Fall Creek Elk Herd Unit (E103)
Brucellosis Management Action Plan Update
April 2016

A. Introduction and herd unit overview

This update to the Fall Creek elk herd (FCEH) Brucellosis Management Action Plan (BMAP) was prepared to evaluate brucellosis management recommendations developed and implemented during this plan's original development in 2006 and revision completed in 2011. Meetings among Wyoming Game and Fish Department (WGFD) personnel, interested livestock producers, federal land managers, and state and federal livestock health and regulatory officials were held to discuss progress on the plan's recommendations, review the various brucellosis management action options, and develop new brucellosis management recommendations based upon updated information. The WGFD has made progress in the FCEH to better understand characteristics of elk to elk brucellosis transmission, refine elk parturition delineations, and to reduce the risk of both intra- and inter-specific brucellosis transmissions. This update should be considered complementary to the original FCEH BMAP written in 2006 and the 2011 update.

The FCEH includes elk hunt areas 84 and 85 and encompasses 686 square miles (mi^2) in Teton, Sublette, and Lincoln Counties. Land ownership is distributed between U.S. Forest Service (USFS [91%]), private (6%), Bureau of Land Management (BLM [3%]), and WGFD [1%]) (Figure 1). Approximately 488 mi^2, or 72% of total occupied elk habitat is designated spring, summer, and fall range. Included in this is approximately 258 mi^2 considered parturition range. There are 29 mi^2 (4%) designated crucial winter range, and 83 mi^2 (12%) are considered winter yearlong range (Figure 2).

The primary land uses in the FCEH include livestock grazing, timber harvest, and recreation (camping, horseback riding, hunting, fishing, firewood gathering). The number of roads in the area is limited and much of the area is designated as roadless, wilderness, or wilderness study area. Apart from the highways in the Snake River and Hoback canyons, Cliff Creek, Granite Creek, and the Munger Mountain-Mosquito Creek area are the only areas accessible by roads. The USFS Bridger-Teton National Forest (BTNF) land east of the Snake River from Snow King Mountain south to Poison Creek is closed to all human presence from December 1 - April 30. Also, the southern end of Munger Mountain (west of Hoback Junction to the Dog Creek feedground) and the WGFD Wildlife Habitat Management Areas (WHMA) are closed to all human presence from December 1 - April 30. Four feedgrounds are located within the FCEH: South Park, Dog Creek, Camp Creek, and Horse Creek. These feedgrounds were established primarily to reduce depredation to privately-owned stored hay, minimize risk of interspecific co-mingling of elk and livestock, and reduce winter mortality.

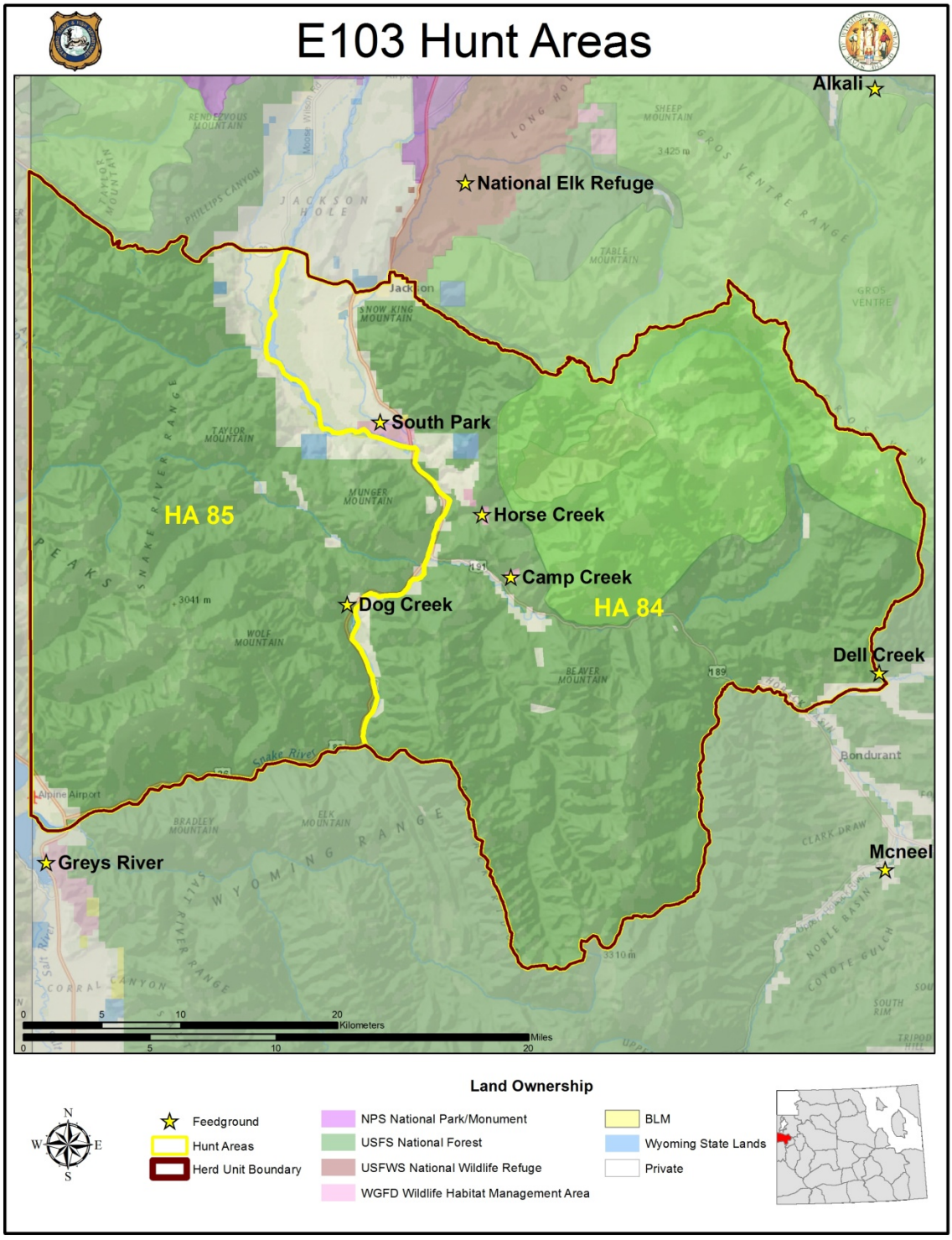

Figure 1. Land ownership, feedground locations, and hunt areas within the FCEH.

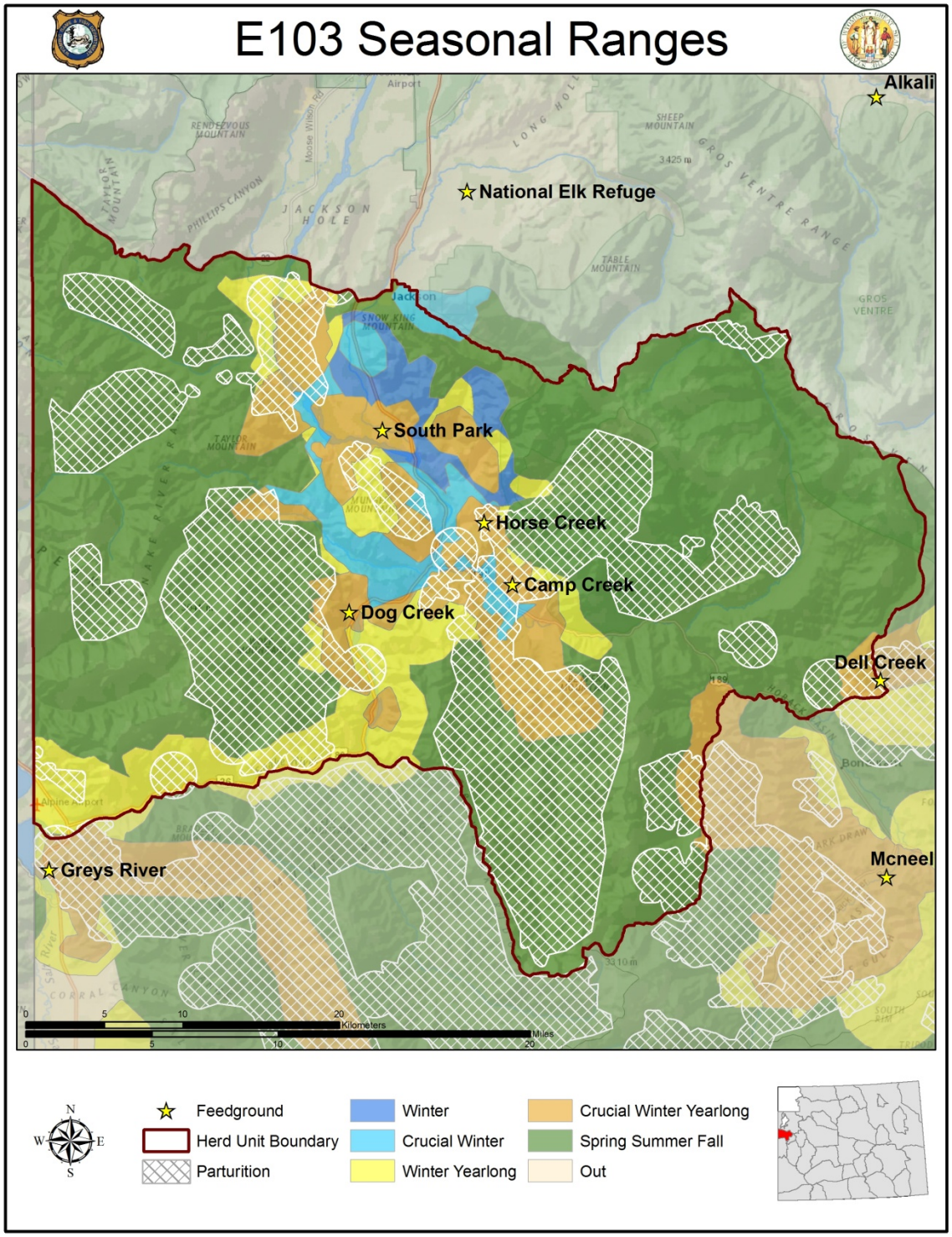

Figure 2. Currently delineated seasonal elk ranges and feedgrounds within the FCEH.

B. Brucellosis Management Options

Listed below are potential options for managing brucellosis on the four feedgrounds in the FCEH. Short-term objectives of these options are to reduce co-mingling of elk and cattle and the prevalence of brucellosis in elk. Long term objectives include eliminating the reservoir of brucellosis in wildlife in the Greater Yellowstone Ecosystem (GYE) if determined to be technically feasible, maintain livestock producer viability, reduce/eliminate dependence of elk on supplemental feed, maintain established elk herd unit objectives, improve range health, and maximize benefits to all wildlife. Implementation of several options together will likely be more effective than instituting any option alone. The Wyoming Game and Fish Commission (WGFC) will require support from various constituencies (agriculture, land management agencies, sportspersons, etc.) prior to pursuing these options, and several options will require decisions from entities other than the WGFC.

1. Feedground phase-out.
2. Reduced feeding season length.
3. Re-locating a feedground to a lower elevation site with increased area for elk to disperse and increased distance from winter cattle operations.
4. Reducing numbers of elk on a feedgrounds through increased harvest.
5. Elk-proof fencing to prevent elk from moving onto private land to reduce commingling/damage, or to facilitate elk migration.
6. Elimination of seropositive elk on a feedground through test and slaughter.
7. Conducting habitat enhancements in suitable winter ranges near feedgrounds where the potential of commingling with livestock is minimal.
8. Acquisition of native or potential winter ranges through fee-title purchase, conservation easements, or other methods.
9. Continue to investigate options for elk vaccination.
10. Utilize elk GPS location and vaginal implant transmitter (VIT) data to delineate areas of brucellosis risk.

C. Discussion of Options

1. Feedground phase-out

Phasing out a feedground would require much planning, effort and coordination. If conducted successfully, the dense aggregations of elk associated with feeding during the brucellosis transmission period would cease, reducing brucellosis transmission and seroprevalence. However, serology from winter-free ranging elk in Northwest Wyoming and other portions of the GYE suggest that the disease can persist without feedgrounds, so phasing out a feedground would not eliminate brucellosis in the GYE. However, if current conditions and herd objectives change, through implementation of one or more of options 2, 4, 5, 6, 7 and 8, this option may become more practical. The WGFC has the authority to make this decision.

Pros:

- Reduced elk-elk brucellosis transmission
- Indirectly reduces risk for elk-cattle brucellosis transmission
- Facilitates efforts to reduce elk populations where desired

- Reduced feedground and brucellosis management expenses

Cons:

- Increases the risk of elk damage and elk-cattle brucellosis transmission and associated damage control costs
- Increased elk winter mortality
- Reduced elk populations and hunter opportunity
- Increases potential for vehicle-elk collisions

This option in the FCEH is most feasible for the Camp Creek feedground, followed by Dog Creek, Horse Creek, and then South Park feedgrounds.

2. Shortened feeding seasons

Most of the variation in brucellosis seroprevalence among elk attending a particular feedground is correlated to the length of the feeding season; the longer a feedground operates into spring, the higher brucellosis prevalence is among the elk at that feedground, most likely because the peak of brucellosis-induced abortions occur from March-May (Cross et al., 2007; Cross et al., 2015). The correlation indicates that truncating the feeding season by an average of 3 weeks could lead to a 66% reduction in brucellosis seroprevalence.

Pros:

- Reduced elk-elk brucellosis transmission and the transmission of other density-dependent diseases
- Indirectly reduces risk for elk-cattle brucellosis transmission
- Maintains elk populations at or near current levels
- Reduces feedground and brucellosis management expenses

Cons:

- Increases the risk of elk damage and elk-cattle brucellosis transmission and associated damage control costs
- Increased elk winter mortality, especially of juveniles
- Increased potential for vehicle-elk collisions
- Success or failure is highly dependent upon weather

Truncation of the feeding season is a much more viable option at Horse and Camp Creek feedgrounds. In the past, considerable damage occurred on private lands directly adjacent to the Horse Creek feedground. In 2015, the WGFC approved acquisition of lands and directed funding to construct an elk exclusion fence around areas where damage occurred annually. With these management actions, elk are now able to move freely to and from the Horse Creek feedground and onto available native winter ranges with little to no damage and comingling with the neighboring livestock operation. Due to the predominantly south-facing aspect of the ridge directly adjacent to Dog Creek feedground, elk often leave the feedground early in the spring as snow conditions allow. The major concern with early end dates at Horse, Camp and Dog Creek feedgrounds is that elk may choose to move to the highway right-of-way once feeding ceases, resulting

in increased vehicle collision risk. South Park feedground is located on a WHMA surrounded on the west and south by BTNF lands with active cattle allotments, and several private properties with winter cattle feeding operations are adjacent to the unit's north and east boundary. Both producers and managers have voiced concern with early end dates at this feedground citing increased concerns of inter-species brucellosis transmission associated with increased comingling risk.

3. Feedground Relocation

This option would initially require a suitable area ideally in a lower elevation and precipitation location with no winter cattle operations in the vicinity. Current habitat conditions should be evaluated to determine vegetation production, health, and approximate potential of the area. Most federal lands in the area are leased for grazing, so it is likely one or more permittees would need to be involved in the selection of a particular area. If purchase of grazing rights is acceptable to a permittee, this could reserve forage for elk, other wildlife and livestock. Decision authority would lie with the private landowner, permittee, federal land managers, and the WGFC.

Pros:

- Lowered brucellosis prevalence
- Larger feeding area for lowered elk densities while feeding
- Elk numbers could be maintained at or near current levels
- Decreased damage and co-mingling
- Moving from federal lands to private would reduce chances of litigation under NEPA

Cons:

- Brucellosis will persist
- Requires funds for erection of new structures, fences, roads, etc.
- Logistically challenging to relocate and habituate elk to the new site
- Reduced vegetation diversity around the new site
- Requires permitting process and NEPA review if relocated on federal lands

Feedground relocation options are limited in the FCEH because feedgrounds in this herd are located on or near existing native winter ranges. Suitable adjoining areas lower in elevation or flatter in terrain are limited. There are very few if any available sites where interspecific disease transmission possibilities could be improved by moving a feedground. Feeding operations at Dog Creek should, if possible, remain on the Dog Creek Ranch property as opposed to the Pritchard Pond area. The Dog Creek Ranch property offers a much larger feeding site, which reduces the density of elk while on feed lines. Elk at the Horse Creek site have occasionally been fed on the bench north of the feedground. This alternative site is part of the WHMA; thus this would only be a slight relocation. Feeding here would reduce the density of elk while on feedlines, but would also move the elk to a location where damage on neighboring private lands might be more likely to occur.

There is vacant space (private property) across the highway from the Camp Creek feedground on Bryan Flats. If elk were fed here, it would reduce the number of elk at the

Horse Creek and Camp Creek feedgrounds (if they remained operational) and potentially reduce elk-vehicle collisions due to increased distance from the highway, but could increase elk conflicts with landowners and a winter horse feeding operation near Bryan Flats. This option would not entirely eliminate elk-vehicle collisions as some elk would still need to cross the highway to reach the feedground in winter and leave to reach spring, summer and fall ranges in spring.

4. Elk Reduction

Reducing elk numbers on feedgrounds through liberalized hunting seasons could allow more flexibility to pursue options 1, 2, 3 and 6, and could lead to more favorable conditions for options 7 and 8. The WGFC has the authority to make this decision.

Pros:

- Decreased elk densities and lower brucellosis prevalence
- Increase hunting opportunities and license revenues in the short term
- Reduced conflicts on private lands
- Reduced costs of supplemental feeding

Cons:

- Brucellosis will persist
- General public currently unwilling to accept large reductions in elk numbers
- Success is limited to hunter effort
- Loss of some hunting opportunity in the long term

Current management strategies have been successful in bringing the FCEH down to objective. This was achieved through increased type 6 and 7 (i.e., cow/calf only) licenses in both area 84 and 85. By 2010, the population was reduced to the WGFC objective, and managers began reducing the amount of type 6 licenses to stabilize the population. The majority of the current cow/calf licenses and type 1 licenses (any elk) are limited to private lands and issued to address damage concerns in the Snake River bottoms, where a segment of the FCEH resides yearlong on private properties near South Park feedground. These individuals tend to have a higher recruitment rate and offer limited hunting opportunity yet contribute to disease and damage problems and increased management costs. The elimination/reduction of this segment of the FCEH would be desirable in most aspects.

5. Fencing

Elk proof fencing of feedgrounds may contain most elk within a given area, and fencing of winter cattle feedlines can prevent elk from co-mingling with cattle. Fencing roadways would facilitate migration to winter ranges which would reduce dependency on supplemental feeding. This would require favorable decisions by the landowner (private, state or federal).

Pros:

- Reduced risk of elk-cattle brucellosis transmission
- Reduced elk damage

- Reduced elk and other wildlife vehicle collisions
- Controls elk distribution

Cons:
- Expensive
- Congregating all or most of the elk or cattle within a fence may be unfeasible
- Extensive fencing could impede migrations of non-target wildlife
- Does not address elk-elk brucellosis transmission
- Requires landowner cooperation and potential NEPA review for federal lands

Opportunities for fencing around feedgrounds in the FCEH are limited. About one mile of fence separates the South Park feedground and the private properties north of the feedground. Two situations allow co-mingling: 1) elk can leave the feedground and walk around the ends of the fence; 2) migrating elk can approach from the north side of the fence and then cannot readily access the feedground. In 2015 an elk-proof fence around an adjacent private property near Horse Creek feedground was completed to alleviate chronic damage and brucellosis transmission concerns.

6. Elk Test and Slaughter

This option was conducted on the Muddy, Fall and Scab Creek feedgrounds from 2006-2010. Following removal of 196 seropositive elk, brucellosis prevalence was reduced at all three feedgrounds. Capture operations occurred every year at Muddy Creek feedground, where brucellosis prevalence was reduced most significantly from 37% to 5% in the five years, yet prevalence rebounded to 32% in 2016. Test and slaughter could also reduce elk numbers to more efficiently pursue options 1, 2, 3, 7, and 8. The WGFC has the authority to make this decision.

Pros:
- Reduces brucellosis prevalence in elk
- Increased tolerance of elk if brucellosis prevalence is decreased
- Increases other State's acceptance of cattle from within the GYA
- Capture infrastructure currently established in some areas

Cons:
- High cost and complex logistics
- Does not eliminate brucellosis transmission
- Must be implemented perpetually to maintain brucellosis prevalence reductions
- Could result in reduced hunting opportunity

Brucellosis seroprevalence would decrease on all feedgrounds within the FCEH given implementation of this option for as long as test and slaughter would be conducted, but prevalence would rebound if the method were not continued in perpetuity or some other additional measure were not taken (e.g., options 1-4). Also, expenditures are not allocated for such a project at this time. The WGFC has the authority to make this decision.

7. Habitat Enhancement

Habitat projects have been utilized in areas adjacent to feedgrounds with some success in reducing feeding duration. Projects should be designed in areas that provide opportunity for elk to free range during the brucellosis transmission period in areas away from cattle. The decision authority is with the BLM and USFS for most areas. Affected permittee and landowner consultation and cooperation is also necessary. This option may be best used in conjunction with options 1, 2, 3 and 8 to achieve maximum success.

Pros:

- Reduced feeding duration and brucellosis prevalence
- Provides long-term benefits to many species of wildlife and cattle
- Funding is available through government and non-government agencies

Cons:

- Use of treated areas is highly dependent upon weather
- Complex pre- and post logistics (sensitive species considerations, rest period)
- Increased likelihood of invasive species establishment

Habitat enhancement projects may reduce the time elk spend on feedgrounds. If habitat improvements are completed near feedgrounds or between summer range and feedgrounds, the enhanced forage produced will decrease the dependence of elk on artificial feed, snow conditions permitting. Reduced feeding durations and lower elk concentrations on feedgrounds, especially during the high transmission risk period, may decrease the probability of intraspecific brucellosis transmission events. Habitat enhancement projects also create vegetative diversity, enhance aspen communities, and improve range conditions for other species.

Decision authority is with the USFS for most areas in the FCEH, and USFS personnel have indicated there are opportunities, particularly for aspen treatments within the herd. WGFD personnel are involved with USFS in the planning and implementation stages of habitat enhancements along the east side of the Snake River Range. Mechanical thinning and prescribed fires are being used in the Wildland-Urban Interface in the Beaver Mountain, Palmer Creek, Horse Creek and Willow Creek areas in order to mitigate the effects of future wildfires. These projects should also have some habitat enhancement benefits, and the WGFD is actively involved in the planning and post-treatment monitoring of those projects and will continue to cooperate with the USFS to pursue habitat enhancement options. In addition to habitat on USFS lands, the WGFD will explore options to increase palatability of forage on feedgrounds owned by the WGFC in the FCEH. Increased forage quality in the fall may entice elk onto the feedgrounds and away from damage situations, without an earlier initiation of feeding.

8. Acquisition/Conservation Easements

Disease transmission risk on feedgrounds in the FCEH might be decreased by managing lands adjacent to, or connected with, areas used by wintering elk. With adequate intact, healthy, and accessible elk winter habitat available, elk feeding can be reduced. This option also secures habitat for other wildlife species. The buying or long-term leasing of land to be managed commensurate with wildlife benefits is an option that

can be used to maintain stabile and healthy wildlife populations. This option could also facilitate options 1, 2, 3, 4, 5 and 7. Decision authority is with the private landowner and purchaser.

Pros:

- Could lead to reduced brucellosis prevalence in elk
- Secures habitat for all wildlife
- Long-term solution
- Helps secure future revenues for the WGFD

Cons:

- High cost and complex logistics
- Decreasing availability of undeveloped suitable properties
- Dependent upon willing seller and buyer

Disease transmission risk on feedgrounds in the FCEH might be decreased by managing lands adjacent to, or connected with, areas used by wintering elk. There may be opportunity in the future to purchase large, intact areas near BTNF lands to better facilitate reduced damage and comingling risk. Another option would be to work with landowners to acquire long term leases of private lands to either relocate or enlarge the current feeding areas. Decision authority is with the private landowner.

9. Investigate Options for Vaccination

The WGFD initiated the *Brucella abortus* strain 19 ballistic elk vaccination program in 1985 on Grey's River feedground and vaccinated approximately 85,000 elk through 2015 on 22 state-operated feedgrounds and the National Elk Refuge. Controlled studies with captive elk indicated strain 19 was mildly protective (Roffe et al. 2004). However, by periodically sampling brucellosis seroprevalence over time and using vaginal implant transmitters that are expelled upon birth or abortion, the WGFD found that brucellosis seroprevalence among vaccinated elk has not been reduced since the vaccination program began, and the number of abortions has not been different between vaccinated and unvaccinated elk (Maichak et al., *in press*). Furthermore, the company that produced biobullets® has not sold the rights to produce biobullets, thus biobullets are no longer available. Other options for brucellosis vaccination on elk feedgrounds are being developed and may become available in the future, especially upon the recent consideration by the Animal and Plant Health Inspection Service (APHIS) to delist *B. abortus* from the select agent list, enabling vaccine research and challenge studies outside of BSL3 facilities. Another approach is the immune-contraceptive vaccine Gonacon™ which can prevent conception, thereby preventing brucellosis transmission. An effective vaccine would increase opportunity to implement options 1, 2, 4. The decision authority to implement a new vaccination program lies with the WGFC.

Pros:

- Reduces infected elk fetuses aborted on and off feedgrounds
- Indirectly reduces risk for elk-cattle brucellosis transmission
- Oral vaccines can be delivered to winter free-ranging populations

- Has been used in successful disease eradication campaigns

Cons:

- Vaccine development and approval is expensive
- Unknown effectiveness in a field setting
- Immuno-contraceptives could limit hunting opportunity

10. Map Areas of Brucellosis Risk

Since 2006, as part of the Wyoming Governor's Brucellosis Coordination Team's recommendation for elk brucellosis research, the WGFD has collected elk distribution data from 475 GPS collared elk, and reproductive data using VITs from 562 elk captured on or near feedgrounds in 7 elk herd units. Areas where elk are located during the brucellosis transmission period of February 5 - June 15 can be considered brucellosis risk areas within the elk herd unit, and maps can be developed identifying these areas. These risk areas can be refined by selecting elk locations during March-May, when data from VITs indicate that most brucellosis-induced abortions occur. Utilizing the risk maps, producers, land managers and livestock regulatory officials can focus efforts and make informed decisions to implement strategies that minimize brucellosis risk to cattle herds.

Pros:

- Data required to identify brucellosis risk areas are available
- Illustrates areas where disease management actions should be focused
- Repeatable to determine if elk management strategies were effective

Cons:

- Reduced vigilance in areas of lower brucellosis risk
- Risk areas dependent upon sample size
- Confidentiality concerns

This technique could be used when working with private landowners and federal land grazing permittees to further inform and assist in allotment management planning to help reduce risk of inter-specific disease transmission.

D. Coordination Meetings

1. Producer Meeting

A meeting was held December 16th, 2015 at the Camp Creek Inn near Hoback Junction to discuss the 10 options among livestock producers and associated land and resource management agencies within the FCEH. A presentation was given by the WGFD that summarizing brucellosis management and research strategies and their relation to the ten options. Three producers, six WGFD personnel, and two USFS personnel attended the presentation. Several questions and comments were proposed by attending producers regarding habitat treatments, strain 19 vaccination, test & slaughter, and brucellosis in elk and cattle outside of the feedground area. No substantial changes or actions were recommended for the BMAP or management of the feedgrounds within the FCEH following this meeting.

2. Public Meeting

A meeting was held March 23rd, 2016 between the WGFD and concerned members of the public to discuss the ten options as they pertained to the Jackson, Fall Creek, and Afton Elk herd units. Six public individuals and six WGFD personnel attended the presentation which summarized WGFD brucellosis management and research strategies and their relation to the nine options. Several topics were discussed following the presentation including the potential for exclusionary elk-proof fences around winter livestock feeding areas in order to maintain separation between elk and livestock, pros and cons of feedground phase-out, impacts of wolves on feedground elk populations and management, strain 19 vaccination efficacy in elk and new vaccination options, and financial impacts of brucellosis. No major changes were proposed at that time for any herd unit, and members of the public found the presentation informative and useful.

E. Proposed Management Actions

1. Feedground Elimination

The WGFD will not pursue this option in the near future in the FCEH given existing elk brucellosis seroprevalence rates and the utility of elk feedgrounds in manipulating winter distributions of elk.

2. Reduction in feeding season length

Reduced feeding season length is currently being implemented in areas where elk can find adequate early spring forage without greatly increasing the risk of elk-cattle comingling and damage.

3.Feedground relocation

Feeding on the private property adjacent to Dog Creek feedground is beneficial, and WGFD will continue working with the landowner to allow this.

4. Elk Reduction

The WGFD manages for current, WGFC-established elk herd unit population objectives. The current population objective for the FCEH is 4,400, and a lower population objective would require a public input process to discuss the issue and determine the level of support. Thus, authority over this option ultimately lies with the WGFC. The WGFD will continue to implement harvest strategies that maintain the population at objective, while maintaining hunting pressure on private lands in order to affect elk distribution to reduce risk of elk-cattle commingling.

5. Fencing

The WGFD will encourage cattle producers in the FCEH to fence areas where hay is stored (stackyards) for winter-feeding operations and continue delivery of materials for stackyard construction. As opportunities arise for additional fencing projects (e.g., winter cattle feeding exclosures), the WGFD will assess those opportunities on a case-by-case basis.

6. Elk Test and Slaughter

The WGFD implemented the pilot Test & Slaughter project in the Pinedale elk herd from 2006 through 2010. Given the financial and personnel constraints required to implement this management action at the herd unit level and the ephemeral results, the WGFD will not implement this option in the FCEH in the foreseeable future.

7. Habitat Enhancement

The WGFD will continue to coordinate with private landowners, federal land managers, and livestock permittees to develop and implement habitat improvements that may reduce elk dependency on supplemental feed in the FCEH. The WGFD will emphasize project coordination with the BTNF. These projects will focus on areas designated as winter and transitional ranges, while working within the constraints of sensitive-species management and funding.

8. Acquisition/Conservation Easements

The WGFD will attempt to identify and pursue opportunities to implement this option. As projects are identified, proposals will be drafted and submitted, either through the Department's process of obtaining fee-title lands, or to various funding agencies to facilitate implementation of this option.

9. Investigate Options for Vaccination

The WGFD will continue to investigate new options for elk vaccination. Currently, the creation of an effective vaccine in elk is the limiting factor, but in early 2016, the USDA APHIS proposed to delist *B. abortus* as a "select agent or toxin" as defined by the Agricultural Bioterrorism Protection Act of 2002. Removal of the bacteria from this designation would greatly increase brucellosis vaccine research and development due to lowered costs of challenge trials.

10. Map Areas of Brucellosis Risk

This management option is currently being implemented by the WGFD's brucellosis program. The completed product will be distributed to the appropriate cattle producers, land managers and livestock health regulatory officials upon completion for use in their brucellosis risk management activities.

F. Best Management Practices

In addition to the above options and commensurate with their short and long term goals, the following best management practices should be considered for elk feedgrounds. Some may be currently employed, and should be maintained. Others may or may not be viable options for each feedground during any given winter.

Feedground Management

1. Manipulate elk distribution by supplemental feeding to reduce elk/cattle commingling and the risk of brucellosis transmission from elk to cattle.
2. Disperse feed evenly in a checkerboard pattern throughout the feedground on clean snow (low-density feeding) to reduce contacts with aborted fetuses.
3. End feeding as early in late winter/spring as possible; March-May is the peak

abortion period and preventing dense aggregations during this period reduces elk-elk brucellosis transmission.

4. Where possible, implement large-scale habitat treatments at strategic locations near feedgrounds.
5. Elk feeders shall report any aborted fetus which will be collected and submitted to WSVL for testing; disinfect abortion site
6. Predators and scavengers (i.e., coyotes, foxes) shall not be killed on/near feedgrounds by WGFD employees due to their beneficial role of quickly removing aborted fetuses.

G. Additional Actions

Brucellosis Surveillance

The WGFD currently captures and tests elk for exposure to brucellosis on 7 to 15 feedgrounds every year. Around 4,500 cow elk were tested from feedgrounds during 2000-2015, with 27% of the elk showing positive reactions. This practice should continue on as many feedgrounds as possible annually to monitor prevalence of the disease. To assess efficacy of target feedground management activities (e.g., low-density feeding and early end feeding dates), the WGFD has partnered with a Ph.D. candidate out of Utah State University. The student is planning to quantitatively assess these brucellosis mitigation strategies aimed at reducing prevalence of the disease. Additionally, hunter-harvested elk brucellosis surveillance will occur annually in an effort to survey the entire state over a 4-year period.

Research

Reducing both the incidence of brucellosis in elk on feedgrounds and the risk of the disease's transmission from elk to cattle is facilitated by accurate and reliable data to guide management decisions. Prior to the development of the BMAPs, most research concerning brucellosis and feedgrounds focused on elk vaccination and its efficacy on reducing brucellosis prevalence at the population level. Over the last decade, the WGFD has partnered with the USGS, Montana State University, Iowa State University, and the University of Wyoming on several studies to determine spatiotemporal characteristics of brucellosis transmission, including timing of abortions and attributes of elk-to-fetus contacts. Data gathered from these endeavors has expanded our knowledge of how the disease is transmitted and led to specific management strategies to reduce incidence of the disease.

1. **Effects of management and climate on brucellosis seroprevalence of feedground elk**

Cross et al (2007) compiled 16 years of seroprevalence data from feedground elk and 54 years of feeding and climate data from feedgrounds and local weather stations throughout the Greater Yellowstone Ecosystem. They found that brucellosis seroprevalence was positively correlated to the length of the feeding season and feeding end date. However, feedground population size and density had little to no influence on seroprevalence. They suggested management strategies that reduce the length of the feeding season (e.g., early end dates) to reduce the period when a high

potential for elk-fetus contacts exists should ultimately reduce prevalence of the disease among elk attending feedgrounds.

2. **Effects of management, behavior, and scavenging on risk of brucellosis transmission**

Maichak et al (2009) collected 48 culture-negative fetuses from elk associated with the test and slaughter pilot project and placed these on various locations on feedgrounds and on native winter range locations from 2005 through 2007. They found that the majority of elk-fetus contacts occurred on the feedlines on feedgrounds (<2m of haypiles), and there were no contacts off of feedgrounds. Most elk did not demonstrate a propensity to investigate fetuses, as few contacts occurred when a fetus was located ≥ 2m from the feedline. Additionally, they found that scavengers removed fetuses much faster from feedgrounds than native winter range locations, reducing the number of elk contacting fetuses. They suggested that altering hay distribution patterns could reduce elk densities on feedlines, leading to fewer elk-fetus contacts, and recommended the protection of scavengers near feedgrounds to ensure aborted fetuses are removed from the landscape as quickly as possible.

3. **Parturition ecology of feedground elk**

From 2006 through 2010, the WGFD collaborated with Iowa State University, the University of WY, Montana State University, and the USGS to deploy and recover over 300 vaginal implant transmitters (VITs) placed in elk captured from 19 feedgrounds and 3 native winter ranges as part of a multi-faceted project to document characteristics of elk parturition and abortion. Barbknecht et al. (2009) reported that VITs were an effective tool for locating elk parturition sites, and Barbknecht et al. (2011) found that most elk tended to select parturition sites with substantial horizontal and overhead cover, ranging from low elevation riparian areas to high-elevation alpine habitats. In 2015-2016, the WGFD utilized location data of over 500 VITs expelled during parturition, along with elk GPS collar location data, to update parturition range delineations for the 7 elk herd units containing feedgrounds. Land managers are already using the highly defensible data for land use planning purposes.

4. **Effects of supplemental feeding on stress levels in elk**

Forristal et. al. (2011) assessed stress levels in elk by measuring fecal glucocorticoid metabolite concentrations (fGCM) derived from numerous fresh fecal samples collected from feedgrounds and native winter ranges. Elk from feedgrounds had at least 31% higher fCGM levels than those on native ranges, suggesting higher levels of stress due to crowding. Increases in stress and glucocorticoid concentrations can reduce immune function and increase susceptibility to brucellosis, necrotic stomatitis and other diseases present on feedgrounds.

5. **Target Feedground Management: low-density feeding and early end dates**

Based on research findings of some of the projects previously mentioned, the WGFD developed and implemented management actions pertaining to the Target Feedground Management Plan (WGFD 2016). The two primary objectives are to increase dispersion of hay throughout the feedground (low-density feeding) and

actively end the feeding season with a goal of ending three weeks prior to the current 10-year average. Creech et al. (2012) compared low-density (LD) to traditional feedlines via data-logging radio collars and digital video cameras and found that LD feeding reduces elk-to-fetus contacts by 66%-75% and, based on disease models, should substantially reduce seroprevalence in elk if successfully implemented over a decade or more. Active early termination of feeding is possible on some feedgrounds in light snow years, but the impacts on actual seroprevalence at the population level will require implementation of eight to 10 years (Cross et al. 2007). Since 2008, the average feeding end date has been shortened by up to 19 days at some feedgrounds, yet some feeding seasons have not changed and a few are now actually longer than prior to initiation of target feedground management (Table 1).

Table 1. WGFD-operated elk feedgrounds in western Wyoming grouped by those managed for early end dates and those with traditional end date management with mean feeding end dates (in days since November 1st) for the 10-years preceding target feedground management (1998-2007), the eight years since (2008-15), and the difference in days between those figures.

	FEEDGROUND	PRE-TFG (98-07)	POST-TFG (08-15)	DIFF
Early End Mgmt	Scab Creek	163.3	*144.6	**18.70**
	Fall Creek	151.1	132.8	**18.35**
	Bench Corral	143.2	131.4	**11.83**
	Soda Lake	150.8	**140.9	**9.95**
	Forest Park	169.1	168.6	**0.47**
	Green River Lakes	150.1	**156.9	**-6.79**
Traditional End Mgmt	Franz	177.1	166.9	**10.23**
	Black Butte	171.6	165.3	**6.35**
	Camp Creek	162.7	156.4	**6.32**
	Jewett	172.8	166.5	**6.30**
	Greys River	169.4	164.1	**5.28**
	Dog Creek	164.7	159.6	**5.07**
	Finnegan	169.6	165.4	**4.22**
	South Park	161.0	158.0	**3.00**
	Horse Creek	166.6	165.3	**1.35**
	Muddy Creek	161.5	161.3	**0.25**
	Gros Ventre	147.7	150.5	**-2.80**
	Dell Creek	172.3	175.4	**-3.07**
	McNeel	160.6	164.9	**-4.28**

**represents 2009-15*

***excludes 2010 when elk were not fed*

6. **Contacts rates of female feedground elk during brucellosis transmission season**

It has been hypothesized that the majority of disease transmission in wildlife populations can be attributed to a small number of individuals. However, using proximity data logging collars deployed on 149 elk across feedground and winter free ranging elk populations, Cross et al. (2013) found that environmental conditions

associated with high contact rates is more important than a handful of efficient disease spreaders. Although, pairwise contacts were similar during and after feeding, per capita contacts were two times greater during the feeding season. Results from this study also suggest supplemental feeding may increase per capita contact rates beyond what might be expected from group size alone. This study illustrates how feedgrounds can be a driving force of disease transmission among elk in western Wyoming.

7. **Cost-benefit analysis of elk brucellosis seroprevalence reduction in the southern GYE**

Boroff (2013) compared the effectiveness and cost of 3 brucellosis management options for elk, including test & slaughter, *Brucella abortus* strain 19 vaccination and low-density feeding (based on a previous elk feeder compensation plan in which low-density feeding was incentivized) using a combination of stochastic risk and economic models. Her analysis concluded that all options had a negative net benefit (cost), and while test & slaughter was most effective at reducing seroprevalence quickly, the cost to implement this management option far exceeded that of vaccination and low-density feeding. She concluded that low-density feeding was the most cost-effective management strategy currently available to manage brucellosis. Early end date management was not included in the analyses.

8. **Effects of supplemental feeding of elk on seasonal migration**

Jones et al. (2014) utilized data from GPS collars deployed on 219 adult female elk at 18 feedgrounds and 4 adjacent native winter ranges to evaluate the effect of supplemental feeding on migration. They found that fed elk were consistently less responsive to spring green-up and more responsive to cold temperatures and precipitation events. Feedground elk had a delayed arrival to and early departure from summer range; residing on summer range 26 fewer days than unfed elk. Feedground elk carried slightly more body fat than unfed elk by March, though differences were not significant. This study indicates that feedground elk may be exploiting hay in lieu of building body reserves on summer ranges, resulting in higher program costs and increased brucellosis prevalence. Early cessation of feeding, where and when possible, would likely increase elk response to green-up and could maximize the distance between elk and cattle, as opposed to lingering on transitional ranges where commingling risk is higher. Future research could experiment with determining a "feeding threshold" on feedgrounds; the minimum amount of hay needed to trigger elk to more closely mimic migration behavior of free-ranging elk while also controlling elk movements and distributions to minimize risk of elk damage and elk-cattle commingling during winter.

9. **Timing of birth, abortion, and brucellosis transmission**

Cross et al. (2015) utilized results of elk implanted with VITs (498, 2006-2014) and data on elk abortions discovered by WGFD personnel working on feedgrounds (79, 1968-2014) to determine risk periods for birth and abortion in elk. Reviewing reproductive results from seronegative (333) and seropositive (165) elk implanted with VITs, they found that 2% and 16%, respectively, experienced reproductive failures.

The study reported that the abortion risk period in feedground elk was from 5 February to 10 July, peaking in March through May. 95% of the brucellosis transmission risk period was over by 6 June. This information, in combination with elk GPS collar location data, are being utilized by the WGFD to develop models of spatiotemporal brucellosis transmission risk across the entire elk feedground system.

10. **Evaluation of the 30-year *B. abortus* strain 19 ballistic elk vaccination program**

Maichak et al. (*in press*) used feedground elk brucellosis seroprevalence data and the results of vaginal implant transmitters implanted in vaccinated and unvaccinated elk populations since 2006 to evaluate the efficacy of a *B. abortus* strain 19 elk vaccination program initiated by the WGFD in 1985. The study reported mean annual coverage of elk calves among vaccinated feedgrounds was 97%, but found no differences between: 1) seroprevalence data pre-vaccination vs. post vaccination; 2) seroprevalence of vaccinated elk populations vs. an unvaccinated population; and 3), the abortion rate of elk attending vaccinated vs. unvaccinated feedgrounds. The authors attributed the poor efficacy of the *B. abortus* strain 19 elk vaccination effort on reducing seroprevalence to the weak efficacy of the vaccine in elk itself, and the high transmission potential (R0) even a single fetus represents.

Furthermore, many aspects of feedground elk ecology, brucellosis transmission and pathology, and feedground management have not been investigated. Potential research topics that could assist in management decisions include:

1. Successes or failures of implementing the Target Feedground Management Plan (WGFD 2016). Before determining whether target feedground management is affecting brucellosis seroprevalence, it must first be determined if the two primary objectives (i.e., low-density feeding and early end dates) are being implemented properly and consistently. There are currently no adequate measures available to determine the degree to which low-density feeding is being implemented, and there appears to be considerable variation in how low density feeding is being conducted on the ground. Additionally, there are currently no measures to determine how successful managers have been in ending the feeding seasons earlier outside of subjectively comparing photo points and snow levels at feeding end times. Without an adequate measure of how successfully these two objectives have been applied, it will be difficult to attribute any potential changes in brucellosis seroprevalence to target feedground management. Research that could have significant management applications may include the following:
    a. Use elk GPS collars, GPS trackers on feed sleds and aerial cameras to develop a low density feeding index that measures the density of hay distribution at each feedground.
    b. Compare a low density feeding index to brucellosis seroprevalence data to determine relationships.
    c. Use feeding end dates and GPS collar and snow cover satellite data to predict when elk would have left feedgrounds on their own volition, compare elk movements on target feedgrounds vs. non-target feedgrounds

to determine how successful managers were (in days) of encouraging elk to redistribute from feedgrounds.

d. Evaluate effect of feed type (grass vs. alfalfa vs. pelletted hay) on end feeding date and distances elk move from feedgrounds during the latter portion of the feeding season, with respect to lbs/head fed, native habitat availability, and feedground population size.
e. Develop a methodology for determining optimal end feeding dates in real time using remote sensing.

2. Virulence of the various *Brucella abortus* strains found in feedground elk.
3. Role of native habitat enhancement and snow water equivalent (SWE) near feedgrounds on feedground dependence of elk (i.e. distribution, dispersal, length of feeding season, brucellosis seroprevalence).
4. Disease presence (other than brucellosis) and parasite loads in elk on feedgrounds.
5. Relationship of local scavenger densities and specie assemblages vs. scavenging rates on feedgrounds.
6. Reproductive impacts of *B. abortus* infections in elk over time.
7. Genetic comparison of seropositive elk that do or do not abort.
8. Potential of aerosol transmission of brucellosis.
9. Potential for salt/mineral licks as sites of inter- and intraspecific brucellosis transmission.
10. Gonacon™: model impacts to feedground elk populations and seroprevalence.
11. Comparisons of hay quality from where elk are vs. are not fed on irrigated meadows.
12. Seroprevalence in elk that are frequently vs. infrequently captured on feedgrounds ("bottom-feeder" hypothesis).

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