in water table and wetlands near Sand Creek (Wurster et al. 2003), and this may explain the willow and cottonwood decline. Also, dune movement increases during dry periods which may explain the burial of some willow patches.

The primary purpose of this project is to provide information and management scenarios for elk and bison. These management scenarios will enable managers to resolve new conflicts and to develop a bison-elk grazing program that will protect the rare and sensitive dune complex vegetation in the area.

Objectives:
Our objectives are to:

(1) Determine the current population status of elk, and current year-round distribution and movements of elk.
(2) Evaluate the effects of bison and elk herbivory on plant communities, especially on shrub and tree recruitment, not only from browsing, but also from rubbing and thrashing.
(3) Determine the suitable habitat and population potential (carrying capacity) for elk on Nature Conservancy lands, in the Park Unit, the Preserve Unit, the U.S. National Forest Units, and the new national refuge lands.[1]
(4) Develop an elk/bison grazing model that includes grazing as a significant natural ecological process, and also protects sensitive native plant communities. Cattle grazing will be included in the model.
(5) Provide information for developing a predictive model to be used in a planning process for management agencies. Lay out management scenarios to predict effects on ungulate populations, changes in distributions, habitat selection, and migrations.
(6) Monitor the effects of treatments and new experiments on the distribution and movements of elk. Experiments and treatments that have been discussed include special hunts to move elk from certain areas, removal of water, removing fences, and adding fences (e.g. to keep elk from crossing main Highway 17 and adjacent seed potato farms). When developing predictive scenarios, the study team should identify goals that are common amongst the management agencies or organizations. Emphasize GIS products for each scenario that are easy to understand and clear to managers. Develop alternative scenarios. Cattle grazing needs to be incorporated into the potential scenarios, since continuing with some form of cattle grazing is an option to not only TNC, but also the refuge and the park. The managers suggested that standard values for forage intake, energy needs, typical grazing areas, etc. be used in the model and that extensive efforts not be made to generate new basic values for cattle.
(7) Evaluate the effect of bison grazing on soil nitrogen processes.
(8) Evaluate the interaction of climate and ungulate herbivory on cottonwood and willow through establishment and analysis of recruitment dates (using dendrochronology) and correlations to water tables and precipitation patterns.

Interagency Oversight:
The team of agency and organization partners is key to the ultimate success of this project. The partners have different management philosophies, different management goals and different assignments. It is important, however, that the various groups can identify those goals that they do have in common and cooperate in management actions addressing any common goals. The team has agreed to meet 2x/year to evaluate progress of this study; to provide input, ideas and support; and to discuss common needs and potential common management actions and experiments.

EnvironmentalPlanning:
National Park Service and USFWS (Refuge) permits will be acquired to sample plants and soils, and establish temporary PVC pipe wells. We are required to go through the International Animal Care and Use committee for USGS approval for capturing and radio-collaring elk. This approval process will be completed before the elk capture in December 2004. Bison handling will be done by TNC in routine round-ups. In addition, we will be required to follow DOI animal capture guidelines and protocols, and we will prepare and have an approved ACETA plan. The PIs have strong experience handling ungulate species, and no problems are foreseen with these approval processes. There are no other legal considerations (NEPA, ESA, etc.) for this project.

Principal Project Managers:
Dr. Francis J. Singer, Research Ecologist and Project Leader, Ungulate Ecology Studies, U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Avenue, Bldg. C, Fort Collins, Colorado 80526, 970-491-7056, Fax 970-491-1965, Email: francis@nrel.colostate.edu.

---

[1] The study area for this project is provided in Fig. 1 and is defined as the low elevations of Great Sand Dunes National Park and adjacent lands west to the main Highway 17 (including the refuge), north to Highway T, south to include the Medano-Zapata Ranch, and all lands south to Highway 160. We will evaluate carrying capacity in three ways: 1) a gross forage-based model using our empirical data in different vegetation types and mapping, 2) a population-based model based on logistic growth rate (a rougher model, but still worthwhile), and 3) a nutritional carrying capacity model based on Hobbs (1982) where we measure nutrient content in ungulate forage species.

Kathryn A. Schoenecker, Ecologist and Assistant Project Leader, Ungulate Ecology Studies, U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Avenue, Bldg. C, Fort Collins, Colorado 80526, 970- 226-9329, Fax: 970-226-9230, Email: kate_schoenecker@usgs.gov.

Linda C. Zeigenfuss, Ecologist, Ungulate Ecology Studies, U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Avenue, Bldg. C, Fort Collins, Colorado 80526, 435-789-0555, Email: Linda_Zeigenfuss@usgs.gov.

Dr. Bruce C. Lubow, Research Associate, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado 80523, 970-229-9637, Email: bruce@cnr.colostate.edu

Dr. Gary Wockner, GIS Modeler, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado, 80523-1499, 970-491-5724, Email: Gwockner@nrel.colostate.edu

Approach and Methods:

Elk Distribution and Habitat Use. We will capture and radio collar 65 adult elk using a net gun and OAS approved contractor. We will radio-locate these animals twice per month during the migration period to determine extent and range of movements. 65 radio collars with 2 flights/month will be 1,560 locations/year – an adequate sample size for building a sightability model (B. Lubow, per. Commun.) and for determining animal movements. We will also track animals with ground crews. We will estimate elk population size by flying aerial surveys 3x/winter and recording sighting variables. We will plot elk groups to determine distribution. A GIS-based elk habitat model will be developed using the elk locations. Using this model we can project the areas that elk will potentially use across the entire study area.

Elk Population Size and Dynamics. We will estimate elk population size by flying aerial surveys 3x/winter and recording sighting variables. We will provide a basis for improved abundance estimates for this population. Currently, annual aerial surveys are conducted by CDOW that classify a sample of the population to sex and age. No methods are used, or data collected, to correct these raw counts for sighting bias, nor does this method provide a basis for computing precision (confidence intervals). Sightability bias correction models have been developed (Samuel et al. 1987; Unsworth et al. 1994, Lubow et al. 2002) and tested for other elk herds (National Bison Range, Starkey Research Area). Existing models require collection of additional covariates such as group size, snow cover, and tree cover. We will gather the required variables and apply these to raw counts to improve population estimates. We will use models developed across large areas of Idaho and also models tested in Colorado (Freddy et al. 2000; Lubow et al. 2002) that have been found generally applicable to large areas. For example, the White River and Rocky Mountain National Park models were generally equivalent. Forty data points will be gathered for sightability variables and these points will be tested against the Idaho model. If the Great Sand Dunes data is parsimonious with the Idaho model, we will proceed with a combined model of Idaho and Great Sand Dunes data points. If the Great Sand Dunes data is not consistent with the Idaho data, we will develop a specific sightability model for the Great Sand Dunes complex of lands.

We will combine our unbiased estimates of population size with existing calf production and yearling recruitment rates sampled by CDOW to provide a basis for a simple population model of this elk herd. About 15 years of helicopter data is available for the entire elk herd. We will fit a series of alternative hypothesized models to the available data using maximum likelihood estimation and select the most appropriate, parsimonious model from the set using Akaike's Information Criterion (Burnham and Anderson 2002). We will calculate the rate of population increase (lambda) and attempt to identify evidence for density dependence, particularly in calf recruitment. Correlations of appropriate weather covariates with annual recruitment can be explored. If possible, we will estimate food-limited carrying capacity from the population growth trajectory following procedures described in Lubow et al. (2002) and White and Lubow (2002). This model will provide an improved basis for evaluating management alternatives, including harvest options.

Bison Habitat Use and Distribution. Ten bison will be radio-collared with VHF collars during routine corral trap operations. We will also radio-collar 4 bison with GPS collars for frequent monitoring and better habitat use information. The Nature Conservancy has asked for several monitorings/month to describe in detail the seasonal movements of bison for the bison habitat analysis, and the grazing model for both elk and bison. We will also collect hair samples from 200 bison (randomly selected as they are rounded up) for genetics evaluation. Hair samples will be stored until analysis in paper bags, and analysis will be conducted if new funds are available. Lab costs for genetics tests are not covered under this proposal.

Vegetation and Management Studies. We will erect 16 new ungulate proof exclosures; 4 in cottonwood, 4 in willow, 4 in swale, and 4 in wet meadow (especially spiderflower sites). We will also locate any other suitable already existing exclosures (e.g., any ungrazed fenced areas). We will sample these exclosure and paired grazed sites in years 2-3 of the study for plant production responses; plant species responses (using modified Whittaker plots); offtake (grazing utilization cages and shrub measurements); and willow/cottonwood density, recruitment, and death. We will also measure a majority of these variables across a landscape-scale sample of cottonwood and willow stands (n = 35). We will conduct management treatments in versus out of exclosures (factorial design) including burning, summer flooding of meadows (for willow/spiderflower), movement of bison by driving them, management hunts to move elk, dune management, and evaluate management treatments in Year 3. A variety of management experiments may be conducted by the agencies starting in year 2-3 of the study that might include reductions of elk, increase in bison, experiments with duration and timing of elk hunts to minimize effect on their distribution, and possible management of the refugia to eliminate over-concentrations. We will monitor and evaluate the effects of the experiments the agencies plan to use.

Interactions of Herbivory, Climate and Irrigation. We will age both cottonwood and willow (willows aged at basal root crowns) to determine the year they were established. We will establish water wells at each paired exclosure/grazed site. We will attempt to correlate fluctuations in water tables and precipitation to periods of woody establishment. Is herbivory correlated to declining water tables or to partial sand burial? Damaged or stressed plants are often more susceptible to browsing and are often more palatable to ungulates during periods of stress. Thus drought could exacerbate the effects of herbivory of an increasing ungulate population. We will irrigate 2 of the paired willow sites, reduce water flow to 2 others, and study the remaining 2 sites as controls, and observe responses of rates of elk herbivory to the treatments. We will compare partially buried to unburied willows. Plant physiology responses to the treatments would also be desirable information (rate of water stress, photosynthesis, isotope signatures of water sources) but are beyond the scope of this study. We are currently investigating the potential for an additional study of plant physiology of the willows and cottonwoods.

Elk and Bison Grazing Model and Estimates of Carrying Capacity. We will estimate carrying capacity using three methods: First, we will use the method of forage biomass-based estimate of carrying capacity for elk that has been used for elk and bison in the Greater Teton Ecosystem (Hobbs et al., 2003). This method uses available forage, estimated offtake levels, and forage requirements to estimate ungulate numbers that can be supported across large landscapes. Using GIS technology, this method will be coded into a model which will allow simulation of the needed management scenarios outlined in the next section. Inputs for this model will be products derived from the Vegetation Studies described in the previous section, Park and area vegetation maps which already exist, and estimates of ungulate forage requirements derived from previous research in similar systems. Second, we will estimate carrying capacity using the mathematical approach outlined by Hobbs et al. (1982) and also used in the Greater Teton Ecosystem (Hobbs et al., 2003). This spreadsheet/mathematical method relies on forage quantity/quality and ungulate nutritional needs to derive an estimate. Inputs for this model will come from sampling of forage quality (nitrogen concentrations) in key elk habitats, as well as prior research in similar systems. These first 2 methods proved highly successful in a very similar project in the Greater Teton Ecosystem and met the needs of project stakeholders including USFWS, NPS, Wyoming Game and Fish, and USFS. In addition, we will use a population-based model that is based on the logistic growth rate of the population. This is a rougher estimate, but still worthwhile. We plan to use all 3 methods to gain confidence in our final estimates of carrying capacity for the area.

Elk and Bison Population Management Scenarios. We will evaluate the effect of special hunts in moving elk out of lands in which they are concentrating through radio-tracking and monitoring radio-collared elk, and aerial flights of elk distributions. The NPS will conduct simulated dispersal hunts in lower Sand Creek in years 2 or 3 of the study to attempt to drive elk into nearby hunt zones. USGS will closely monitor this drive effort. How long do elk stay away from any areas they vacate and where do they move? Using the GIS-based Grazing Model (above), we will predict effects of the following scenarios: reducing bison numbers, reducing elk numbers, moving bison around by driving them, encouraging annual migrations of bison, and moving elk around with hunts or drives. We will evaluate fencing elk and bison from key vegetation stands.

Park and Agency Management After Model Development. Following the 3-year effort, NPS and the other agencies will be provided with: (a) elk sightability corrections for continued reliable population estimates, (b) GIS-based habitat model outlining all of the potential elk and bison habitat, and GIS-based carrying capacity estimates for elk and bison, (c) elk population-harvest model, and (d) elk-bison grazing model. Population modeling and the grazing model will be used in developing a variety of management scenarios.

Dispersal Hunts

Managers seek answers to the following questions on dispersal hunts: (1) what % of the elk left the hunt area? (2) how many could be harvested? (3) how long did the elk stay away from the hunt area? (4) was their habitat use similar upon return to the hunt area -- did the use of cover increase? (5) was there any long-term avoidance of the area, especially for areas hunted for several years in succession? (6) was there a vegetation response due to dispersal hunts? (7) were dispersal hunts successful in limiting herd growth rate to zero? and (8) were dispersal hunts successful in reducing or eliminating the presence of elk west of Highway 17? We will assist CDOW and the other agency clients with evaluation of responses of elk to dispersal hunts to the extent feasible. The dispersal hunts occur over a long (6.5 month) period, and thus pre- and post-hunt data collection does not appear feasible because seasonal movements could be confused with movement responses to dispersal hunts. The movement of elk in hunted compared to control (unhunted) areas might provide useful information on elk responses to the hunts. Apparently elk numbers have declined in some areas (west of Hwy 17, Deadman Creek) following 2 winters of dispersal hunts. Our herd-wide distributional surveys over the 3-years of the study may prove useful to evaluating the shifting response of elk, because these are both large hunted and large unhunted (control) areas within the study area to compare.

The NPS will conduct a simulated dispersal hunt within the park in lower Sand Creek in year 2 or 3 of the study. Twelve to 15 workers will simultaneously drive ¼ mile wide strips in both tall woody riparian habitats and then later in adjacent upland vegetation types. Workers will walk the areas slowly within sight of each other. Cracker shells will be shot off at periodic intervals and whenever any elk are encountered. The hypothesis is that elk can be driven from the park lands into adjacent hunt areas where some of the animals can be harvested. We hypothesize some of these elk will have been so recently hunted that they will run from the drivers and cracker shells. Flight response is a behavior easily passed on to other elk in the group. If the elk slip around the drivers and remain in the habitat or return that night back into the park, then the drives will not be a useful technique to move elk into huntable areas.

We propose to collect both detailed information on grazing and browsing levels and on elk distribution and movements in lower Sand Creek before the simulated hunts take place. Two years of pretreatment data has been suggested (S. Chaney, pers. commun.). The most desirable situation is to obtain both *before* and *after* vegetation data from the same hunt area. Height of browsed species, any recruitment, level of offtake, and biomass production will be sampled, and pictures of key browsed sites will be taken pretreatment and 1-year (plus subsequent years) post treatment (post hunt). This is the most desirable experimental situation. We propose to collect the same vegetation data in these areas and to use hunting as a covariate in a regression analysis.

Body Condition Model for Elk

NPS and USGS seek to develop a model of elk condition for the Great Sand Dunes - Crestone - Sangre de Cristo complex. Managers want to know what effect the following variables have on elk condition: elk population density (the density may be greatly reduced in the next few years), drought (the area is subject to periodic severe drought), and subpopulation or area (how do elk fair in the more typical higher summer range of the Sangre de Cristos versus the less typical low elevation summer range that some elk select in the valley floor). The study should include not only cows, since they are producers and the typical class of concern for reproduction, but also adult and raghorn bulls since they use very different areas from cows, and calves where feasible because calf condition and calf survival are the most sensitive class to respond to environmental change. The model should first portray the importance of these variables to elk condition, but secondly project scenarios. How might condition (and calf production) differ in the population as management may seek to alter elk distribution? What will be the effects of any protracted drought on elk condition? Conversely, the effects of irrigation of some (desired) elk use areas? There will be 2 sources of information on the body condition of elk. First, the capture of elk for radio-tagging presents an opportunity to sample body mass, and body fat samples using ultrasound that do not harm the elk.

Second, dispersal hunts present the opportunity to collect all of these measures, plus also measure rump fat and loin muscle from the dead animals.

We propose to sample elk body condition using a score developed by John Cook and coworkers (Cook et al. 2004). This score combines a measure of palpation of the wither, ribs and rump (= BCS score) combined with a measure of subcutaneous rump fat thickness, the latter measured using ultrasound (Stephenson et al. 1998). We will sample the catabolism of lean mass of elk during the winter months by measuring the thickness of the longissimus dorsi (loin) muscle between the 12^{th} and 13^{th} rib. The BCS score will be converted to an estimate of body fat (%) and gross energy using the equations developed by Cook et al. (2001a, b).

Pregnancy rates are also a sensitive indicator of the nutritional status of elk. This is particularly true for yearling cows where the pregnancy rate may be high in herds in good condition to almost zero in herds that are not. We propose to sample pregnancy from the live captured cows (that will be radio-collared) using pregnancy-specific protein B (Noyes et al. 1997) from serum from cows captured fall-winter. We will inspect for the presence/absence of a fetus in cows harvested August to February in the hunts.

The capture of elk for the study and the dispersal hunts over the next few yeas will provide a unique opportunity for a comprehensive study of elk body condition. There has been no prior assessment. In particular, managers want to know: 1) What is the relative condition of elk that both calve and spend the summer on the valley floor? The area is very atypical summer range for elk. Are those elk in poor or good condition? What motivates these elk to summer in what appears to be a poor area; the area is dry, hot, and in a sand dune complex. 2) What is the condition of elk summering high on the mountain meadows and subalpine areas? These elk share this summer range with the state's largest bighorn sheep population. 3) The valley is very low in precipitation and prone to periodic severe droughts. How is elk body condition influenced by annual precipitation in such a dry environment? 4) What is the age composition of the elk population? A primary goal of this part of the study is to assess the nutritional potential for both elk and bison in Great Sand Dunes and adjacent areas. Body mass and body condition are critical variables used in the suite of nutritional-energetic models of ungulate carrying capacity developed by Hobbs et al. (1982). These body variables are almost never available from study areas, and modelers typically guess what these variables would be based upon reports from other areas from the literature. Body fat is closely and positively correlated to survival of adult elk over winter. Body mass was positively associated with higher survival of elk calves in Yellowstone National Park – i.e., bigger calves survived at a higher rate from all sources of mortality, including predation (Singer et al. 1997). N.T. Hobbs, a research ecologist for CDOW, strongly urged our study team to gather data on elk body condition, as did G. Wockner.

As a second goal, we propose to sample the condition of elk in order to better understand the ecology of a rare and unique population of elk that resides in a complex of active and stabilized sand dunes. The diet of elk in summer for this herd may be unique in that the dunes have large amounts of sedges, rushes, and willow (F. Singer, L. Zeigenfuss, pers. obs.). These forages typically represent very small amounts of the diet of elk (Singer et al. 2004), and sedges and rushes are typically viewed as poor forages for elk. Understanding the nutritional ecology of elk in the greater sand dunes ecosystem may provide insights that could later be used in the management program for elk. The potential usefulness for this information can not be completely predicted at this time – the information may prove quite useful.

CDOW is constrained from spending Habitat Preservation Program (HPP) funds on anything other than management topics. NPS and USGS are not so constrained. NPS will pay for the collection of the data on elk nutritional ecology and patterns in body condition and USGS will collect the data. We propose to hire a field veterinarian on the project. One-quarter of that individual's responsibility will be the collection of data on elk body condition, body mass, pregnancy, etc. from elk harvested during the dispersal hunts, and from elk captured for radio-collaring. The veterinarian will work with the Cook's of Oregon (John and Rachel) to correctly use the ultrasound fat-measures for elk. The person we intend to hire already knows and has strong experience with standard ultrasound technology.

<u>Chronic Wasting Disease</u>. The USFWS has asked that the study incorporate some testing for the disease. The study area is out of the general range for CWD, but some monitoring would be useful. The dispersal hunts of elk, in particular, will provide an opportunity for sampling of tissues for the detection of chronic wasting disease (CWD). We propose that CDOW collect 75 elk/year (225 total) from dispersal hunts, and brain tissues of collected animals

be examined for the presence of CWD. Currently no live test exists for elk for CWD, so a sample of harvested animals would need to be tested. Animals that are aerial captured and animals that are collected during dispersal hunts will also be observed visually for signs of CWD; namely weak, thin body condition or abnormal behavior. Suspect animals will be collected and tested for CWD. Funds for CWD testing can come from USFWS directly to CDOW.

Relation of this Project to U.S. Fish and Wildlife Service Needs. The Refuge will be an active cooperator and participant in the project. The State will fulfill USFWS needs for CWD testing, and this project will address bison effects on the system to assist USFWS in their decision as to where bison will be permitted. In addition, USFWS will need information about elk carrying capacity and elk range condition on and off the Baca National Wildlife Refuge in order to make informed and solid management decisions.

Data Analysis

Data will be analyzed using SAS statistical software V8 (SAS Institute 1988). Experimental design of the vegetation study will be a stratified random design with 4 vegetation associations (swale, cottonwood, willow, wet meadow). We will use multivariate methods and ANOVA procedures to evaluate differences in treatment effects. Ungulate consumption will be determined using the difference method: % Consumption = $100 \times (B_i - B_o)/B_i$, where B_i = dry weight of biomass inside grazing cage, and B_o = dry weight of biomass outside cage. Herbaceous biomass differences will be analyzed using ANOVA procedures. For exclosure site selection and establishment, we will use a random design within vegetation strata. We will use regression analysis to analyze body condition data, where the parameters to be tested include a comparison of the body condition and pregnancy rate of elk using high elevation summer range versus low elevation summer range, the effect of drought on elk pregnancy and body condition, the effect of subpopulation or habitat area on body condition, and the effect of elk population density on body condition and pregnancy rate.

Tasks, Organization, and Schedule:

Chronology	Task	Responsible Agency	Completion Date
1	Collect pre-treatment data in exclosure site locations	NPS/USGS	Aug. 2004
2	Purchase radio-collars for elk and bison	USGS	Nov. 2004 (order in Aug. 2004)
3	Submit application for International Animal Care and Use Committee (IACUC) permit and plant collecting permits	USGS	Aug. 2004
4	Schedule aerial capture with H&P	USGS	Aug. 2004
5	Prepare ACETA plan	NPS	Sep. 2004
6	Hire staff (1crew leader, 2 biotechs, 3 volunteers, 1 field veterinarian)	USGS/NPS	Oct. 2004 (field veterinarian) and Jan. 2005 (rest of crew)
7	Hire staff/contractors for exclosure building	NPS	Oct. 2004
8	Build grazing exclosures	NPS/TNC/USGS	Oct.-Nov. 2004
9	Find housing for biotechs and volunteers	NPS/TNC	Oct. 2004
10	Address any environmental assessment considerations	NPS	Oct. 2004
11	Begin collection of elk carcasses for CWD testing, and body condition analysis	CDOW/USFWS/USGS	Nov. 2004
12	Schedule 3 aerial surveys for elk with H&P	USGS	Dec. 2004
13	Locate and secure a flight manager for aerial surveys	NPS/USGS	By first flight
14	Round-up and radio-collaring of bison	TNC/USGS	Dec. 2004
15	Aerial capture and radio-collaring of elk	CDOW/USGS/NPS	Jan. 2005
16	Purchase PVC pipe and establish temporary wells	USGS	Mar. 2005
17	Build and set out grazing cages	USGS/NPS	Mar.-Apr. 2005
18	Metadata development	USGS	Dec. 2005
19	Annual reports to NPS (AAR)	USGS	Dec. 2005 and Dec. 2006
20	Modeling reports completed	USGS/CSU/NREL	Dec. 2007
21	AAR and Final report to NPS	USGS	May, 2008

Deliverables and Reporting Requirements:
We will submit an annual accomplishment report (AAR) each year of the study to the NPS. A final report to NPS will be completed by May 2008, with drafts to be reviewed beforehand by NPS staff. Metadata will be developed for the project according to NBII requirements.

Quality Assurance and Quality Control:
Analysis of plant samples for nutrient concentration will be conducted by the Range Nutrition Lab, Colorado State University, in Fort Collins, Colorado. Collection permits from NPS will be acquired for all plant clippings, any plant removals, and soil samples. Soil nutrient concentrations will be analyzed at the ARS/USGS Lab in Fort Collins, Colorado. All animal handling and collaring will be approved by the International Animal Care and Use Committee and ACETA processes, and any state permits acquired from the Colorado Division of Wildlife. Analyses of blood from radio-collared animals, and from elk collected by CDOW in special hunts will be analyzed by Wyoming State Vet Lab, Laramie. Dental cementum aging analyses of elk collected in special hunts will be conducted by Matson's Lab in Milltown, Montana. Body condition analyses of elk collected in special hunts and during aerial captures will be conducted by a licensed veterinarian specifically trained in the ultrasound technology for body fat of elk.

References:

Boyce, W.M., A.K. Mazert, J. Mellies, R.A. Clark, and D.A. Jessup. 1991. Kinetic ELISA for detection antibodies of *Psoroptes* spp. in bighorn sheep. Journal of Parasitology 77:642-696.

Burnham, K. P., and D. R. Anderson. 2002, Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, NY, USA. 488 pp.

Cook, J.G., B.K. Johnson, R.C. Cook, R.A. Riggs, T.Delcurto, L.D. Bryant, and L.L. Irwin. 2004. Effects of summer-autumn nutrition and parturition data on reproduction and survival of elk. Wildlife Monographs 155:1-61.

Cook, R.C., J.G. Cook, D.L. Murray, P.Zager, B.K. Johnson, and M.W. Gratson. 2001a. Nutritional condition models for elk: which are the most sensitive, accurate, and precise? Journal of Wildlife Management 65:988-997.

Cook, R.C., J.G. Cook, D.L. Murray, P.Zager, B.K. Johnson, and M.W. Gratson. 2001b. Development of predictive models of nutritional condition for Rocky Mountain elk. Journal of Wildlife Management 65:973-987.

Frank, D.A., S.J. McNaughton and B.F. Tracey. 1998. The ecology of the earth's grazing ecosystems. Bioscience 48:513-521.

Freddy, D.J. 2000. Mammals Research; Elk Management: Estimating Survival Rates of Elk and Developing Techniques to Estimate Population Size. Colorado Division of Wildlife, Project Number: CO W-153-R-13. 20 pp.

Hobbs, N.T., D.L. Baker, J.E. Ellis, D.M. Swift, and R.A. Green. 1982. Energy and nitrogen based estimates of elk winter range carrying capacity. Journal of Wildlife Management 46:12-21.

Hobbs, N.T., G. Wockner, and F. J. Singer. 2003. Assessing Management Alternative for Ungulates in the Greater Teton Ecosystem using Simulation Modeling. USGS-BRD and NREL-CSU.

Holzgang, O. 1997. Herbivore carrying capacity of grasslands in the Swiss National Park. Thesis. Swiss Federal Institute of Technology, Zurich.

Lubow, B.C., F.J. Singer, T.J. Honson, and D.C. Bowden. 2002. Dynamics of interacting elk populations within and adjacent to Rocky Mountain National Park. Journal of Wildlife Management 66: 757-775.

Noyes, J.H., R.G. Sasser, B.K. Johnson, L.D. Bryant, and B. Alexander. 1997. Accuracy of pregnancy detection by serum protein (PSPB) in elk. Wildlife Society Bulletin 25:695-698.

Samuel, M.D., E.O. Garton, M.W. Schlegel, and R.G. Carson. 1987. Visibility bias during aerial surveys of elk in north-central Idaho. Journal of Wildlife Management 51:622-630.

SAS Institute. 1988. SAS/Systat User's Guide. Release 8.0 edition. SAS Institute, Cary, N.C., USA.

Schoenecker, K.A., F.J. Singer, L.C. Zeigenfuss, D. Binkley, and R.Menzes. 2004. Effects of ungulate herbivory on plants and nitrogen processes in Rocky Mountain National Park. Journal of Wildlife Management: In Press.

Singer, F.J., A. Harting, K.K. Symonds, and M.B. Coughenour. 1997. Density dependence, compensation, and environmental effects on calf mortality. Journal of Wildlife Management 61:12-25.

Singer, F.J. and J. Mack. 2000. Predicting the effects of wildfire and carnivore predation on ungulates. Pages 189-237 *in* T.W. Clark et al., editors. Carnivores in ecosystems. University Press.

Singer, F.J., T. Hobbs, and G. Wang. 2002. The role of large grazing ungulates and large keystone predators on plant structure and ecosystem processes. *In* R. Anthony and C. Zabel, eds. Cambridge University Press. (In press)

Singer, F.J., and K.A. Schoenecker. 2003. Do ungulates accelerate or decelerate nitrogen cycling? Forest Ecology and Management 181:189-204.

Singer, F.J., D.M. Swift, M.B. Coughenour, and J.D. Varley. 1998. Thunder on the Yellowstone revisited: An assessment of management of native ungulates by natural regulation, 1968-93. Wildlife Society Bulletin 26:375-390.

Singer, F.J., M.B. Coughenour, and J.E. Norland. 2004. Elk biology and ecology before and after the Yellowstone fires of 1988. Pages 117-139 *in* L. Wallace, ed., After the fires: the ecology of change in Yellowstone National Park. Yale University Press, New Haven and London.

Smith, B.L. and R.L. Robbins. 1994. Migration and management of the Jackson elk herd. National Biological Survey Research Publication No. 199. National Biological Survey, Washington, D.C.

Stephenson, T.R., K.J. Hundertmark, C.C. Schwartz, and V.VanBallenberghe. 1998. Predicting body fat and body mass in moose with ultrasonography. Canadian Journal of Zoology 76:717-722.

Unsworth, J.W., F.A. Leban, D.J. Leptick, E.O. Garton, and P. Zager. 1994. Aerial survey: User’s manual. Idaho Fish and Game Department, Boise.

White, G. C., and B. C. Lubow. 2002. Fitting population models to multiple sources of observed data. JWM 66:300-309.

Wurster, F.C., D.J. Cooper, and W.E. Sanford. 2003. Stream/aquifer interactions at Great Sand Dunes National Monument, Colorado: influences on interdunal wetland disappearance. Journal of Hydrology 271:77-100.