Project Title: Forecasting in Support of Adaptive Management of the Rocky Mountain National Park Elk Herd

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Investigators and Agency Representative:
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Project Abstract: The National Park Service manages the abundance of elk wintering in Rocky Mountain National Park (RMNP) to meet objectives specified in the recently developed Elk and Vegetation Management Environmental Impact Statement (EIS. The EIS specifies that the elk population will be maintained within a target range of 600 – 800 animals. To achieve these objectives, the population will be managed adaptively. Each year, the size of the population will be assessed relative to the target range and, based on this assessment, management actions will be chosen to assure that the trajectory of the population remains within that range.

Essential to the success of this approach is a model of elk population dynamics that allows managers to forecast the effect of alternative management actions on the elk population. In earlier work, Hobbs and Hoeting (2009) developed a forecasting model that predicts the future size of the RMNP elk population based on historic data and current census estimates. Because the model uses historic data to estimate uncertainties associated with these predictions, it is feasible to specify the probability that the next year's population will be within limits specified by park management. It is also feasible to estimate the probability distribution of the current population size in a way that includes historic as well as current data and that responds to all sources of uncertainty revealed by the full, historical time series of observations of the elk population.

This model provides a firm, statistically defensible basis for adaptive management of the park's elk herd. Adaptive management will be implemented as follows. Each year, the size of the park's population and its sex and age composition will be estimated using modern census methods developed in a separate project. Using the forecasting model, the current year's data will be combined with the full time series of data in from previous years to estimate the probability distribution of the current and subsequent year's population size. These probability distributions form the basis for choice of management actions, particularly the number of animals to be culled. Moreover, the model's predictions from the previous year will be compared with the current, realized population estimate obtained from census. This comparison may motivate changes in the model to improve the accuracy of its predictions. This cycle will be repeated annually, allowing continuous improvement in the model and in management.

Work will be accomplished to support this cycle of adaptive management. Each year, the following tasks will be accomplished:

1) During March-April, RMNP will provide annual data on total population size, sex and age composition, and management culling to the Principle Investigator. The data provided by the park will include means and standard deviations of the total population size. There will be standard deviations representing the errors in the estimation model used in the census as well as standard deviations representing sampling variation (when multiple estimates are made). In addition, the park will provide counts of adult males, yearling males, adult females, and calves obtained during census (i.e., classification counts) as well as data on the number and sex and age of animals culled and treated with fertility control agents. The PI will assimilate these data into the Bayesian forecasting model. Model output will include means, medians, and probability distributions for elk population size, sex and age composition, and vital rates (survival and recruitment), and other parameters of interest.
2) The PI will compare model predictions of the current year's population size with the current year's data and will propose and implement improvements in the model, if they are needed.
3) In consultation with park staff, scenarios will be developed to represent alternative management actions chosen to influence the subsequent year's population size. The PI will implement these scenarios in model runs and will forecast the probability distribution of the

elk population size under each of the chosen scenarios. These forecasts will be reported to park staff annually during July-August.

4) The PI will be available to give presentations on the modeling effort to public meetings and to park staff.

5) The PI will meet as needed with other researchers working on census methods and with park staff to assure close coordination of census efforts and modeling.

Outcomes with Completion Dates: 1) Annual reports summarizing model results and future modifications, as described in task 2 and 3 above and 2) Oral presentations to the public and park staff as required.

Keywords: ecological modeling, elk, population management, Rocky Mountain National Park, Colorado State University