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

Decision Framing Overview and Performance of Management Alternatives for Bison and Elk Feedground Management at the National Elk Refuge in Jackson, Wyoming

Chapter A 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. A single bull walking across a field on the National Elk Refuge. Photograph taken by Kari Cieszkiewicz, U.S. Fish and Wildlife Service, January 2021.

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Abbreviations

“BEMP”	“Bison and Elk Management Plan”
CWD	chronic wasting disease
FS	U.S. Department of Agriculture—Forest Service
FWS	U.S. Fish and Wildlife Service
GYE	Greater Yellowstone Ecosystem
JHU	Jackson Elk Herd Unit
NER	National Elk Refuge
PrP^{CWD}	misfolded prion protein
SD	standard deviation
WGFD	Wyoming Game and Fish Department

Decision Framing Overview and Performance of Management Alternatives for Bison and Elk Feedground Management at the National Elk Refuge in Jackson, Wyoming

By Jonathan D. Cook[1], Gavin G. Cotterill[1], Margaret C. McEachran[1], Tabitha A. Graves[1], Eric K. Cole[2], Paul C. Cross[1]

Executive Summary

This report was developed to evaluate the performance of a set of proposed alternatives for *Cervus elaphus canadensis* (Excleben, 1777; elk) and *Bison bison* (Linnaeus, 1758, bison) management at the National Elk Refuge (NER) in Wyoming, U.S.A., and to inform a National Environmental Policy Act Environmental Impact Statement focused on developing the next “Bison and Elk Management Plan” (“BEMP”). The U.S. Geological Survey facilitated a structured decision-making process for the U.S. Fish and Wildlife Service (FWS) to develop the alternatives and the criteria (performance metrics) for evaluating the alternatives.

The effects of proposed bison and elk supplemental feeding alternatives were estimated for a 20-year period. The study considered outcomes related to bison and elk population abundance, chronic wasting disease (CWD) prevalence in elk, human-wildlife conflict indicators, as well as effects on NER visitors, visitor spending, and hunting-associated revenues. The NER managers developed five future management alternatives:

1. *Continue feeding*.—The NER will continue to provision supplemental food to bison and elk during winter months based on forage availability and number of conflicts.

2. *No feeding*.—The NER will immediately stop provisioning food to bison and elk during winter months.

3. *Increase harvest, then stop feeding (increase harvest)*.—The NER will continue to provision food to bison and elk during winter months for the next 5 years, then stop feeding. During those 5 years, the NER will work with the Wyoming Game and Fish Department (WGFD) to increase elk harvest and attempt to reduce the population of elk that overwinter at the NER to 5,000 animals.

4. *Reduce feeding, then stop feeding (reduce feeding)*.—The NER will provision a reduced ration to elk during winter months for the next 5 years to reduce the elk population size prior to feedground closures. Exclosures will be designed to protect aspen stands in the south region of the NER, and for willow and cottonwood north of the NER.

5. *Stop feeding after 3 percent CWD prevalence is measured in Jackson elk (disease threshold)*.—The NER will continue to provision food to bison and elk during winter months until CWD sampling reveals 3 percent prevalence in the Jackson elk herd, at which point all feeding activities will cease at the NER.

Since at least 1907, elk have been fed in the area that is now the NER during the winter to reduce overwinter mortality. After bison “discovered” supplemental food at the NER in the 1980s, a portion of the herd has overwintered there. In addition to reducing bison and elk overwinter mortality, supplemental feeding may limit human-wildlife conflicts in winter months, including vehicle collisions and private property use by bison and elk. However, it also encourages aggregations of bison and elk that increases the potential for intraspecific disease transmission, such as brucellosis (in bison and elk) and CWD (in elk). Chronic wasting disease is a prion infection that was recently detected in the Jackson Elk Herd Unit (JHU). Out of 1,485 elk tested for CWD between 2020 and 2023 there has been one confirmed positive case. Despite the apparent low prevalence as of 2024, experts expect that prevalence will increase and that the effects of CWD on Jackson elk will exceed what has been observed in other wild elk populations given the dense aggregations of animals that occur at the NER and the long-term persistence and infectivity of the CWD prions in the environment.

Given the benefits and potential drawbacks of supplemental feeding, the alternatives were evaluated under advisement of three separate technical teams. Each team was composed of experts with specific, local knowledge of system attributes; one team focused on wildlife effects (bison and elk), another

[1]U.S. Geological Survey.

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

focused on physical landscape effects, and the third on human dimensions, visitor dynamics, and local economic effects. The technical teams helped to develop the methods, provided feedback on assumptions required by the analyses, and provided data. The study area boundaries were created through an expert elicitation process and included the entirety of the JHU, Grand Teton National Park, NER, and the northern third of the Fall Creek Elk Herd Unit, which included three other State elk feedgrounds.

Chapter A (this chapter) provides scoping details of the "BEMP", a summary of the 19 metrics that are used to evaluate the performance of each of 5 alternatives, and methodological details of 2 performance metrics that were not covered in other technical chapters. Additional technical details, results, and interpretations are briefly covered in this chapter, but are mostly contained in chapters B–E.

The two metrics covered solely in chapter A are the costs of feedground management to FWS and the risk of invasive species introduction and spread at the NER (for example, *Bromus tectorum*). For evaluating costs, the study calculated that managing the feedground program requires FWS to expend between $15,213 and $16,448 per day of feeding activities for the direct costs of feed, labor, fuel, and maintenance of machinery. These daily cost estimates were used to predict that the continue feeding alternative will have an average cumulative cost of $19,335,000 over 20 years. The reduce feeding and increase harvest alternatives would have an average 20-year cost estimate of $4,839,000 and the disease threshold would cost $2,189,000. Finally, the study assumed no additional costs to FWS under the no feeding alternative and did not include any costs associated with constructing exclosures under the reduce feeding alternative.

The cumulative number of feeding days over 20 years were used as a proxy measure to estimate the relative invasive plant species introduction and spread risk across the alternatives. It was assumed that more feeding would require more mechanical damage by feedground equipment and an elevated use of localized areas by bison and elk. The disturbance would negatively affect existing vegetation (mostly sagebrush communities) and allow more opportunities for invasive plant species, such as cheatgrass (*Bromus tectorum*), to expand and establish in new areas. The highest number of feeding days were estimated under the continue feeding alternative (average of 1,243 days) and intermediate feeding days under the reduce feeding and increase harvest (311 days) and disease threshold (140 days). The no feeding alternative was assumed to have 0 feed days on NER over the next 20 years.

Chapter B analyzes elk population and CWD dynamics under the five alternatives. Elk populations are predicted to decline under all alternatives, but timing, cause, and magnitude of those declines differ among alternatives. Alternatives that halt the feeding program had more immediate population declines but fared better by year 20 by partially mitigating future CWD effects. The no feeding alternative resulted in a larger elk population size in 70 out of 100 simulations, with a median elk population decline of 39 percent from the current size, whereas the continue feeding alternative led to a median decline of 55 percent from the current size. The other alternatives resulted in intermediate declines. The continue feeding alternative was predicted to result in a higher CWD prevalence by year 20 in 83 out of 100 simulations, with a median CWD prevalence of 36 percent compared to 23 percent for the no feeding alternative.

Chapter C evaluates elk space-use based on data collected from global positioning system collars on elk and expert elicitation for scenarios with limited data. The resource selection function for fed and unfed elk during average and severe winters was estimated and then used to evaluate metrics including elk use of private property and sensitive vegetation communities at monthly timesteps and under varying winter conditions. Then, monthly estimates of elk under each alternative from chapter B were distributed over the predictive resource selection surfaces developed in this chapter. The continue feeding alternative minimized time spent by elk on private property and brucellosis transmission risk from elk to cattle compared to other alternatives. However, the increase harvest and reduce feeding alternatives minimized elk damage to sensitive aspen, cottonwood, and willow vegetation communities during winter compared to other alternatives. Following the projected population declines, the negative consequences of elk space-use declined by 35–57 percent over the 20 years, and differences among alternatives ranged from 6 to 20 percent.

Chapter D evaluates bison population dynamics, conflict, and harvest patterns under the five alternatives. The bison population is predicted to maintain current population sizes under the continue feeding alternative (median size in year 20 of 541 bison), but it is expected to decline over the next 20 years under all alternatives in which the NER halts feeding (median sizes in year 20 ranged from 469 to 473). Further, these declines are likely to lead to a reduction in available bison harvest by resident, nonresident, and Tribal hunters; the continue feeding alternative leads to a median cumulative harvest estimate across 20 years of 1,879, and the no feeding alternative had a median cumulative harvest estimate of 1,292. Finally, following from results of an expert panel, human-bison conflicts were predicted to increase under no feeding alternatives because bison may venture onto private lands in greater numbers if feed is not provisioned during winter months.

Chapter E assesses social and economic consequences. The alternatives are anticipated to affect bison and elk population abundance and space use dynamics, with potential effects on the wildlife-related recreation and tourism in the area, including winter-season visitors to NER, and hunters and outfitters in the JHU. Limited evidence was found to suggest that NER visitation rates were correlated with historical elk counts at the NER. Projecting this forward, limited differences were found among alternatives in visitation metrics relative to the uncertainty within predictions for each alternative. Larger differences were estimated for elk tag license sales, hunter-associated spending, and outfitter revenues, but these are subject to strong assumptions about human responses to predicted elk changes. The increase harvest alternative was predicted to have higher average revenue from elk tag sales ($6.6 million compared to $4.8–5.5 million, on average, for the other alternatives), spending by elk hunters ($101.3 million compared to $73.0–88.5 million, on average, for the other alternatives), and outfitter revenues ($14.5 million, on average, compared to $10.4–12.6 million for the other alternatives) because more elk were harvested under this alternative instead of dying from other causes (for example, CWD, severe winters).

The analyses in this report estimated 19 performance metrics that were important to decision makers. No single alternative performed best for all metrics. The next step in a structured decision analysis could be to weight the relative importance of different objectives against one another, such that the overall performance of each alternative can be summarized including all sources of prediction uncertainty.

Introduction

The U.S. Fish and Wildlife Service (FWS) manages the 24,700-acre National Elk Refuge (NER or the Refuge), situated in the Greater Yellowstone Ecosystem (GYE) in northwestern Wyoming (fig. A1). The Refuge was initially established in 1912 as a winter game reserve (16 U.S.C. 673) and later expanded to include the management of habitats for breeding birds, fish, and other big game animals, as well as the conservation of threatened and endangered species. These management purposes have resulted in the protection of important habitats for many species including *Cervus elaphus canadensis* (Excleben, 1777; elk), *Bison bison* (Linnaeus, 1758; bison), *Canis lupus* (Linnaeus, 1758; grey wolves), *Ursus arctos* (Linnaeus, 1758; grizzly bears), *Cygnus buccinator* (Richardson, 1831; trumpeter swans), *Haliaeetus leucocephalus* (Linnaeus, 1766; bald eagles), *Ovis canadensis* (Shaw, 1804; bighorn sheep), and *Oncorhynchus clarkii* (Richardson, 1836; cutthroat trout), and have provided recreational opportunities for visitors.

To guide the management of bison and elk populations on NER, FWS has developed a series of planning documents, including a “Bison and Elk Management Plan” (“BEMP”; FWS and National Park Service [NPS], 2007) and a “Step-Down Plan for Bison and Elk Management” (“Step-Down Plan”; FWS, 2019). One of the major elements of the “BEMP” and “Step-Down Plan” is the provisioning of pelleted feed to bison and elk on 5,000 acres of Refuge land during winter months, typically between January and April. Between 2018–2021, the NER fed an average of 7,540 elk out of a population in the Jackson Elk Herd Unit (JHU) that exceeded 12,000 total individuals (fig. A2) Over a similar period (2016–20), NER fed an average of 317 bison out of a total of 550 individuals in the Jackson bison herd (U.S. Fish and Wildlife Service, written comm., 2024).

A total of 22 elk feedground locations in western Wyoming are primarily managed by Wyoming Game and Fish Department (WGFD); the NER feeding program is the only one under the authority of FWS (Wyoming Game and Fish Department, 2024b). Winter feeding is used to reduce overwinter mortality, maintain elk numbers near population objectives, reduce competition between bison and elk, ensure harvest opportunities, and reduce human-wildlife conflicts, such as disease transmission risk among livestock, elk, and bison (Wyoming Game and Fish Department, 2024b). While winter feeding is successful in sustaining animals during harsh winter conditions and sequestering them to reduce private property conflict, the practice also elevates local densities and animal-to-animal contact, thereby increasing the potential for intraspecific disease transmission (National Academies of Sciences, Engineering, and Medicine, 2020; Janousek and others, 2021). Diseases that may be transmitted more quickly in feedground settings include chronic wasting disease (CWD) in elk and brucellosis (caused by *Brucella abortus*) in bison and elk.

The arrival of CWD to the Jackson elk herd, combined with the potential for accelerated spread in dense aggregations of fed elk, has motivated a reevaluation of existing bison and elk feedground management. Chronic wasting disease is a fatal neurodegenerative disease caused by a misfolded prion protein (PrP^{CWD}) that affects members of the *Cervidae* family (elk, *Odocoileus virginianus* [Zimmerman, 1780; white-tailed deer], *Odocoileus hemionus* [Rafinesque, 1817; mule deer], and *Alces alces* [Linnaeus, 1758; moose]). The disease is transmitted directly during social contact among animals and indirectly when susceptible animals contact a prion-contaminated environment. The PrP^{CWD} protein remains infectious in environments for extended periods of time, possibly years (Williams and Young, 1980; Williams and others, 2002; Miller and others, 2004). As of early 2024, no effective treatments for CWD at the individual, population, or landscape level exist. Previous research has shown population declines in mule deer and white-tailed deer that were correlated with CWD prevalence (Edmunds and others, 2016; DeVivo and others, 2017), and the Jackson elk population was predicted to decline when prevalence reaches 7–13 percent (Monello and others, 2017, Galloway and others, 2021).

Brucellosis, another bacterial disease transmitted in feedground settings, affects elk, bison, and domestic livestock in the Yellowstone region. The disease is mainly transmitted in the spring prior to calving by contact with fetuses aborted from infectious individuals (NAS, 2020). Previous analyses of brucellosis seroprevalence in elk on feedgrounds suggested that longer feeding seasons and higher elk densities were correlated with higher seroprevalence (Cross and others, 2007). Subsequent attempts to mitigate brucellosis transmission on feedgrounds, however, had little success (Cotterill and others, 2020). In addition, increases in brucellosis seroprevalence in elk populations that do not overwinter on feedgrounds suggests that this disease will persist even in the absence of supplemental feeding (Cross and others, 2010a; 2010b; Brennan and others, 2017).

Beyond the disease concerns surrounding fed bison and elk, these species are valued by the many stakeholders for their roles in healthy ecosystems, as a charismatic species for wildlife viewers, and as game. Regionally, bison and elk support local economies and provide viewing and harvest opportunities for Tribes, members of the public, and outfitters. Elk hunting alone has generated more than $4.9 million in annual income and 269 jobs in Teton County, Wyoming, according to Koontz and Loomis (2005). A more recent study

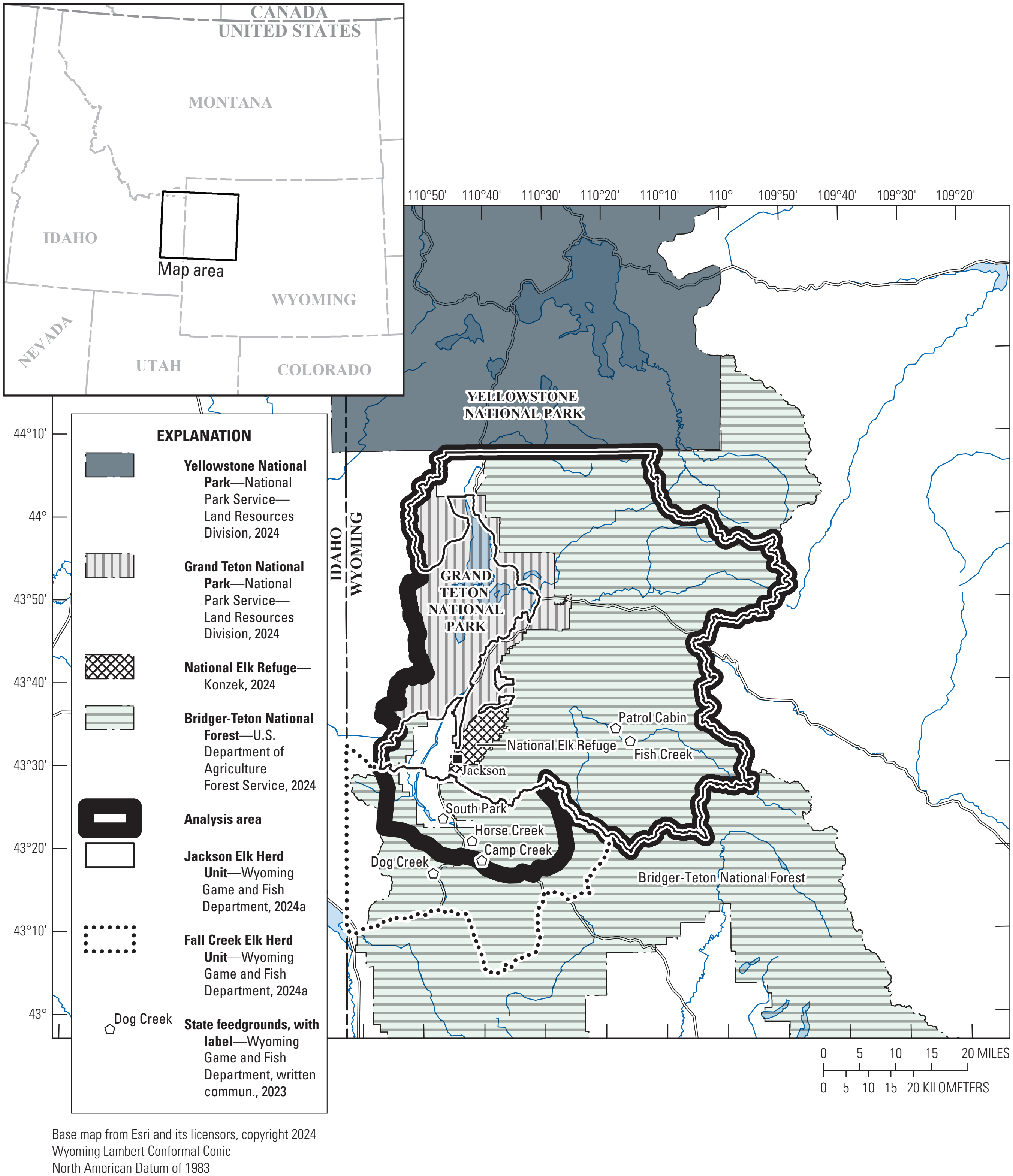

Figure A1. Map showing the study area. The analysis area (thick black polygon) is composed of the Jackson Elk Herd Unit (thin black polygon), part of the Fall Creek Herd Unit (dotted border polygon), the National Elk Refuge and Grand Teton National Park. Also included are the locations of six State feedgrounds, Patrol Cabin, Fish Creek, South Park, Horse Creek, Camp Creek, and Dog Creek, that were considered in the analyses of this report.

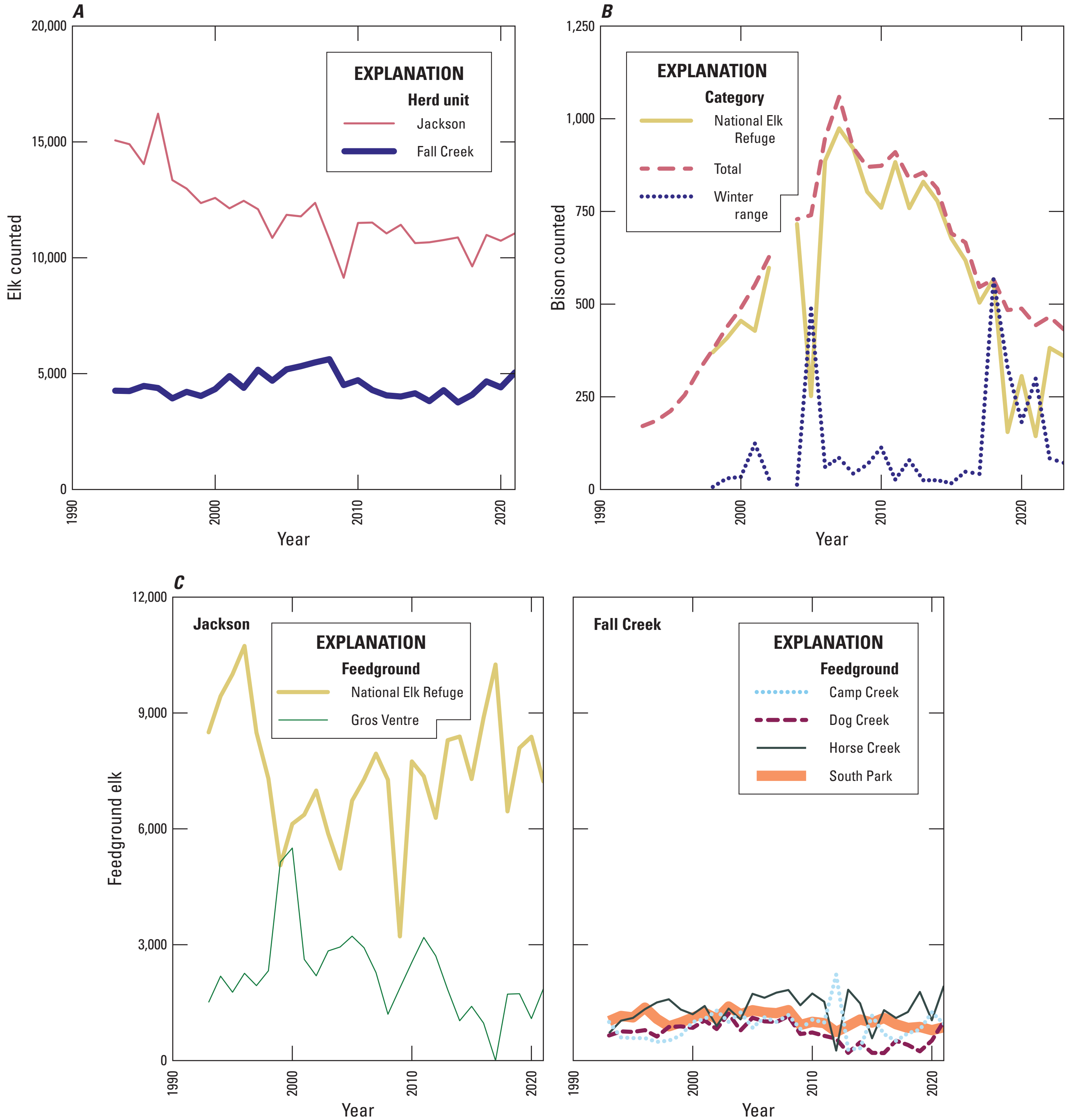

Figure A2. Line graphs showing the population counts of elk (*A* and *C*) and bison (*B*) in the Jackson region from 1993 to 2021 (shown by herd unit [*A*], and by feedground [*C*]). The Gros Ventre feedground in panel *C* includes Patrol Cabin and Fish Creek feedgrounds.

by Dietsch and others (2020) found that visitors continue to visit the NER for opportunities to hunt, fish, and ride horse-drawn sleighs, and that these activities may be affected by any changes to winter feeding of bison and elk.

This multichapter report describes a structured decision-making process that was led by the U.S. Geological Survey to evaluate potential management alternatives and support the drafting of the next “BEMP”. This chapter covers the detailed decision-framing elements of the “BEMP” decision, an abbreviated description of methods employed to evaluate alternatives, and presents summarized results for each of four technical chapters on elk disease and population dynamics (Cross and others, 2025, this volume, chap. B), elk space-use patterns including private land use patterns (Cotterill and others, 2025, this volume, chap. C), bison population dynamics and conflict potential (Cook and others, 2025, this volume, chap. D), and human effects including nonhunting and hunting visitation trends and economic effects (McEachran and others, 2025, this volume, chap. E).

Decision Framing

The process of structured decision making was used to frame and evaluate the set of potential bison and elk management alternatives on a set of objectives that were identified by FWS. Structured decision making is a normative process that helps break down and analyze distinct components of decisions using a series of steps. The steps include (and are described in this chapter) defining the problem and identifying objectives, alternatives, consequences, and trade-offs (Hammond and others, 1998).

The decision problem can be described using a formal problem statement that articulates important scoping details about the decision. The details about the following elements are typically included:

- A specific description of the decision itself;
- The decision maker;
- The decision maker’s authority to act;
- The scale of the decision (including spatial and temporal scoping); and,
- Any aspects that might make the decision difficult.

Next, the fundamental objectives describe the complete set of concerns that a decision maker has when making a management decision. Fundamental objectives are designed to be a direct expression of the mission and goals of an agency, their motivations, and any relevant values or desires of stakeholders as related to the specific decision context. Then, performance metrics are developed for each fundamental objective to evaluate the performance of the alternatives and to make comparisons against one another. The consequence assessment measures that performance and provides a quantitative comparison of each alternative relative to the others. Finally, tools and strategies from decision analysis can be used to help decision makers evaluate trade-offs and identify the alternative that best meets the full range of concerns specific to the decision context. The process of structured decision making has been successfully used in natural resources settings (for example, refer to Runge and others, 2015), including a recent application to another feedground decision on nearby Bridger-Teton National Forest (fig. A1; Cook and others, 2023). Using this process implemented in a series of facilitated discussions, the following “Problem Statement,” “Fundamental Objectives and Performance Metrics,” and “Management Alternatives” were developed.

Problem Statement

The physical, biological, and cultural resources of the NER are managed in accordance with several location-specific acts of Congress (for example, 16 U.S.C. 673, establishing an elk reserve), executive orders, and other Federal legislation, such as the National Wildlife Refuge System Administration Act of 1995 (16 U.S.C. 668dd), National Wildlife Refuge System Improvement Act of 1997 (Public Law 105-57), and Endangered Species Act of 1973 (16 U.S.C. 1531). A primary focus of the NER (FWS, 2019) is to help manage the bison and elk herds—both are culturally and ecologically important at the Refuge and throughout the region. To guide the management of these species, FWS uses an existing “BEMP” (FWS and NPS, 2007), and “Step-Down Plan” (FWS, 2019). Decisions at the NER are under the direct authority of the Refuge manager and other leadership of FWS; however, close partnerships exist across State, Federal, local, and Tribal leaders in the GYE that also influence management decisions.

As of 2024, bison and elk are fed at the NER during winter months to reduce overwinter mortality of elk, reduce human-wildlife conflicts, and minimize competition between bison and elk. The NER distributes pelleted feed on 5,000 acres during the months of January–April to offset a loss of native winter range because of human development. Bison and elk feeding is also considered an effective tool to reduce human-wildlife conflicts that can occur when animals seek out alternative food resources in nearby urban areas or comingle with livestock and thereby increase risk of wildlife-to-livestock disease transmission. However, the concentration of elk on feedgrounds has led to loss of diverse woody plant communities that provide habitat for other species and may increase disease transmission as animals are aggregated in high densities on feedgrounds. In addition to feeding, the Refuge acts to improve habitat quality, including large-scale restoration projects and the irrigation of as much as 4,500 acres (FWS, 2019).

The spread of CWD across Wyoming and into the GYE has motivated a reevaluation of bison and elk management, including the practice of bison and elk feeding. Given the potential for CWD to alter the system, the complex setting under which management decisions are made, and the 17 years since the last “BEMP” was drafted, the NER seeks to revise the plan (FWS, 2023) in a manner that considers new knowledge and science, as well as the elevated threat that CWD presents to the Jackson elk herd. The Refuge also wants to better understand the effects that management alternatives might have on bison, physical and cultural resources, and human activities. The temporal scope of the "BEMP" metrics was 20 years to approximately align with the period of implementation for the prior plan. The spatial scope of the "BEMP" is the Refuge, but managers are also interested in considering the effects of the management alternatives on surrounding Federal, State, and private lands (herein called the analysis area, fig. A1). The analysis area was first proposed by WGFD staff using WGFD datasets and local expertise. The analysis area was later confirmed with the interagency team of science experts, including members from the FWS, U.S. Department of Agriculture—Forest Service (FS), National Park Service (NPS), and WGFD.

Fundamental Objectives and Performance Metrics

As established by the NER, fundamental objectives describe the unique set of concerns that a decision maker wants to (or is mandated to) achieve when making a decision (Gregory and others, 2012). As such, the set of fundamental objectives, when comprehensively analyzed, may help a decision maker understand how each alternative might perform and select the option that is expected to provide the best outcomes. The National Elk Refuge used a series of meetings facilitated by the U.S. Geological Survey, as well as feedback from other agencies, stakeholders, and public comments to identify nine fundamental objectives. Many are drawn directly from an interpretation of the mission of the National Elk Refuge and guiding documents such as 16 U.S.C. 673, establishing the NER as an elk reserve, the National Wildlife Refuge System Administration Act of 1995 (16 U.S.C. 668dd), National Wildlife Refuge System Improvement Act of 1997 (Public Law 105-57), as well as prior Refuge plans including the existing "BEMP" (FWS and NPS, 2007) and "Step-Down Plan" (FWS, 2019).

Fundamental Objective 1. *Maximize the health and well-being of wildlife.*—According to the National Wildlife Refuge System Administration Act of 1995 (16 U.S.C. 668dd) and National Wildlife Refuge System Improvement Act of 1997 (Public Law 105-57)), FWS will manage refuge resources to "ensure that the biological integrity, diversity, and environmental health * * * are maintained for the benefit of present and future generations of Americans." The introduction and spread of CWD in elk populations will lead to sick and dying animals and a departure from management goals related to the health and conservation of elk. Further, if elk repeatedly aggregate in the same geographic location because of management activities like supplemental feeding, the NER lands may be contaminated by infectious pathogens, including CWD prions, leading to locally elevated indirect disease transmission and further negative effects.

Performance metric 1a.—Minimize the prevalence of CWD in elk after 20 years.

Performance metric 1b.—Maximize the population size of elk after 20 years.

Performance metric 1c.—Minimize the suffering of elk during the first 5 years of implementation of a new management plan as defined by the cumulative number of natural and disease-induced elk deaths during the winter months (November through March) of the first 5 years.

Performance metric 1d.—Maximize the population size of bison after 20 years.

National Elk Refuge managers were interested in maintaining long-distance elk migrations (Cole and others, 2015). However, elk population size was used as a proxy because of the high uncertainty in how the management alternatives could affect migration patterns. National Elk Refuge managers were also interested in maintaining the genetic diversity of the bison herd in alignment with the Department of Interior Bison Conservation Initiative (2020), for which bison population size in year 20 was used as a proxy.

Fundamental Objective 2. *Maintain ecosystem fluctuations and processes associated with bison and elk*.—Big game populations, including bison and elk, are important to the structure and composition of plant and animal communities across the GYE. For example, elk forage heavily on riparian *Salix* L. (willow) during winter months and reduce the availability of willow for other species, including songbirds and *Castor canadensis* (Kuhl, 1820; beaver). The reduction of beavers heavily alters landscapes because beaver dams create ponds, wetlands, and stream channels that retain moisture and create habitat for a diversity of other plants and biota, both terrestrial and aquatic (FWS and NPS, 2007). Bison and elk herbivory similarly affects other woody plants and grasslands, including *Populus tremuloides* (quaking aspen), *Populus angustifolia* (narrowleaf cottonwood), and willow.

Performance metric 2a.—Minimize elk use of aspen stands on and around NER over the next 20 years.

Performance metric 2b.—Minimize elk use of cottonwood stands on and around NER over the next 20 years.

Performance metric 2c.—Minimize elk use of willow stands on and around NER over the next 20 years.

Fundamental Objective 3. *Minimize the risk of invasive species introduction and spread associated with bison and elk management activities*.—Human activities associated with bison and elk feeding have the potential to introduce or further spread invasive plant species and alter the dynamics of sensitive ecosystems.

Performance metric 3a.—Minimize the number of feeding days at the Refuge over the next 20 years as a proxy for invasive plant species introduction and spread risk from mechanized disturbance.

Fundamental Objective 4. *Protect and restore the chemical, physical, and biological quality of water resources*.—The NER has a legal mandate and trust responsibility to protect and restore lands and waters for the conservation and enhancement of fish and wildlife, and for the benefit of current and future Americans (National Wildlife Refuge System Administration Act of 1995 [16 U.S.C. 668dd] and National Wildlife Refuge System Improvement Act of 1997 [Public Law 105-57]). Aggregations of big game animals, including bison and elk, can affect the water quality and morphology of waterways in areas of high use (FWS and NPS, 2007). Excessive nutrient inputs from the biological waste of bison and elk may elevate nutrients, fuel algal growth, and elevate the risk of cyanotoxins and harmful algal blooms. Grazing along rivers and stream beds can further affect water quality and morphology by increasing erosion and suspended sediment and altering habitat for riparian plants and aquatic species (FWS and NPS, 2007). In addition, bison and elk aggregations may lead to an elevated prevalence of wildlife diseases whose pathogens can be introduced into streams and rivers, either directly or by surface water runoff (FWS and NPS, 2007). This fundamental objective was raised as important by NER managers (in alignment with FWS and NPS, 2007); however, subject matter experts from the FWS, NPS, FS, and WGFD expected that the effects of bison and elk on the chemical, physical, and biological properties of water resources at the Refuge would be the same under all alternatives and therefore this objective was not considered further in this report.

Fundamental Objective 5. *Maintain and enhance multiple use opportunities and public enjoyment*.—Abundant and healthy populations of bison and elk help to preserve the multiple uses of cultural, biological, and physical resources of the NER. At the NER, hunting, education, and wildlife viewing are important wildlife-oriented activities to maintain and are listed in the comprehensive conservation plan (FWS, 2015).

Performance metric 5a.—Maximize the number of elk harvested in the JHU over the next 20 years.

Performance metric 5b.—Maximize the number of visitors using the NER over the next 20 years.

Fundamental Objective 6. *Minimize human-wildlife conflicts*.—During winter months, bison and elk management has been primarily focused on minimizing human-wildlife conflict and maximizing overwinter survival during harsh winter conditions. The bison and elk supplemental feeding program was established to provide forage, given the large-scale loss of historical winter range because of human developments. If feeding were to stop, bison and elk may redistribute across the landscape in search of other sources of winter forage. The search for winter feed might increase depredation on private haystacks and suburban landscaping. Additionally, it is possible that elk might come into more frequent contact with livestock, and thus increase local rates of brucellosis transmission.

Performance metric 6a.—Minimize the use of private lands by elk over the next 20 years.

Performance metric 6b.—Minimize the number of bison expected to conflict with humans over the next 20 years.

Performance metric 6c.—Minimize the risk of brucellosis transmission events from elk to livestock over the next 20 years. Only the risk that elk present to livestock was evaluated because elk were identified as the primary source of brucellosis transmission in the GYE (NAS, 2020).

NER managers were interested in measuring bison and elk caused vehicle collisions under each alternative (FWS, oral comm., 2024), but data and expert knowledge to inform behavioral responses of bison and elk to feedground operations at fine spatial and temporal scales were unavailable at the time of this study.

Fundamental Objective 7. *Minimize costs of bison and elk management activities*.—Management activities at the NER are limited by annual budgets. Currently, bison and elk management activities require annual monetary costs exceeding $500,000 (FWS, written comm., 2023). These budgetary allocations compete with other activities and programs, including habitat restoration, public education and outreach, and species conservation.

Performance metric 7a.—Minimize direct monetary costs to FWS for bison and elk management activities over the next 20 years.

Fundamental Objective 8. *Maximize local economic benefits associated with bison and elk presence at the NER and surrounding lands*.—Bison, elk, and other big game animals at the NER are valued among visitors, residents, and Tribes (FWS and NPS, 2007). Bison and elk support local and regional economies by providing millions of dollars in annual revenues to businesses associated with hunting or viewing big game animals (lodging, restaurants, hunting guides, outfitters, and others; FWS and NPS, 2007).

Performance metric 8a.—Maximize the annual economic value of elk hunting as measured by harvest tag sales over the next 20 years.

Performance metric 8b.—Maximize annual spending, in dollars, by elk hunters in the JHU and by nonhunting visitors to the NER over the next 20 years.

Performance metric 8c.—Maximize annual economic value for outfitters and outfitted hunts over the next 20 years.

Fundamental Objective 9. *Maximize opportunities for Tribes to engage in activities related to their buffalo culture*.—Bison are important to the traditional cultures, beliefs, and practices of Tribes (Department of Interior Bison Conservation Initiative, 2020). Decisions on how to manage bison and elk must consider how management practices affect opportunities for Tribes to maintain their traditional practices and interactions with bison. This objective also captures bison harvest opportunities for nonTribal resident and nonresident Wyoming hunters.

Performance metric 9a.—Maximize the number of harvested bison over the next 20 years.

Management Alternatives

Consistent with the development of the fundamental objectives, the NER used a series of meetings facilitated by U.S. Geological Survey to develop five management alternatives that explore a range of management actions that could be effective at achieving some (or all) of the fundamental objectives. The text in parentheses are the short names for these alternatives.

- *Continue feeding*.—The NER will continue to provision food to bison and elk during winter months. Hunting practices are assumed to remain the same, but the rate of female elk harvest is assumed to decline to zero from current levels if the elk population approaches 80 percent of the Jackson or Fall Creek Herd Unit objectives.

- *No feeding*.—The NER will immediately stop provisioning food to bison and elk during winter months. Following cessation of feeding, restoration will take place on former feedground locations to improve conditions for native plant regeneration.

- *Increase harvest then stop feeding (Increase harvest or increased harvest)*.—The NER will continue to provision food to bison and elk during winter months for the next 5 years, during which time the NER will work with WGFD to increase elk harvest and attempt to reduce population of elk that overwinter on NER feedgrounds to 5,000. After year 5, feeding is ceased. Restoration will occur after year 5 on feedground locations to improve conditions for native plant regeneration. Note that this alternative requires adjustment to the current harvest rates of the JHU and thus is not fully under the authority of FWS.

- *Reduce feeding then stop feeding (Reduce feeding or reduced feeding)*.—The NER will provision a fixed daily ration to bison and elk during winter months for the next 5 years to reduce elk population size prior to feedground closures. After 5 years feeding will stop. Restoration will occur after year 5 on feedground locations to improve conditions for native plant regeneration. Exclosures may be put into place to protect aspen stands in the southern region of the NER, and for willow and cottonwood in the northern region of the NER.

- *Stop feeding after 3* percent *CWD prevalence (Disease threshold)*.—The NER will continue to provision food to bison and elk during winter months until CWD sampling reveals 3 percent prevalence in the Jackson elk herd, at which point all feeding activities will cease at the NER. Following cessation of feeding, restoration will take place on former feedground locations to improve conditions for native plant regeneration.

Overview of Analytical Methods Used to Evaluate Consequences of Alternatives

The alternatives were evaluated using several interagency panels of subject matter experts (including staff of FWS, NPS, FS, and WGFD) who focused on physical landscapes and habitats, wildlife effects, hunter and nonhunting visitor groups, and economic effects of bison and elk management. Two expert panels were assembled that used formal methods of elicitation to estimate important but unknown relationships that may affect the performance of management alternatives. The methods are briefly described here (table A1), but full details can be found in Cross and others (2025, this volume, chap. B), Cotterill and others (2025, this volume, chap. C), Cook and others (2025, this volume, chap. D), and McEachran and others (2025, this volume, chap. E; table E1).

To simulate elk population dynamics, CWD, and elk harvest under each alternative, Cross and others (2025, this volume, chap. B) developed a sex- and age-structured population model that included direct and indirect CWD transmission. The model followed several previous studies, including Cross and Almberg (2019), Rogers and others (2022), and Cook and others (2023). The model tracked seven different elk population segments in the Jackson region. The JHU was split into the following three subpopulations: elk that come to the NER in winter, elk that are fed in the Gros Ventre drainage at Patrol Cabin and Fish Creek feedgrounds (fig. Al), and all other elk in the herd unit (referred to as unfed elk). The Fall Creek herd unit was split into four subpopulations—fed and unfed elk inside the analysis area and fed and unfed elk outside the analysis area (fig. Al). Then, the subpopulation results across the JHU or across the analysis area were summarized. The results of Cross and others (2025, this volume, chap. B) were also used to inform population projections for Cotterill and others (2025, this volume, chap. C) and McEachran and others (2025, this volume, chap. E).

Table A1. Bison and Elk Management Plan objectives and performance metrics related to the bison and elk feeding program. The table also includes a citation for the chapter in this report that develops the technical methods to estimate each performance metric.

[Fundamental objective four was raised as important by NER managers (in alignment with FWS and NPS, 2007); however, subject matter experts from the FWS, NPS, FS, and WGFD expected that the effects of bison and elk on the chemical, physical, and biological properties of water resources at the Refuge would be the same under all alternatives and therefore this objective was not considered further]

Performance metric number	Performance metric	Performance metric units	Reference chapter
Objective 1—Maximize the health and well-being of wildlife			
1a	Minimize prevalence of CWD in elk	CWD prevalence in elk in 20 years	Cross and others, 2025 (this volume, chap. B)
1b	Maximize population size of elk	Number of elk in 20 years	Cross and others, 2025 (this volume, chap. B)
1c	Minimize suffering of elk	Natural and CWD elk mortality in first 5 years	Cross and others, 2025 (this volume, chap. B)
1d	Maximize bison population	Number of bison in 20 years	Cook and others, 2025 (this volume, chap. D)
Objective 2—Maintain ecosystem fluctuations and processes associated with bison and elk			
2a	Minimize use of aspen habitats	Cumulative elk-use days across 20 years	Cotterill and others, 2025 (this volume, chap. C)
2b	Minimize use of cottonwood habitats	Cumulative elk-use days across 20 years	Cotterill and others, 2025 (this volume, chap. C)
2c	Minimize use of willow habitats	Cumulative elk-use days across 20 years	Cotterill and others, 2025 (this volume, chap. C)
Objective 3—Minimize risk of invasive species introduction associated with bison and elk management activities			
3a	Minimize invasive species introduction and spread risk	Cumulative feeding days across 20 years	Developed in this chapter
Objective 4—Protect and restore the chemical, physical, and biological quality of water resources			
Objective 5—Maintain and enhance multiple use opportunities and public enjoyment			
5a	Maximize elk harvested	Cumulative number of elk harvested over 20 years	Cross and others, 2025 (this volume, chap. B)
5b	Maximize NER visitors	Cumulative number of NER visitors over 20 years	McEachran and others, 2025 (this volume, chap. E)
Objective 6—Minimize human-wildlife conflicts			
6a	Minimize the use of private lands by elk	Cumulative elk-days across 20 years	Cotterill and others, 2025 (this volume, chap. C)
6b	Minimize the use of private lands by bison	Cumulative number of conflict bison across 20 years	Cook and others, 2025 (this volume, chap. D)
6c	Minimize the risk of brucellosis transmission	Cumulative number of elk abortions on sensitive properties	Cotterill and others, 2025 (this volume, chap. C)
Objective 7—Minimize costs of bison and elk management activities			
7a	Minimize direct monetary costs of bison and elk management	Cumulative cost in U.S. dollars across 20 years	Developed in this chapter
Objective 8—Maximize local economic benefits associated with bison and elk presence at the NER and surrounding lands			
8a	Maximize hunting revenues	Cumulative hunting license sale revenue	McEachran and others, 2025 (this volume, chap. E)
8b	Maximize local economic revenues	Cumulative hunting- and nonhunting-associated revenues	McEachran and others, 2025 (this volume, chap. E)
8c	Maximize hunting revenues	Cumulative revenues of outfitters	McEachran and others, 2025 (this volume, chap. E)
Objective 9—Maximize opportunities for Tribes to engage in activities related to their buffalo culture.			
9a	Maximize bison available to be harvested	Cumulative bison harvested across 20 years	Cook and others, 2025 (this volume, chap. D)

To predict elk space-use under each alternative, Cotterill and others (2025, this volume, chap. C) developed a resource selection model that distributed the numbers of elk projected by Cross and others (2025, this volume, chap. B) at monthly intervals. The resource selection model generally followed Cook and others (2023) but, importantly, incorporated additional environmental covariates suggested by subject matter experts. Separate models were developed for "fed" and "unfed" elk that varied according to relative winter severity. Differences among alternatives resulted from varying abundance under the elk CWD model, if and when NER ceased winter feeding operations, and additional assumptions informed by the expert elicitation process. Elk use of sensitive vegetation communities at the NER and across important elk wintering areas in the region were estimated. The number of elk predicted to use private lands and properties where cattle overwinter, as a proxy for brucellosis risk, were summarized.

To model bison population dynamics, harvest, and conflict potential, Cook and others (2025, this volume, chap. D) adapted an existing sex- and age-structured matrix model of ungulate population dynamics (Cross and Almberg, 2019; Cook and others, 2023; Cross and others, 2023). The adapted model incorporated information from the subject matter expert team who had expertise in bison ecology and wildlife management principles. The team described expected changes to bison space-use and population dynamics under the alternatives. Cook and others (2025, this volume, chap. D) then used published literature and expert judgment to estimate vital rates, harvest statistics, and other parameters necessary to predict abundance, harvest, and bison conflicts under the management alternatives.

McEachran and others (2025, this volume, chap. E) integrated bison and elk population and harvest projections, as well as elk space-use patterns, to estimate economic and visitor-related effects that included NER visitation and visit-related spending, and hunting-related spending in the Jackson region. Monthly NER visitor center counts were modeled using predictors typically associated with visits to refuges (Loomis and Caughlan, 2004) and projected changes to visitation and spending according to relationships that these response variables had with elk abundance at the Refuge. McEachran and others (2025, this volume, chap. E) also evaluated the potential for the alternatives to affect sleigh ride businesses using historical data and future elk projections. Lastly, McEachran used harvest projections from Cross and others (2025, this volume, chap. B) and estimates of hunter behavior from Koontz and Loomis (2005), which used best-practice survey methodology, to project future economic revenues from hunting and hunting-associated activities.

Finally, the methods used to calculate the direct costs of the feedground program to FWS (fundamental objective 7) and the total number of feeding days (proxy for fundamental objective 3) are briefly covered in this chapter because they are not covered in a separate technical chapter. First, to estimate costs for each alternative, the average monetary expense of the feedground operations per year for feeding season 2021–22 and 2022–23 was calculated (FWS, written comm., 2024). The annual cost was then divided by the total number of feed days for each of those years to get a cost per day of feedground operations. Finally, those costs were projected across the 20 years by multiplying the cost per day by 20 randomly drawn feed season lengths from the historical data from 2004 to 2023 and summing the total (FWS, written comm., 2023). Net present value or future expectations about monetary inflation were not adjusted for. The sum of the 20 randomly drawn feed season lengths were used to calculate the proxy measure for invasive species (fundamental objective 3).

Important Modeling Assumptions

All models are simplifications of complex processes that are intended to capture only the most important factors. As such, the following assumptions were made in this study's models:

- The reduction in elk populations because of not feeding at the NER was enforced by the severe winters reducing unfed elk survival rates. Our model's assumptions were based on Hobbs and others (2003), but the frequency and severity of these winter effects are uncertain along with the potential redistribution of previously fed elk to other regions, or potentially other feedgrounds.

- Climate change projections were not incorporated, despite projections of 30–40 percent reductions in April snowpacks in the study area by midcentury (Hostetler and others, 2021). The reduced snowpack may result in shorter feeding seasons under the continue feeding alternative. Other climate effects on bison and elk may include elevated summer temperatures, increasing severity and frequency of drought, shifting forage phenology, and possibly reducing summer growth of winter forage (MacNulty and others, 2020).

- The potential effects that predators, such as wolves and cougars, may have on elk CWD dynamics were not included (Krumm and others, 2010; Brandell and others, 2022). If predators preferentially kill infected individuals and shorten the infectious period, they may reduce transmission and prevalence. However, substantial uncertainty remains in the selectivity of predators for diseased individuals and the relative timing of transmission and disease symptoms (Brandell and others, 2022).

- Other diseases besides CWD and brucellosis and their potential interactions were not evaluated. Other pathogens that this study lacked the data to include but may be important in the future are *Fusobacterium necrophorum* (Flügge, 1886; Moore and Holdeman, 1969) in elk and *Mycoplasma bovis* (Hale et al., 1962; Askaa and Erno, 1976) in bison. It is likely that animal aggregations that result from supplemental feeding may increase the transmission of both diseases.

- Evolutionary changes in either elk or CWD were not included. Some elk genotypes progress to disease and CWD-induced death more slowly than others (Moore and others, 2018). Similarly, some CWD strains develop and cause mortality more quickly than others depending on host genotype and species (Pritzkow, 2022). The evolution and interaction of hosts and strains are still unclear.

- Any management changes other than those evaluated by NER or attempts to predict land-use changes that may affect bison and elk habitat selection were also not included. Many potential management actions could be taken by agencies that manage bison, elk, as well as public and private lands, which could affect the performance of the alternatives. For example, although concern exists over the potential for increases in traffic accidents, it was unclear whether and how surrounding land management agencies would respond to any changes in bison and elk distribution (for example, erect new fencing, conduct hazing operations).
- For the socioeconomic analyses, historical relationships between wildlife presence and visitation to the NER were assumed to adequately predict future dynamics, and that historical patterns in visitors' trip purpose, general spending patterns, and drivers of visitation are maintained in the future. It is possible that persistent declines in the number of elk available for viewing or hunting in the area could uncouple these relationships in ways not captured by our analyses. Changes in hunting were also assumed to be directly proportional to changes in elk numbers according to historical relationships; in other words, a decline in animals harvested predicted by the elk population model would result in a proportionate decline in hunter spending in the region.

Consequences

We present a summarized set of findings (consequences) for each of the performance metrics under the five alternatives. For complete details and description of the consequences, please refer to Cross and others (2025, this volume, chap. B), Cotterill and others (2025, this volume, chap. C), Cook and others (2025, this volume, chap. D), and McEachran and others (2025, this volume, chap. E; table E1).

The no feeding and disease threshold alternatives had the lowest CWD prevalence estimates in elk at year 20 (table A2). They were 24 (Standard deviation [SD]=8) and 23 percent (SD=7), respectively (Cross and others, 2025, this volume, chap. B). The continue feeding alternative had the highest 20-year CWD prevalence of 35 percent (SD=6), and the reduce feeding and increase harvest alternatives had intermediate values of 26 to 27 percent (SD=9 and 10). Further, the Jackson elk population is predicted to decline under all management alternatives. The continue feeding alternative resulted in the largest declines of elk on average, 54 percent, from 14,500 to 6,700 elk (SD=1,600), whereas the disease threshold alternative resulted in the smallest decline of 40 percent to 8,600 (SD=1,600; table A2). The no feeding alternative performed similarly to the disease threshold alternative and only had a few hundred less individuals in year 20. The reduce feeding and increase harvest alternatives resulted in intermediate outcomes between continue feeding and disease threshold alternatives. Finally, the increase harvest alternative had the lowest number of CWD and natural elk mortalities in the first 5 years of plan implementation (mean=7,100, SD=700), and the continue feeding had intermediate values (mean=8,000, SD=700). The disease threshold, reduce feeding, and no feeding alternatives were all expected to perform worse than continue feeding and increase harvest alternatives in terms of elevating natural mortality from a variety of sources, not limited to harsh winter conditions, increasing human-elk conflicts, and competition with other large ungulates (fig. A3).

For bison population performance, the continue feeding alternative would result in the largest population of bison after 20 years (median=541, SD=57), and the no feeding (median=469, SD=65), disease threshold (median=470, SD=67), increase harvest (median=472, SD=70), and reduce feeding (median=473, SD=65) alternatives had smaller population size estimates that were indistinguishable from one another (Cook and others, 2025, this volume, chap. D).

Negative effects of elk space-use declined over time as elk numbers fell. For sensitive vegetation communities at the NER, effects were reduced by all alternatives that ceased feeding compared to continuing to feed. Across the broader study area, the alternatives had a mixed performance where the continue feeding alternative performed better for willow and worse for aspen (Cotterill and others, 2025, this volume, chap. C). Considering the degree of variation across simulations, increase harvest and reduce feeding were the alternatives that most consistently performed well for these metrics. Importantly, the reduce feeding alternative called for exclosures to be installed surrounding aspen, willow, and cottonwood stands at the NER, which primarily improved the performance of this alternative with respect to aspen.

For invasive species introduction and spread risk, the number of feeding days over the next 20 years was highest under the continue feeding alternative with an average of 1,243 days (SD=100). Fed days were intermediate under the reduced feeding and increased harvest (311 days, SD=50) and disease threshold (140 days, SD=43) alternatives. The no feeding alternative was assumed to have 0 fed days at the Refuge over the next 20 years.

The effect of elk monthly counts on visitation was small and the Bayesian posterior substantially overlapped 0. The small effect size (median=0.03) led to no differences among alternatives even when elk numbers changed substantially in the underlying data. Although it is certainly possible that elk abundance changes at the NER influence winter visitation under the alternatives, the historical data do not support that conclusion (FWS, written comm., 2023).

For human-wildlife conflicts, the continue feeding alternative had the least private land use by elk, whereas disease threshold and no feeding had the highest use of private lands (in other words, performed the worst; Cotterill and others, 2025, this

Table A2. Consequence table showing the performance metrics and alternatives.

[See Table A1 for full performance metric details. Measures for 1a -c were rounded to two significant figures. Fundamental objective four was raised as important by NER managers (in alignment with FWS and NPS, 2007); however, subject matter experts from the FWS, NPS, FS, and WGFD expected that the effects of bison and elk on the chemical, physical, and biological properties of water resources at the Refuge would be the same under all alternatives and therefore this objective was not considered further. min., minimum; CWD, chronic wasting disease; max., maximum SD, standard deviation]

Performance metric, direction and unit	Continue feeding		Disease threshold		Reduced feeding		Increase harvest		No feeding	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Objective 1—Maximize the health and well-being of wildlife										
1a, CWD prevalence, min. at year 20	0.35	0.05	0.26	0.06	0.27	0.08	0.28	0.08	0.26	0.07
1b, elk population size, max. at year 20	6,700	1,600	8,600	1,600	7,700	1,800	7,600	1,900	8,400	1,700
1c, minimize elk suffering, min. mortality in first 5 years	8,000	730	8,100	830	8,100	740	7,100	650	8,100	850
1d, bison population size, max. at year 20	546	57	464	67	469	65	467	70	462	65
Objective 2—Maintain ecosystem fluctuations and processes associated with bison and elk										
2a, elk use of aspen, min. cumulative elk days [1,2]	616	61	585	48	539	51	518	44	532	43
2b, elk use of cottonwood, min. cumulative elk days[1,2]	1,615	179	1,657	187	1,591	178	1,547	154	1,616	198
2c, elk use of willow, min. cumulative elk days[1,2]	385	36	441	39	406	40	393	35	440	36
Objective 3—Minimize risk of invasive species introduction associated with bison and elk management activities										
3, invasive species risk, min. cumulative feeding days[1]	1,243	100	140	43	311	50	311	50	0	0
Objective 5—Maintain and enhance multiple-use opportunities and public enjoyment										
5a, elk harvest, max. cumulative elk harvested[1]	13,181	1,885	13,215	2,082	11,834	2,036	14,276	1,467	12,603	2,071
5b, number of visitors, max. visitors[1,3]	3.4	0.8	3.3	0.8	3.3	0.8	3.3	0.8	3.3	0.8
Objective 6—Minimize human-wildlife conflicts										
6a, elk use of private lands, min. elk days[1,3]	12.4	1.0	13.8	1.2	13.1	1.2	12.8	1.0	13.8	1.2
6b, human-bison conflict, min. number of conflict bison	143	16	905	482	756	442	756	473	1,077	474
6c, Brucellosis risk, min. abortions on private lands[1]	161	16	181	21	173	19	170	17	180	21
Objective 7—Minimize costs of bison and elk management activities										
7, cost of management, min. dollars[1,3]	19.3	1.6	2.2	0.7	4.8	0.8	4.8	0.8	0	0
Objective 8—Maximize local economic benefits associated with bison and elk presence on the NER and surrounding lands										
8a, elk harvest tags, max. dollars[1,3]	5.5	0.6	5.2	0.7	4.8	0.8	6.6	0.6	5.0	0.8
8b, regional economic inputs for hunting activities, max. dollars[1,3]	88.6	12.2	82.0	14.3	73.0	14.1	101.3	9.6	76.1	14.8
8b, regional economic inputs for nonhunting, max. dollars[1,3]	3.0	0.7	2.9	0.7	2.9	0.7	2.9	0.7	2.9	0.7
8c, revenue of outfitters, max. dollars[1,3]	12.6	1.7	11.7	2.0	10.4	2.0	14.5	1.4	10.9	2.1
Objective 9—Maximize opportunities for Tribes to engage in activities related to their buffalo culture										
9, bison harvest, max. bison harvested	1,879	197	1,387	248	1,508	234	1,496	245	1,292	247

[1]Cumulative across the 20-year simulation.

[2]Rounded, in thousands.

[3]Rounded, in millions.

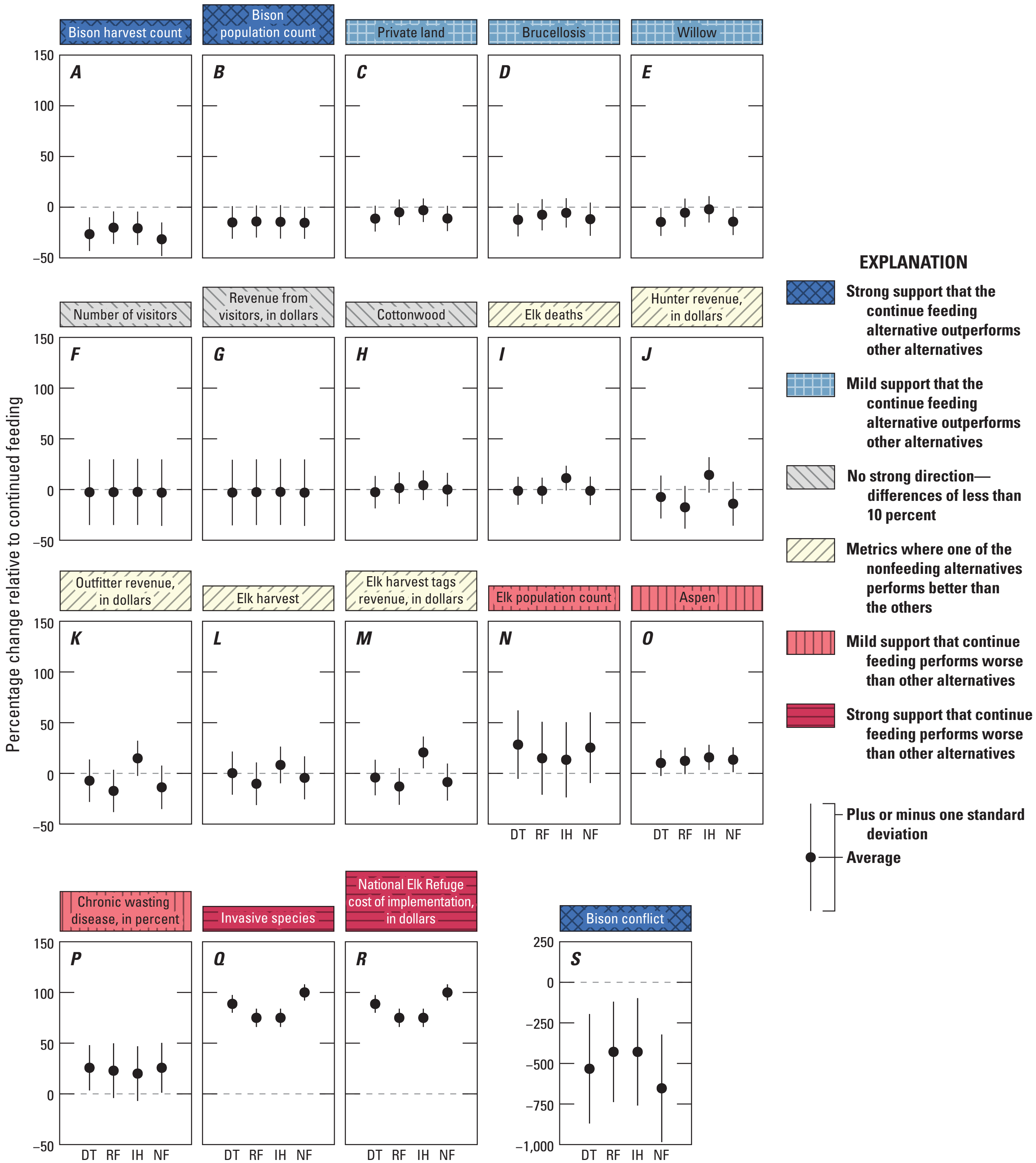

Figure A3. Graphs showing the percentage change in different performance metrics across management alternatives relative to the continue feeding alternative. Performance metrics where minimizing the value is preferred were multiplied by –1 so that negative values indicate the alternative does worse than continue feeding, but positive values indicate that the alternative does better than continue feeding across all metrics. Note that bison conflict is on a different scale for the y-axis. DT=disease threshold; RF=reduce feeding; IH=increase harvest; NF=no feeding.

volume, chap. C). However, the differences between continue feeding, reduce feeding, and increase harvest were small considering the overall magnitude of the estimates, declines in elk numbers, and the associated uncertainty in outcomes. In contrast, substantial differences, in terms of the potential for human-bison conflict, were found between the continue feeding alternative and the other four alternatives that stopped feeding. Over the next 20 years under the continue feeding alternative, 143 bison were estimated to be involved in conflict, whereas between 756 and 1,077 bison were in conflict under reduce feeding, disease threshold, increase harvest, and no feeding alternatives (Cook and others, 2025, this volume, chap. D). Finally, the brucellosis risk to livestock was assessed to be lowest under the continue feeding alternative (Cotterill and others, 2025, this volume, chap. C); however, the median estimates across all five alternatives were similar considering the uncertainty across simulations (table A2).

For the monetary costs of bison and elk management activities, the program was calculated to cost the FWS between $15,210 and $16,450 per day of feeding activities for the direct costs of feed, labor, fuel, and maintenance for machinery. In terms of feed season length, days of feeding varied between 0 days in 2017–18 to 101 days in 2010–11. The average length was 62 days (SD=24). In terms of total costs over 20 years, the continue feeding alternative was the most expensive, with an average cost of $19.3 million (SD=1.6 million), and the lowest cost was no feeding, which was assumed to have no direct costs (in other words, $0). The other alternatives varied according to the number of years until feeding stopped with reduce feeding and increase harvest alternatives costing $4.8 million (SD=$0.78 million) over the next 20 years and disease threshold having a cumulative 20-year cost of $2.2 million (SD=$0.67 million). The cost of exclosures that are included in the reduce feeding alternative was not considered.

Elk harvest tag sales, spending by hunters, and outfitter revenues were found to be highest under the increase harvest alternative. Although the increase harvest alternative did have initial hunting rates and hunting-related revenues that were higher than the other alternatives, revenues dropped after a few years. When considering changes over time, the increased harvest alternative had higher predicted tag revenues (mean=$6.60 million, SD=$574,000) and hunter-related spending (mean=$101.3 million, SD=$9.6 million), but like other performance metrics, the estimated ranges of the alternatives overlapped.

Projecting effects on outfitters over the next 20 years, the increase hunting alternative had the highest predicted number of clients with an average estimate of 3,758 clients (SD=416 clients) served over the next 20 years and a cumulative outfitter revenue of $14.5 million (SD=$1.4 million). The next highest performing alternative was the continue feeding alternative with an average of 3,480 clients (SD=565 clients) and $12.6 million (SD=$1.7 million) in revenue, followed by the disease threshold alternative, with an average of 3,319 clients (SD=627 clients) and $11.7 million (SD=$2.0 million) in revenue. The lowest cumulative number clients and revenues were predicted under the reduce feeding alternative, with 2,879 clients (SD=575 clients) and $10.4 million (SD=$2.0 million) in revenue over the next 20 years.

The last fundamental objective associated with bison harvest and Tribal ceremonial take had the best performance under the continue feeding alternative (median=1,879 bison harvested; SD=197) and the worst performance under the no feeding alternative (mean=1,292, SD=247). The reduced feeding (mean=1,508, SD=234), increase harvest (mean=1,496, SD=245), and disease threshold (mean=1,387, SD=248) all performed intermediate between continue feeding and no feeding.

In terms of tradeoffs, the largest differences among alternatives were measured in bison and elk population sizes at year 20, the cumulative invasive species risk as measured by feeding days, cumulative number of bison that conflict with humans, management costs, and cumulative harvest of bison. The continue feeding alternative was the worst alternative for elk population size, CWD prevalence, invasive species, and NER costs but was the best alternative for bison abundance, bison harvest, bison conflict, private land issues, and disease risks to cattle. The management alternatives did not have notably different consequences for visitor numbers, visitor spending, or effects on cottonwoods (fig. A3). The increased harvest alternative tended to perform best on elk harvest metrics as well as minimizing natural and CWD mortality of elk in the first 5 years.

Conclusions and Science Directions

Our results suggest that Jackson elk abundance will decline under all evaluated alternatives but that the mechanism, timing, and degree of declines depend on the specific management actions being taken. Under continue feeding, it is expected that chronic wasting disease (CWD) prevalence will increase over time and reduce abundance from the current population size of around 11,000 down to a median of 4,900 elk in year 20. In contrast, no feeding alternatives may lead to more rapid declines in the near term from natural, harvest, and conflict-associated causes, but after 20 years are projected to have a median size of 6,700 elk. The near-term consequences on elk populations from no longer feeding and the longer term effects of increases in disease mortality crossover between years 7 and 13. The continue feeding alternative predicts more elk initially, but the no feeding alternative predicts the highest elk abundance in year 20.

The disease dynamics that drive these patterns for fed and unfed elk were provided by an expert panel that estimated that direct transmission of CWD would be 1.9 times higher and indirect transmission would be 4 times higher in feedground settings (Cook and others, 2023). These transmission dynamics among fed and unfed elk resulted in the no feeding alternative performing better (in other words, have lower prevalence) than continue feeding in 70 percent of model simulations (Cross and others, 2025, this volume, chap. B). Further, the expert panel was convened to consider CWD dynamics on State feedgrounds that host fewer elk than the National Elk Refuge (NER). The NER elk may have higher (or lower) transmission rates depending on local aggregations of elk, social dynamics, and feed season lengths.

The effect of severe winters on elk mortality, however, remains a source of substantial uncertainty as it is unclear how snowfall and snowpack might affect elk populations under no feeding alternatives. For the purposes of this study, the results of Hobbs and others (2003) were used to enforce a severe winter penalty that led to higher mortality rates with an annual probability of 0.25 once NER stopped feeding operations. This increase in mortality resulted in an average of 38 percent declines projected for Jackson herd elk, compared to estimates of 23 percent for elk in other western Wyoming herd units (Cook and others, 2023). Although the true magnitude of declines remains uncertain, it seems reasonable to expect the Jackson Elk Herd Unit to perform worse than other units that have more critical winter range available relative to the number of elk overwintering in those units.

The population effects and the spatial structuring of different elk populations across the study area under the different alternatives led to some consistent patterns in elk use of private lands and sensitive habitats. Continue feeding is predicted to result in having fewer elk days on private property and lower brucellosis risk (measured by number of abortions on private property where cattle overwinter) across the 20 years of plan implementation. However, continue feeding also led to a higher degree of use of sensitive areas, particularly at the NER. Further, across all alternatives, the negative effects associated with Jackson elk are predicted to decrease because of population declines projected in the elk CWD model. Depending on the alternative, these declines resulted either from CWD, elevated natural mortality associated with severe winters, or in conjunction with specific management efforts to reduce elk abundance.

Translating the proxy measure of brucellosis risk to an actual change in the magnitude of risk to cattle producers is difficult because there has not been a documented instance of elk infecting cattle in the Jackson region. Doing so would require data to inform the connection between the number of abortions and a successful elk-to-cattle transmission event in the Jackson Elk Herd Unit. As a result, it is unclear how meaningful 19 or 20 additional abortions projected under the no feeding or disease threshold alternatives are compared to continuing to feed.

In terms of bison, the continue feeding alternative is predicted to be best, on average, for the three metrics associated with population size, harvest, and conflict potential. However, it is important to acknowledge the limitations of the available data in this study. First, data from the Yellowstone region was relied on to inform bison vital rates. These vital rates produced model behavior (in other words, harvest, population performance) that matched historical data, but may not necessarily be reflective of future conditions. Second, there was a high degree of uncertainty expressed by the expert panels in how human-bison conflicts might occur, and change, over time. As a result, two hypotheses about trends in those conflicts were incorporated: one where conflicts were stable over time, and another where human-bison conflicts changed according to learned behavior or active management activities. It is unclear which hypothesis is a better representation of future dynamics. Finally, it was assumed that there were no high mortality events from *Mycoplasma bovis* over the 20 years in either fed or unfed bison populations because it is uncommon in free-ranging wildlife ungulates (Malmberg and others 2020), even though the bacterial disease has led to 20–40 percent mortality in captive bison herds elsewhere (Janardhan and others 2010).

No discernable pattern for sleigh ride participation or NER visitation rates or spending was found under the different alternatives; however, elk could change their distribution under no feeding alternatives in unpredictable ways such that they become less visible to sleigh riders without supplemental feeding. Further, predicting future visitation to NER is difficult based on the projected changes in bison and elk numbers and the small effect that these species have relative to broader system dynamics, like U.S. human population size and economic conditions that have a greater influence on travel. As expected, NER feeding costs were minimized by alternatives that limited feeding. The increased harvest alternative tended to perform best on elk harvest metrics as well as minimizing the number of natural or CWD-related elk deaths in the first 5 years. As of 2024, however, it is not clear whether increasing harvest tags alone would successfully reduce the number of elk using the NER in winter to 5,000 individuals in 5 years.

Additional work may include NER managers, cooperating agencies, and other stakeholders navigating the tradeoffs embedded in this decision on whether and how to feed bison and elk under threat of CWD and given the range of other effects that are presented in this work. Deliberative tools from decision analysis (for example, swing weighting) could be used to estimate the relative value of the objectives against one another and develop an overall score for each alternative given those weights. This weighting could also help to fully incorporate the many sources of uncertainty embedded in these analyses and explore the role that those uncertainties have on distinguishing the best performing alternative for the next “Bison and Elk Management Plan.”

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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

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