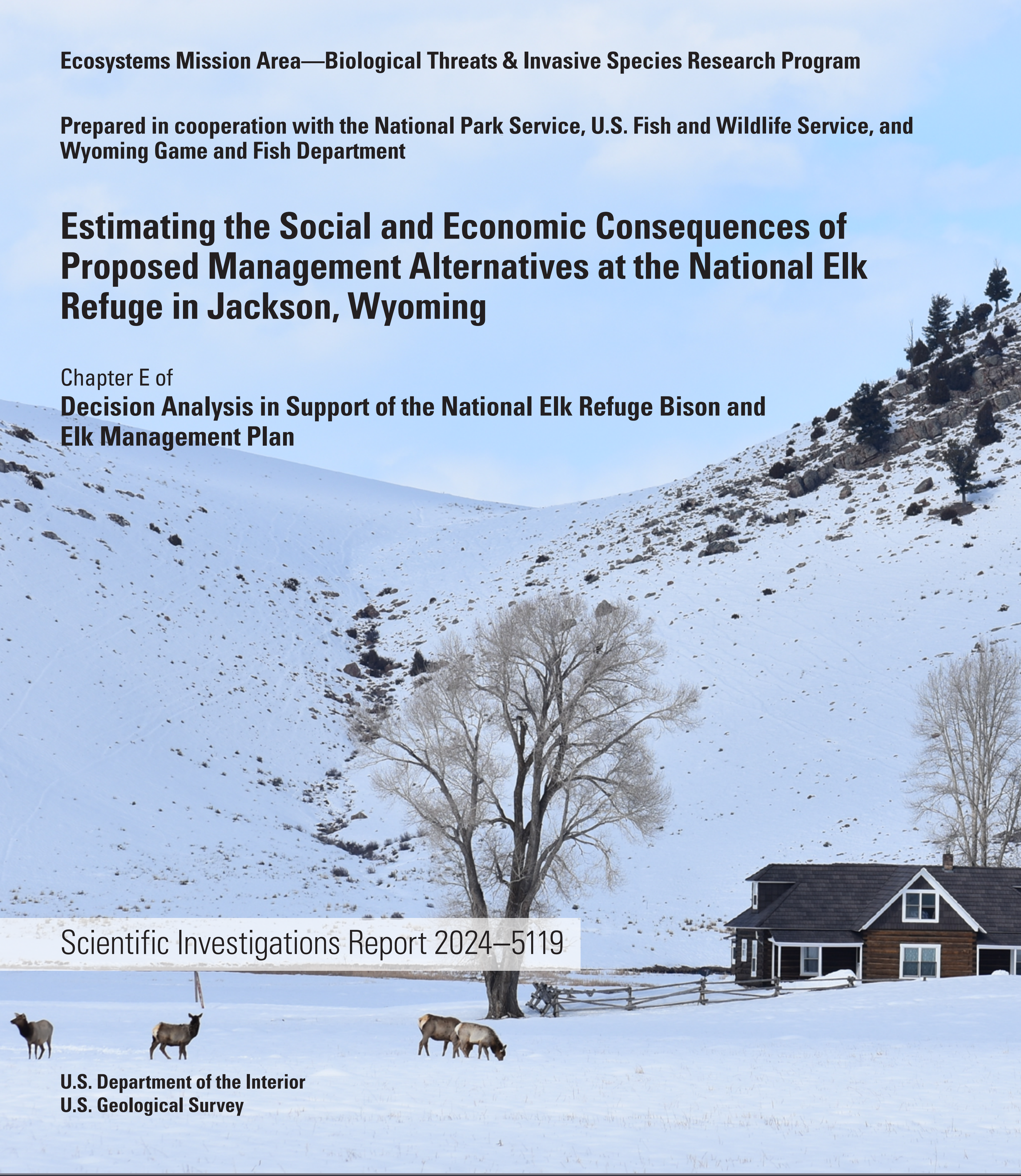
Ecosystems Mission Area—Biological Threats & Invasive Species Research Program

Prepared in cooperation with the National Park Service, U.S. Fish and Wildlife Service, and Wyoming Game and Fish Department

Estimating the Social and Economic Consequences of Proposed Management Alternatives at the National Elk Refuge in Jackson, Wyoming

Chapter E of
Decision Analysis in Support of the National Elk Refuge Bison and Elk Management Plan



Scientific Investigations Report 2024–5119

U.S. Department of the Interior
U.S. Geological Survey

Cover. Elk in the vicnity of the historic Miller Cabin on the National Elk Refuge. The Miller family sold their land to the federal government in the early 1900s, forming the first piece of what would eventually become the National Elk Refuge. Photograph taken by Gannon Castle, U.S. Fish and Wildlife Service, March 2020.

Estimating the Social and Economic Consequences of Proposed Management Alternatives at the National Elk Refuge in Jackson, Wyoming

By Margaret C. McEachran, Andrew Don Carlos, Gavin G. Cotterill, Eric K. Cole, Jonathan D. Cook

Chapter E of

Decision Analysis in Support of the National Elk Refuge Bison and Elk Management Plan

Edited by Jonathan D. Cook and Paul C. Cross

Ecosystems Mission Area—Biological Threats & Invasive Species
Research Program

Prepared in cooperation with the National Park Service, U.S. Fish and Wildlife Service, and Wyoming Game and Fish Department

Scientific Investigations Report 2024–5119

U.S. Department of the Interior
U.S. Geological Survey

U.S. Geological Survey, Reston, Virginia: 2025

Suggested citation:
McEachran, M.C., Don Carlos, A., Cotterill, G.G., Cole, E.K., and Cook, J.D., 2025, Estimating the social and economic consequences of proposed management alternatives at the National Elk Refuge, chap. E *of* Cook, J.D., and Cross, P.C., eds., Decision analysis in support of the National Elk Refuge bison and elk management plan: U.S. Geological Survey Scientific Investigations Report 2024–5119, 11 p., https://doi.org/10.3133/sir20245119E.

Associated data for this publication:
McEachran, M.C., and Cook, J.D., 2024, Socioeconomic effects of bison and elk management alternatives on National Elk Refuge: U.S. Geological Survey software release. https://doi.org/10.5066/P1DZS7MW.

ISSN 2328-0328 (online)

Acknowledgments

We gratefully acknowledge the participation of several employees of the Wyoming Game and Fish Department, U.S. Fish and Wildlife Service, and National Park Service who served as technical experts on the subject matter expert teams or provided data for the analyses presented. We also thank Nicholas Cole and Scott Chiavacci for reviewing and improving this work through their helpful suggestions. The work by Margaret McEachran was done while serving as a visiting scientist with the U.S. Geological Survey.

Contents

Figures

Tables

Abbreviations

>	greater than
<	less than
CWD	chronic wasting disease
FWS	U.S. Fish and Wildlife Service
JHU	Jackson Elk Herd Unit
NER	National Elk Refuge
WGFD	Wyoming Game and Fish Department

Estimating the Social and Economic Consequences of Proposed Management Alternatives at the National Elk Refuge in Jackson, Wyoming

By Margaret C. McEachran[1], Andrew Don Carlos[2], Gavin G. Cotterill[1], Eric K. Cole[2], Jonathan D. Cook[1]

Abstract

The National Elk Refuge (Refuge) is managed by the U.S. Fish and Wildlife Service and includes habitats for bison and elk. Bison and elk provide opportunities for wildlife-related recreation and contribute to the tourism industry in and around Jackson, Wyoming. Over the last century, the Refuge has provisioned supplemental feed to elk and, more recently, bison during winter months to ensure adequate forage and prevent starvation and conflict with private landowners. However, supplemental feeding artificially aggregates animals and can increase rates of disease transmission and localized damage to sensitive habitats near the feeding areas. This report presents analyses and results to support two of the nine management objectives in the next “Bison and Elk Management Plan,” with a particular focus on the social and economic consequences of five management alternatives considered in this study. The alternatives are to continue feeding bison and elk during winter months on the Refuge, stop feeding after CWD is measured at 3 percent prevalence or above in the Jackson elk herd, stop feeding immediately, reduce feeding for five years and then stop feeding, and increase elk harvest for five years and then stop feeding. These alternatives are anticipated to alter bison and elk population and space-use dynamics, with corresponding effects on wildlife-related recreation and tourism, including the number of visitors and sleigh-ride participants on the Refuge, and hunters and outfitters within the Jackson Elk Herd Unit. The performance of each of this study’s alternatives was variable, resulting in overlap in the performance of alternatives on the select objectives over the next 20 years. Generally, visitation-related objectives performed better under the continue feeding alternative, whereas hunting-related objectives performed better under the increase harvest alternative. The results presented here may assist U.S. Fish and Wildlife Service decision makers in balancing social and economic benefits identified in the decision-making process for the “Bison and Elk Management Plan” with other objectives evaluated in this report.

Introduction

The National Elk Refuge (NER or Refuge) spans 24,700 acres in northwestern Wyoming and is a part of the larger Greater Yellowstone Ecosystem that includes the Yellowstone National Park, Grand Teton National Park, and several national forests across Wyoming, Montana, and Idaho (fig. E1). The Refuge provides important seasonal habitats for many species including *Cervus canadensis nelsoni* (Erxleben, 1777; Rocky Mountain elk), *bison bison* (Linnaeus, 1758; bison), *Canis lupus* (Linnaeus, 1758; grey wolves), and *Ovis canadensis* (Shaw, 1804; bighorn sheep). Drawn by opportunities to view wildlife and scenery, participate in outdoor recreation, and visit rich cultural and historical sites, the Refuge receives several hundred thousand visitors annually (Dietsch and others, 2020). In addition, the Refuge offers visitors a place to hunt, fish, and ride horse-drawn sleighs to view the elk herd during winter (Dietsch and others, 2020). The management of the NER is administered by the U.S. Fish and Wildlife Service (FWS), and its primary purpose is to protect habitat for elk and other big game species. However, the Refuge has sought to provide opportunities for wildlife-dependent recreation and environmental education for the public and to prevent human-wildlife conflict (National Wildlife Refuge System Improvement Act of 1997—Public Law 105–57, 111 Stat. 1252).

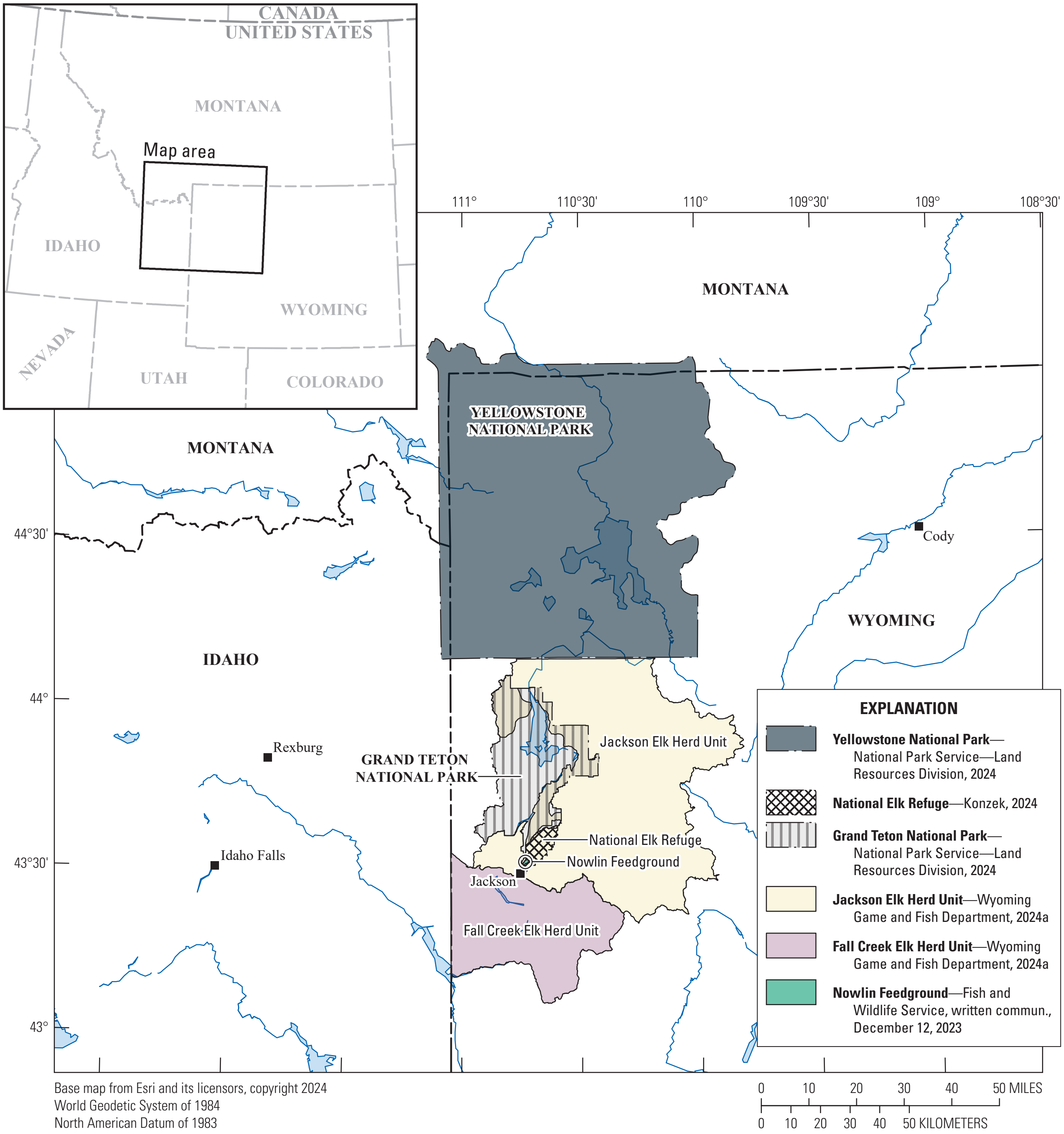
Lower elevation areas surrounding Jackson, Wyoming (fig. E1) have historically provided important overwintering habitat for many wildlife species, including elk. The NER was established in 1912 to ensure access to adequate elk winter range and reduce elk consuming feed or crops intended for domestic livestock when natural winter forage was insufficient. To supplement limited natural winter forage, the local citizens began feeding Jackson elk during winter months in 1910–1911, and, once established, the NER began conducting these efforts (FWS and NPS, 2007); the Refuge also began feeding bison in 1980 when a small free-ranging herd discovered the feedgrounds (Boyce, 1989). This supplemental feeding results in dense aggregations of elk and bison on the Refuge, providing opportunities to view higher numbers relative to unfed settings elsewhere in the Jackson region.

Across the country, over 500 Refuges in the National Wildlife Refuge System generate $3 billion annually and support 40,000 jobs, illustrating the substantial economic and social contributions

---

[1] U.S. Geological Survey.

[2] U.S. Fish and Wildlife Service.



Base map from Esri and its licensors, copyright 2024
World Geodetic System of 1984
North American Datum of 1983

Figure E1. Map showing the location of the National Elk Refuge, Grand Teton National Park, Yellowstone National Park, Jackson Elk Herd Unit, Fall Creek Herd Unit, and Nowlin Feedground within the study area.

that Refuges make (Caudill and Carver, 2019). For the NER, wildlife-related recreation and tourism provide notable economic benefits to the Jackson region. The most recent systematic visitor survey found that many visitors come to the Refuge for unique opportunities to view large numbers of elk up close when elk are being fed during the winter months. This highlights the effect that feeding activities have on tourism in the area (Dietsch and others, 2020) and suggests that changes to bison and elk feeding may affect tourism.

Several thousand hunters also visit the region to purchase harvest tags and pursue elk in the Jackson Elk Herd Unit (JHU), bringing additional economic benefits (Koontz and Loomis, 2005). Finally, hunting outfitters operate businesses and receive economic revenue based on opportunities to guide clients in the pursuit and harvest of elk.

In addition to local recreational and economic benefits, supplemental feeding has been used to reduce elk and bison use of agricultural or other private properties when winter forage is scarce. Wintertime provisioning of supplemental feed is typically triggered when winter sampling of available forage biomass at index sites, selected to represent sites preferred by elk in the south end of NER, indicates that forage availability has fallen below 300 pounds per acre (U.S. Fish and Wildlife Service, 2019). Together with the Wyoming Game and Fish Department (WGFD) wildlife hazing actions designed to actively and non-lethally move elk away from problem areas (U.S. Fish and Wildlife Service, 2019), the provisioning of supplemental feed on the NER effectively minimizes elk and bison use of private lands, thereby minimizing the risk of human-wildlife conflict in the Jackson region. Human-wildlife conflicts include the depredation of agricultural products, damage to structures and livestock by wildlife, and transmission of infectious diseases from wildlife to livestock.

Supplemental feeding also has negative consequences for the social and economic aspects of the system. The dense aggregations of elk on the NER during winter months degrade vulnerable plant communities and increase the likelihood of transmission of several infectious diseases, including diseases with significant economic implications, such as brucellosis and chronic wasting disease (CWD). Brucellosis is a bacterial disease that affects elk, bison, and cattle and is transmitted when a susceptible individual contacts a fetus aborted from an infectious individual (National Academy of Sciences, Engineering, and Medicine, 2020). Brucellosis can lead to substantial costs for cattle producers because of requirements for testing, quarantine, and culling of infected herds if the disease is detected to prevent future spread and risk of human infection (Boroff and others, 2016). Chronic wasting disease is a progressive, neurodegenerative disease of cervids caused by an infectious prion, which persists in prion-contaminated environments and may cause population declines in densely aggregated winter populations using feedgrounds (Galloway and others, 2021; Cook and others, 2023). Chronic wasting disease was first detected in the Jackson elk herd in 2020. Although no further positive elk have been detected despite mandatory testing of all harvested elk on the Refuge, the disease is expected to increase in prevalence which could have significant consequences for Jackson elk populations as well as the social and economic benefits associated with them (Cross and others, 2025, this volume, chap. B).

The FWS is currently creating an Environmental Impact Statement to revise its bison and elk management plan and to determine how to manage these populations in balance with the social, ecological, economic, and cultural features of the Greater Yellowstone Ecosystem landscape. The FWS is using a structured decision-making process to identify the fundamental objectives for this decision, including several related to the social and economic benefits that elk and bison provide to the area (Cook and others, 2025a, this volume, chap. A). A subset of those objectives is the focus of the analyses and reporting of this chapter, including Fundamental Objective 5—Maintain and enhance multiple use opportunities and public enjoyment; and Fundamental Objective 8—Maximize local economic benefits associated with bison and elk presence on the NER and surrounding lands.

To achieve their objectives, FWS is considering at least five alternatives that may affect the social and economic benefits associated with elk and bison in the NER and surrounding areas (Cook and others, 2025a, this volume, chap. A). Under a continue feeding alternative, the NER will continue to provision food to bison and elk during winter months based on forage availability and any human-wildlife conflicts. Under a no feeding alternative, the NER will immediately stop provisioning food to bison and elk during winter months. Under an increase harvest alternative, the NER will continue to provision food to bison and elk during winter months at current feeding rates for the next 5 years and then stop feeding. During this 5-year phaseout, the NER will work with the WGFD to increase elk harvest quotas for Hunt Area 77 (the NER, fig. E1) to reduce the elk population prior to feeding cessation. Under a reduce feeding alternative, the NER will continue to provision food to bison and elk consistently during winter months over the next 5 years but will reduce the daily amount of food that is provided to elk. The goal will be to reduce rations such that the total number of elk wintering on the NER will decline to 5,000 animals; then, after 5 years, feeding will stop completely. Finally, under a disease threshold alternative, the NER will continue feeding operations until CWD reaches 3 percent prevalence in the Jackson elk herd, at which point all feeding activities will cease on the NER.

The analyses presented herein provide decision makers with evidence for the potential effects of these management alternatives on the economic and social performance metrics, including visitation to the NER and visit- and hunting-related spending in the Jackson region. In this report, 20 model years marks the progress after implementation.

Methods

The U.S. Geological Survey developed three models to analyze the effects of the alternatives on visitation, visit- and hunting-related spending. The first model estimated the NER visitation, which we used to project visitor spending and sleigh ride participation; the second model estimated revenue from elk harvest tag sales; and the third estimated other hunting-related revenue for outfitters under changing elk and bison populations.

Modeling Visitation to the NER

Tourism in the Jackson region was expected to fluctuate as a function of several factors including national-scale socioeconomic trends, weather conditions, and wildlife presence (Loomis and Caughlan, 2004). This study's analysis only considered winter visitation (December–April) because that is when elk are concentrated on the Refuge, when feeding occurs, and when most visitors come to the NER, historically.

To predict the changes in the NER visits under each alternative, we worked with technical experts from FWS, National Park Service, and WGFD to model historical visitation to the NER using 2005–23 data. At the time of publication, NER visitation data were not publicly available from FWS. We first developed a set of predictors that could affect visitation patterns at the NER based on expert guidance and a study by Loomis and Caughlan (2004). The predictors included: annual U.S. population estimate (U.S. Census Bureau, 2024), annual per capita income for U.S. residents (U.S. Census Bureau, 2024), monthly consumer price index (Federal Reserve Bank of St. Louis, 2024), monthly vehicle counts at the Moose, Wyoming entrance of Grand Teton National Park (National Park Service, written commun., 2024), monthly average temperature (degrees Fahrenheit), monthly precipitation total (inches) from the Jackson area weather station (Abatzoglou and Hegewisch, undated), and weekly counts of elk and bison on the NER that were summed into monthly counts (FWS, written commun., 2024). Indicator variables for month and year to account for any general short- and long-term trends in visitation that could not be explained by the variables previously listed were also considered.

Initial examination of the variables revealed strong correlations among consumer price index, Grand Teton National Park visitor counts, U.S. population, income per capita, and the variable for year. We retained only the year variable and considered it an index for all variables that trended positively with visitation over time. Further, monthly bison counts were excluded at this stage because of recent changes in bison herd dynamics that have resulted in a smaller population size and less wintertime use of the NER with no observable effect on the NER visitation. All predictor variables were centered and scaled to a mean of 0 and standard deviation of 1 using their historical mean and standard deviation prior to model fitting.

For model fitting and parameter estimation, we fit an initial model of monthly NER visitor center counts as a negative binomial response variable regressed on the remaining variables using a Bayesian approach (elk monthly counts, average monthly temperature, average monthly precipitation, year, and month variables). No evidence that average monthly temperature or precipitation affects the NER visitation was found and therefore these variables were excluded. We then fit a final model using monthly NER elk counts, year and month variables. This model was used to predict winter *visits* to the NER in each month, *i,* with a mean, μ, and dispersion parameter θ given by equation 1:

$$visit\,s_i \sim NegBin(u_i, \theta) \tag{1}$$

$$\log(\mu_i) \;=\; \beta_0 + \beta_1 monthlyelk + \beta_2 monthDec + \beta_3 monthJan + \beta_4 monthFeb + \beta_5 monthMar + \;\beta_6 year.$$

We used uninformative priors distributed as *Normal(0, 100)* for the slope terms, and *Normal(10, 100)* for the intercept. We ran 3 Markov chain Monte Carlo simulations (Gelman and Rubin, 1992) with 50,000 iterations, a thinning rate of 2, and a burn-in of 25,000 to generate posterior distributions for each model parameter, β. We assessed convergence using the Gelman-Rubin statistic (Gelman and Rubin, 1992) and model fit using a Bayesian posterior predictive check to estimate a Bayesian *p*-value (Gelman and Tuerlinckx, 2000). All statistical analyses were performed in R (version 4.3.1) and the r2jags package (R Core Team, 2018; Su and Yajima, 2024).

To predict future NER winter visitation under each alternative, we sampled from the posterior distribution for each variable of the fitted model and multiplied it by the corresponding simulated elk count, and temporal variable (month and year). The posteriors of the fitted coefficients were used to represent parametric uncertainty in the effect that each predictor had on future NER visitation. The results from chapters B and C provided 100 estimates of elk counts at monthly timesteps for 20 years under each alternative (Cotterill and others, 2025, this volume, chap. C; Cross and others, 2025, this volume, chap. B). The other predictors were time variables (month, year) that did not change across alternatives.

Predicting Visitor Spending

Changes in visitor spending were calculated using the projected number of visitors from the previous model in conjunction with NER visitor spending data collected during December 2018 and March 2019 (Dietsch and others, 2020). These data report differences in spending by residency status (local was defined as residing within 50 miles of the Refuge and nonlocal residents defined as holding residence greater than 50 miles from the Refuge) and trip purpose (primary purpose, equal purpose to other local attractions, and incidental purpose includes trips to the NER that were unplanned). These data were also expected to be representative of winter season NER visitors and spending patterns that may be affected by the alternatives. For the visitor-related spending calculations, only data from nonlocal residents (respondents who lived >50 miles away from the Refuge) were included because of limited data for local residents (<50 miles from the Refuge). Local residents represented only 20 percent of survey respondents, were inconsistent in reporting their Refuge-related spending, and did not typically report a number of days associated with each trip. Additionally, local residents were assumed to continue spending money in the local area under all alternatives whereas nonlocal resident spending may be sensitive to any changes caused by the alternatives.

In accordance with guidance prescribed by the Office of Management and Budget (2023) and an assumption that benefits of consumer spending in the near term are more valuable than those that are received farther into the future, future spending values were adjusted using a nominal discount rate of 4.7 percent annually. This nominal discount rate adjusts for declining present value for monetary benefits that are received many years into the future.

Predicting Sleigh Ride Participation

Private concessionaires offer sleigh rides that provide winter NER visitors the opportunity to experience the Refuge and get close to large groups of elk (Loomis and Caughlan, 2004). Given the possibility that feeding changes could affect sleigh ride participation and operations, the historical relationship between sleigh ride participation and weekly elk counts on the Nowlin feeding area where sleigh rides occur were assessed. We used Pearson's correlation coefficient and a generalized linear model with a negative binomial response variable fit to historical sleigh ride data using the glm.nb() function from the MASS package (Venables and Ripley, 2002). At the time of publication, NER sleigh ride data were not publicly available from FWS.

Hunting and Hunter-associated Spending

The changes to future elk populations and associated effects to elk harvest tag sales and hunting-related spending were evaluated under each alternative. In chapter B, Cross and others (2025, this volume) predicted the number of harvested elk in each age and sex class and under each of the five alternatives. Those data were then used to estimate the total number of harvest tags that could be sold annually (n_{tags}) by WGFD under each alternative given by equation 2:

$$n_{tags} = \sum_{c=1}^{4} \frac{n_{huntedc}}{1 - p_{notused} - p_{notfilled}} \quad (2)$$

where

ntags is the number of elk tags that WGFD could sell annually,

$nhunted_c$ is the number of harvested elk in each demographic class, *c*, (juveniles, females, yearling males or adult males) annually,

pnotused is the mean proportion of tags that are purchased but not used by hunters, and

pnotfilled is the mean proportion of tags that are purchased, the hunter went afield, but did not successfully harvest an animal.

The study assumed that hunters who purchased a tag but did not hunt (*pnotused*) contributed to WGFD tag sale revenue but not to local economic revenue, while hunters who went afield contributed to economic revenue regardless of whether they successfully filled the tag (harvested an animal). Average tag use and hunter success rates were derived using 2017–21 harvest data from the JHU (WGFD, 2024b). The total WGFD tag revenue was then calculated by multiplying the number of tags of each type by the corresponding cost per tag (WGFD, 2024b) to account for differences in cost of each tag type. A discount rate of 4.7 percent was applied to elk harvest tag sale revenue.

Hunting on the NER (WGFD Hunt Area 77) is unique in that hunters with unfilled tags for other hunt areas may use the tag on the NER. Given this uncertainty, our results are an approximation of future revenues because we assumed that a decrease in the number of elk that were available to harvest (estimated as total harvested elk in Cross and others, 2025, this volume, chap. B) resulted in an exact proportionate decrease in the number of elk tag sales, elk hunting trips, and elk hunting-related spending for each alternative and did not account for the possibility that hunters may still purchase tags and related goods elsewhere. We also only included elk harvest that occurs in the JHU under the alternatives and did not consider any elk that transitioned to the Fall Creek Herd Unit under the no feeding alternatives. For additional detail see Cross and others (2025, this volume, chap. B) for information regarding elk transition dynamics under the alternatives.

To estimate the total hunting trips and hunting-related spending, we used hunter-spending estimates from Koontz and Loomis (2005) and adjusted for an annual inflation of 2.8 percent between 2001 and 2024. Hunter characteristics were assumed to be consistent over time (for example, spending by residency) and used recent WGFD data to estimate the proportion of resident hunters and hunter success rates. We calculated annual hunting trip-related spending, *totalspend*, using average values from Koontz and Loomis (2005) and given by equation 3:

$$totalspend = \sum_{r=1}^{2} nhunters_r \times tspend_r \times tyear_r \quad (3)$$

where

$nhunters_r$ is number of hunters by residency status, *r* (Wyoming resident or non-Wyoming resident), *tspend* is per-trip spending by hunter residency, and

tyear is number of trips per year by hunter residency.

Wyoming residents were further subdivided and a weighted average of local and nonlocal residency status was calculated based on data from Koontz and Loomis (2005). Finally, the total spending values were multiplied by a discount rate of 4.7 percent.

Outfitter Revenues

To estimate how changes in hunting could affect outfitter revenues, the proportion of hunted elk in JHU harvested by outfitter-guided clients was estimated using historical data (Wyoming State Board of Outfitters and Professional Guides, 2024). Predictions of future permitted outfitters and clients served were then estimated by applying these proportions to the predicted number of harvested elk under each alternative from Cross and others (2025, this volume, chap. B). McWhirter and others (2022) estimated the average cost of a guided elk hunt to be $5,000, so we multiplied this value by the respective number of guided clients (regardless of whether they successfully harvested an elk) that were predicted under each alternative to predict future effects on outfitter revenue under each alternative and applied a discount rate of 4.7 percent.

Results

Predicted Changes in Nonhunting Visitors and Visitor-related Spending Under Each Alternative

The fitted model of historical NER winter visits as a function of monthly elk and temporal variables was consistent with observed data (posterior predictive check value=0.62) and each parameter successfully converged (Rhat<1.1; table E1). The effect of historical monthly elk counts on NER winter visitation was weakly positive (mean, 0.03; 95 percent credible interval, −0.05 to 0.10) and 74 percent of the posterior distribution was greater than zero. The median effect size corresponded to an average of 2.5 additional visitors for every 100 additional elk on the NER. When carrying the fitted model and its posteriors forward to project differences in predicted NER winter visits, minimal differences were found among the alternatives; although, a high degree of uncertainty was found within each alternative (fig. E2). Note that in the negative binomial model, where the predictors were centered and scaled prior to fitting, the parameter estimates represent one standard deviation change in the predictor variable as a result of a change in the log of NER visits.

The average 20-year cumulative estimate for NER winter visitors was slightly higher under the continue feeding alternative compared to the other alternatives (table E2); however, there was large within-alternative variation and substantial overlap of performance estimates for all alternatives. Predicted visitor spending under each alternative maintained this pattern, with nonhunting NER visitor spending predicted to be slightly higher on average under the continue feeding alternative compared the other alternatives, but with a large range of within-alternative variation (table E2).

Table E1. Predictor variables of negative binomial model of historical winter visits to the National Elk Refuge in Jackson, Wyoming, parameter symbology, and fitted parameter estimates.

[The estimates were used to predict future visits under each of the proposed management alternatives and using predictions of future elk counts from Cross and others (2025, this volume, chap. B) and Cotterill and others (2025, this volume, chap. C). %, percent; CI, credible interval]

Variable	Parameter	Mean estimate (95% CI)
intercept	β_0	8.98 (8.80–9.15)
monthlyElk	β_1	0.03 (−0.05–0.10)
monthDec	β_2	0.83 (0.60–1.05)
monthJan	β_3	0.75 (0.51–0.98)
monthFeb	β_4	0.93 (0.67–1.20)
monthMar	β_5	0.90 (0.63–1.18)
year	β_6	0.15 (0.07–0.24)

Table E2. Cumulative predicted nonhunting winter season visitors and net present value-adjusted nonhunting visitor spending during winter months (December–April) on the National Elk Refuge in Jackson, Wyoming, predicted under each alternative.

[Note that these totals do not reflect the spending of local residents that live within 50 miles of the Refuge because of small sample size and inconsistencies in their reporting of local National Elk Refuge-related spending. $, U.S. dollar; SD, standard deviation]

Alternative	Predicted cumulative winter visitors, in thousands		Predicted cumulative spending, in millions ($)	
	Mean	SD	Mean	SD
Continue feeding	3,375	791.7	2,978	698.6
No feeding	3,271	774.4	2,886	683.3
Increase harvest	3,296	763.0	2,908	673.3
Reduce feeding	3,288	755.1	2,901	666.3
Disease threshold	3,286	752.9	2,889	664.3

Predicted Changes in Sleigh Ride Participants Under Each Alternative

A slight positive correlation was revealed between historical elk counts on the Nowlin feeding area and the number of sleigh ride participants (Pearson's correlation coefficient=0.38). The elk-only model showed a small effect of Nowlin feedground

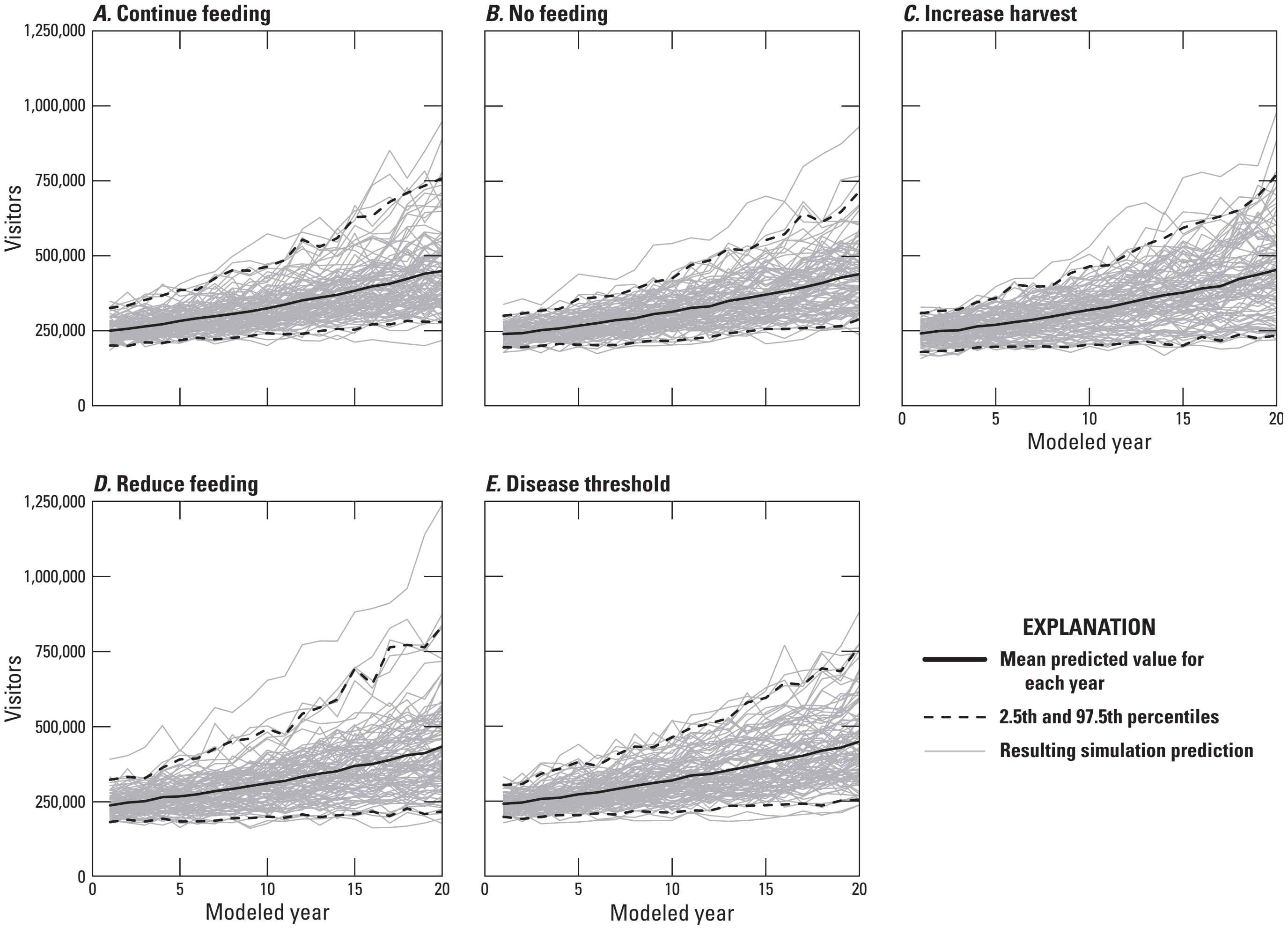


Figure E2. Graph showing annual predicted visitors to the National Elk Refuge in Jackson, Wyoming, during winter months under each alternative. *A*, continue feeding, *B*, no feeding, *C*, increase harvest, *D*, reduce feeding, and, *E*, disease threshold.

elk counts on sleigh ridership (4.23×10^{-05}, $p>0.05$). This small effect corresponded to a one-unit change in elk counted on the feedground resulting in a 0.16-unit change in expected number of sleigh ride participants. As a result, based on an evaluation of historical data, we concluded that sleigh ride participation did not differ substantially across alternatives.

Predicted Changes in Hunting Visitors and Hunting-related Spending Under Each Alternative

The number of harvested elk varied through time and according to the alternative (Cross and others, 2025, this volume, chap. B). The harvest generally decreased as elk population projections fell below the JHU population objective of 11,000 elk (WGFD sets population objectives for each elk herd unit according to their estimates of a sustainable population); the decline in harvest was included in Cross and others (2025, this volume, chap. B) as an assumed response by WGFD to declining elk abundance under the alternatives.

Because we assumed proportionate spending by resident and nonresident Wyoming hunters remained the same as historical data, the increase harvest alternative resulted in hunting rates and hunting-related revenues that were initially much higher than the other alternatives but dropped rapidly after the initial period of intensive elk harvest. When considering these changes over time, the increase harvest alternative had higher predicted tag revenues (Mean=$6.60 million, SD=$574,000) and hunter-related spending (Mean=$101.29 million, SD=$9.56 million), but had substantial overlap in the estimated ranges of the alternatives (table E3; fig. E3).

Predicted Changes in Outfitter Revenues Under Each Alternative

In the last five years, an average of 19.5 outfitters (SD=3) guided an average of 17 clients (SD=17.5) each per year. Annually, elk harvested by outfitter-guided clients averaged 218 elk (SD=71 elk), which accounted for 21 percent of the annual total elk harvested in the JHU (SD=3.7 percent).

Table E3. Twenty-year predictions of the cumulative revenues from elk tag sales and the total predicted spending by elk hunters in the Jackson Elk Herd Unit of Wyoming under each alternative.

[$, dollar; SD, standard deviation]

Alternative	Cumulative tag revenue, in thousands ($)		Cumulative spending by hunters, in thousands ($)	
	Mean	SD	Mean	SD
Continue feeding	5,472	640	88,539	12,214
No feeding	5,004	770	76,140	14,836
Increase harvest	6,604	574	101,294	9,558
Reduce feeding	4,765	758	73,023	14,145
Disease threshold	5,248	717	81,988	14,254

For every elk harvested in JHU annually, outfitters guided an average of 0.35 clients (including those who did not successfully harvest an elk).

Projecting these proportions over 20 modeled years, the increase hunting alternative had the highest predicted number of clients with an average estimate of 3,758 clients served over the next 20 years and a cumulative outfitter revenue of $14.5 million. The next highest performing alternative was the continue feeding alternative with an average of 3,480 clients and $12.6 million in revenue, followed by the disease threshold alternative with an average of 3,319 clients and $11.7 million in revenue (fig. E4). The lowest cumulative number of clients and revenues were predicted under the reduce feeding alternative with 2,879 clients and $10.4 million in revenue over the next 20 years.

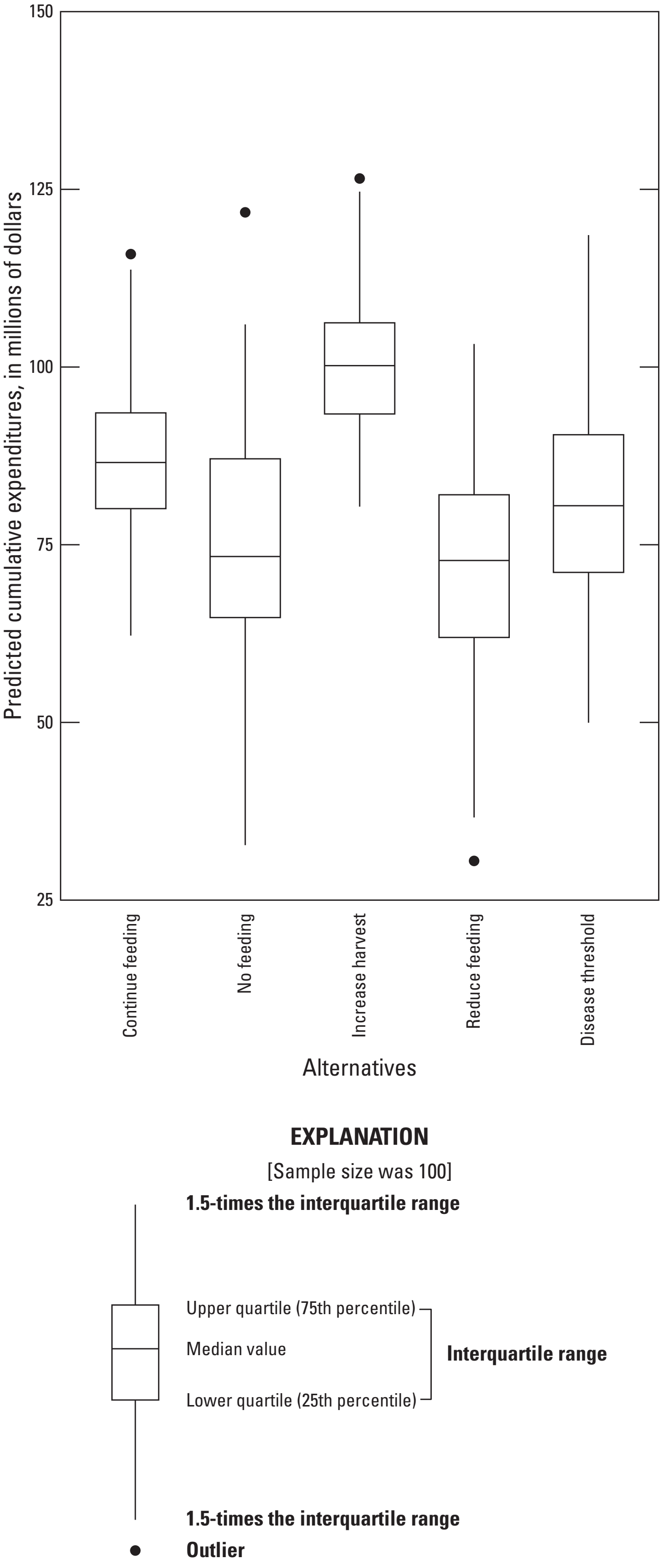


Figure E3. Boxplots showing cumulative predicted spending by elk hunters in the Jackson Elk Herd Unit in Wyoming over 20 model years. Values have been discounted through time using a rate of 4.7 percent.

Summary

After evaluating the effects of the five management alternatives under consideration for bison and elk management on National Elk Refuge (NER or Refuge) on social and economic dimensions of concern, this study found minor to moderate differences in the performance of the alternatives on the cumulative number of NER winter visitors, cumulative revenue from elk hunting license sales, cumulative local economic revenues resulting from hunting and nonhunting visitors, and revenues for outfitters guiding in the Jackson Elk Herd Unit. In general, large variation within predicted estimates of elk populations, harvested animals, and visitation resulted in substantial overlap in the estimates of performance of the alternatives for each performance metric. Although we predicted the highest number of NER visitors under the continue feeding alternative, we found that monthly elk counts explained less than 1 percent of the variation in historical NER winter visitation. However, the results of Cross and others (2025, this volume, chap. B), Cotterill and others (2025, this volume, chap. C), and

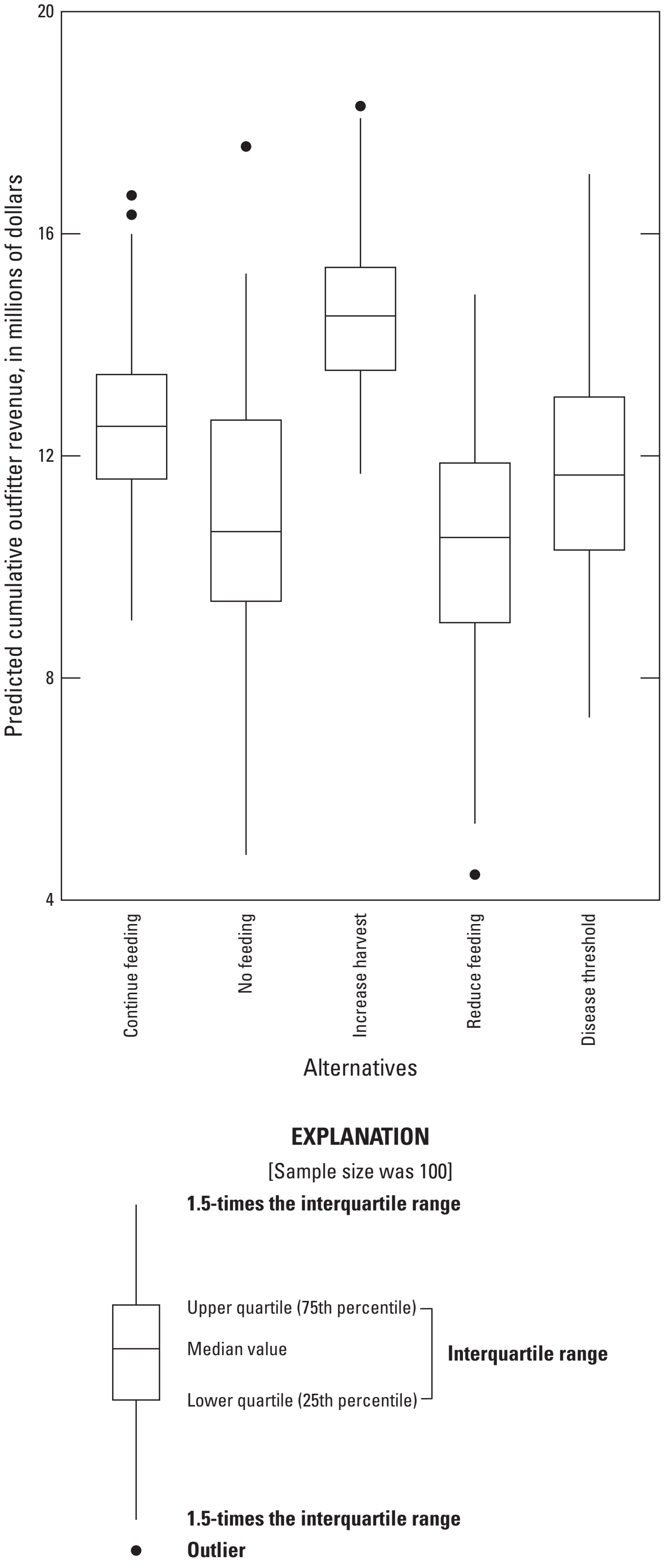


Figure E4. Boxplots showing cumulative predicted revenues from guided elk hunts in the Jackson Elk Herd Unit in Wyoming. Values have been discounted through time using a rate of 4.7 percent.

Cook and others (2025b, this volume, chap. D) predict substantial declines in elk and bison numbers on NER in winter months so the number of NER visitors and associated revenues could change in unexpected ways that are not fully captured by these analyses. The increase harvest alternative performed better on the hunting-related performance metrics on average, including Wyoming Game and Fish Department (WGFD) revenue from elk harvest tag sales, regional revenue from hunting-related spending, and outfitter-revenue, but there was large within-alternative variation.

Some of the estimates presented here are conditioned on strong assumptions about future outcomes. For example, we assumed that any changes in the number of Refuge visitors in winter months resulted in a direct and proportional change in non-hunting visitor spending; however, it is possible that this connection is not as direct. Instead, there is a possibility that non-hunting expenditures do not change in direct proportion to future trends in elk and Refuge visitation, especially given that 87% of Refuge visitors reported that the Refuge was not the only reason to visit the Jackson, Wyoming region (Dietsch and others, 2020). We further assume that future relationships between wildlife populations and visitation, hunting, and related spending can be approximated by relationships of the past. However, if management alternatives drive large changes in elk and bison numbers on the Refuge as indicated in Cross and others (2025, this volume, chap. B), Cotterill and others (2025, this volume, chap. C), and Cook and others (2025b, this volume, chap. D), the relationships might also change. Any effect of elk starvation and CWD-related mortalities that result from changes to NER feeding may negatively affect visitation and hunting in ways not predicted because of public reactions to seeing animals in poor condition.

We assumed that CWD would not affect hunter participation in the region. Previous studies of hunting patterns following CWD emergence have predicted hunting participation declines as CWD prevalence increases (for example, Needham and others, 2006). However, effects on participation vary by state, species pursued, and hunters' emotional response to CWD (Schroeder and others, 2021). Other studies have shown that these declines reverse and hunting returns to normal levels even as CWD prevalence increases (for example, Holland and others, 2020). Therefore, we assumed that hunter participation would remain constant despite predicted increases in CWD throughout the 20-year evaluation period.

Finally, the benefits predicted under the increase harvest alternative may be challenging to implement and thus may affect the revenues generated by outfitters in the region. The harvest regulation changes that would lead to the higher harvest that is predicted in the increase harvest alternative fall primarily under the authority of WGFD. As a result, actions that fall outside of the FWS decision process supported by these analyses would be required to implement this alternative.

Despite the limitations of this study, the findings remain informative for making decisions about elk and bison management of NER. The assumptions were guided by local and regional experts and apply equally across alternatives and thus could be expected to affect each alternative in similar ways. As a result, differences among alternatives may represent good approximations of their relative performance. For this reason, the analyses presented here may assist decision makers in assessing the relative performance of each alternative concerning the anticipated effects on the social and economic benefits that elk and bison provide to the region.

References Cited

Abatzoglou, J.T., Hegewisch, K., and Research Computing Data Services, [undated], gridMET: University of California Merced, accessed January 25, 2024, at https://climatetoolbox.org/.

Boroff, K., Kauffman, M., Peck, D., Maichak, E., Scurlock, B., and Shumaker, B., 2016, Risk assessment and management of brucellosis in the southern greater Yellowstone area (II)—Cost-benefit analysis of reducing elk brucellosis prevalence: Preventive Veterinary Medicine, v. 134, p. 39-48, accessed April 15, 2024, at https://doi.org/10.1016/j.prevetmed.2016.09.025.

Boyce, M.S., 1989, The Jackson elk herd—Intensive wildlife management in North America, Cambridge University Press, 324 p.

Caudill, J., and Carver, E., 2019, Banking on nature 2017—The economic contributions of National Wildlife Refuge recreational visitation to local communities: Falls Church, Va., U.S. Fish and Wildlife Service, 33 p., accessed April 29, 2023, at https://www.fws.gov/sites/default/files/documents/USFWS_Banking_on_Nature_2017.pdf.

Cook, J.D., Cotterill, G.G., McEachran, M.C., Graves, T.A., Cole, E.K., and Cross, P.C., 2025a, Decision framing overview and performance of management alternatives for bison and elk feedground management at the National Elk Refuge in Jackson, Wyoming, chap. A *of* Cook, J.D., and Cross, P.C., eds., Decision analysis in support of the National Elk Refuge bison and elk management plan: U.S. Geological Survey Scientific Investigations Report 2024–5119, 19 p., https://doi.org/10.3133/sir20245119A.

Cook, J.D., Cross, P.C., Tomaszewski, E.M., Cole, E.K., Campbell Grant, E.H., Wilder, J.M., and Runge, M.C., 2023, Evaluating management alternatives for Wyoming Elk feedgrounds in consideration of chronic wasting disease (ver. 2.0, November 2023): U.S. Geological Survey Open-File Report 2023–1015, 50 p., accessed April 15, 2024, at https://doi.org/10.3133/ofr20231015.

Cook, J.D., McEachran, M.C., Cotterill, G.G., and Cole, E.K., 2025b, Bison population dynamics, harvest, and conflict potential under feedground management alternatives at the National Elk Refuge in Jackson, Wyoming, chap. D *of* Cook, J.D., and Cross, P.C., eds., Decision analysis in support of the National Elk Refuge bison and elk management plan: U.S. Geological Survey Scientific Investigations Report 2024–5119, 24 p., https://doi.org/10.3133/sir20245119D.

Cotterill, G.G., Cross, P.C., Cole, E.K., Cook, J.D., McEachran, M.C., and Graves, T.A., 2025, Evaluating elk distribution and conflict under proposed management alternatives at the National Elk Refuge in Jackson, Wyoming, chap. C *of* Cook, J.D., and Cross, P.C., eds., Decision analysis in support of the National Elk Refuge bison and elk management plan: U.S. Geological Survey Scientific Investigations Report 2024–5119, 32 p., https://doi.org/10.3133/sir20245119C.

Cross, P.C., Cook, J.D., and Cole, E.K., 2025, Predictions of elk and chronic wasting disease dynamics the National Elk Refuge and surrounding areas in Jackson, Wyoming, chap. B *of* Decision analysis in support of the National Elk Refuge: U.S. Geological Survey Scientific Investigations Report 2024–5119, 22 p., https://doi.org/10.3133/sir20245119B.

Dietsch, A.M., Sexton, N.R., Megnak, L.F., and Roberts, R., 2020, National Wildlife Refuge visitor survey—2019 results for National Elk Refuge: Columbus, Ohio, The Ohio State University—School of Environment and Natural Resources, 48 p., accessed February 1, 2024, at https://ecos.fws.gov/ServCat/downloadfile/171916.

Federal Reserve Bank of St. Louis, 2024, Consumer price index for all urban consumers—Energy in U.S. city average (CPIENGSL): Federal Reserve Economic Database, accessed January 25, 2024, at https://fred.stlouisfed.org/series/CPIENGSL.

Galloway, N.L., Monello, R.J., Brimeyer, D., Cole, E.K., and Hobbs, N.T., 2021, Supporting adaptive management with ecological forecasting—Chronic wasting disease in the Jackson Elk Herd: Ecosphere, v. 12, no. 10, p. e03776, accessed April 15, 2024, at https://doi.org/10.1002/ecs2.3776.

Gelman, A., and Rubin, D.B., 1992, Inference from iterative simulation using multiple sequences: Statistical Science, v. 7, no. 4, p. 457–472, accessed March 1, 2024, at https://doi.org/10.1214/ss/1177011136.

Gelman, A., and Tuerlinckx, F., 2000, Type S error rates for classical and Bayesian single and multiple comparison procedures: Computational Statistics, v. 15, p. 373–390, accessed March 1, 2024, at https://doi.org/10.1007/s001800000040.

Holland, A.M., Haus, J.M., Eyler, T.B., Duda, M.D., and Bowman, J.L., 2020, Revisiting hunter perceptions toward chronic wasting disease—Changes in behavior over time: Animals, v. 10, no. 2, article 187, accessed February 10, 2024, at https://doi.org/10.3390/ani10020187.

Konzek, D., 2024, FWS National realty tracts simplified: U.S. Fish and Wildlife Service, accessed August 13, 2024, at https://gis-fws.opendata.arcgis.com/datasets/fws::fws-national-realty-tracts-simplified/about.

Koontz, L., and Loomis, J.B., 2005, Economic importance of elk hunting in Jackson Hole, Wyoming: U.S. Geological Survey Open-File Report 2005–1183 21 p., accessed February 1, 2024, at https://doi.org/10.3133/ofr20051183.

Loomis, J.B., and Caughlan, L., 2004. Economic analysis of alternative bison and elk management practices on the National Elk Refuge and Grand Teton National Park—A comparison of visitor and household responses: U.S. Geological Survey Open-File Report 2004–1305, 110 p., accessed February 10, 2024, at https://doi.org/10.3133/ofr20041305.

McWhirter, D., Scurlock, B., Wise, B., Rogerson, J., Hovinga, B., Lund, J., Allen, S., Van Wick, P., Edwards, H., and Gocke, M., 2022, Elk feedgrounds in Wyoming with particular focus on the Forest Park and Dell Creek elk feedgrounds: Wyoming Game and Fish Department, p. 120.

National Park Service—Land Resources Division, 2024, Administrative boundaries of National park system units—National geospatial data asset (NGDA) NPS National parks dataset: National Park Service, accessed August 13, 2024, at https://irma.nps.gov/DataStore/Reference/Profile/2224545?lnv=True.

National Academies of Sciences, Engineering, and Medicine, 2020, Revisiting brucellosis in the Greater Yellowstone Area: Washington, D.C., The National Academies Press, 210 p., accessed March 1, 2024, at https://doi.org/10.17226/24750.

Needham, M.D., Vaske, J.J., and Manfredo, M.J., 2006, State and residency differences in hunters' responses to chronic wasting disease: Human Dimensions of Wildlife, v. 11, no. 3, p. 159–176, accessed March 15, 2024, at https://doi.org/10.1080/10871200600669973.

Office of Management and Budget, 2023, Circular No. A-94—Guidelines and discount rates for benefit-cost analysis of Federal programs, Appendix C: Washington, D.C., The White House, 1 p., accessed March 15, 2024, at https://www.whitehouse.gov/wp-content/uploads/2023/12/CircularA-94AppendixC.pdf.

R Core Team, 2018, R—A language and environment for statistical computing, version 4.3.1: R Foundation for Statistical Computing software release, accessed February 1, 2024, at www.r-project.org.

Schroeder, S.A., Landon, A.C., Cornicelli, L.J., Fulton, D.C., and McInenly, L.E., 2021, Cognitive and behavioral coping in response to wildlife disease—The case of hunters and chronic wasting disease: Human Dimensions of Wildlife, v. 27, no. 3, p. 251–272, accessed March 15, 2024, at https://doi.org/10.1080/10871209.2021.1919340.

Su, Y-S., and Yajima M., 2024, R2jags—Using R to run 'JAGS', accessed March 15, 2024, at https://doi.org/10.32614/CRAN.package.R2jags.

U.S. Census Bureau, 2024, American community survey data, accessed January 25, 2024, at https://data.census.gov/.

U.S. Fish and Wildlife Service, 2019, Bison and elk management step-down plan—National Elk Refuge, Grand Teton National Park, Wyoming: Lakewood, Colo., U.S. Department of the Interior, National Park Service.

U.S. Fish and Wildlife Service and National Park Service [FWS and NPS], 2007, Bison and elk management plan—National Elk Refuge and Grand Teton National Park Report, 238 p.

Venables, W.N., and Ripley, B.D., 2002, Modern applied statistics with SFourth: New York, Springer, 497 p., accessed March 15, 2024, at https://doi.org/10.1007/978-0-387-21706-2.

Wyoming Game and Fish Department, 2024a, Elk herd units: Wyoming Game and Fish open data, accessed February 7, 2024, at https://wyoming-wgfd.opendata.arcgis.com/datasets/88c1b49a064e45b78b1abb5437440a41_0/explore?location=0.020356%2C72.446016%2C0.00.

Wyoming Game and Fish Department [WGFD], 2024b, License prices and fees website, accessed March 2024 at https://wgfd.wyo.gov/Apply-or-Buy/License-Fee-List.

Wyoming State Board of Outfitters and Professional Guides, 2024, Public Records Request.

For more information concerning the research in this report, contact:

Center Director, USGS Eastern Ecological Science Center
U.S. Geological Survey
12100 Beech Forest Rd., Ste 4039
Laurel, MD 20708-4039

Or visit the Eastern Ecological Science Center website at
https://www.usgs.gov/centers/eesc

Publishing support provided by the Baltimore Publishing Service Center.

McEachran and others—**Social and Economic Consequences of Management Alternatives at the National Elk Refuge**—SIR 2024–1119

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20241119E