Hoback Elk Herd Unit (E104)
Brucellosis Management Action Plan Update
April 2016

A. Introduction and herd unit overview

This update to the Hoback elk herd unit (HEH) 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 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 substantial progress in the HEH to better understand characteristics of elk-to-elk brucellosis transmission, refine elk parturition delineations, and reduce the risk of both intra- and inter-specific brucellosis transmission. This update should be considered complementary to the 2006 and 2011 versions of the HEH BMAP.

The HEH covers the upper Hoback River watershed, and is bound on the south by the Hoback Rim, and on the east by the hydrographic divide between the Hoback and Green River drainages. The northern boundary is the hydrographic divide between the Gros Ventre and Hoback River drainages and the western boundary is comprised of Dell Creek, Cliff Creek, and the hydrographic divide between the Greys and Hoback River drainages (Fig. 1). The HEH encompasses 296 mi^2 with 96%, 3.6%, and 0.6% in Sublette, Lincoln, and Teton Counties, respectively. Of the HEH, 9.5% is in private ownership; the United States Forest Service (USFS) manages 89.5%, and the remaining 1% is managed by the Bureau of Land Management (BLM). The major land uses in the area are domestic livestock grazing and year-round recreation. Summer uses include fishing, camping, horseback riding and motorized all-terrain vehicle use. In autumn, hunting is the predominant use. During winter, both private and outfitted snowmachine use is common.

Approximately 159 mi^2 are considered spring, summer, and fall range for elk (Fig. 2). There are 83 mi^2 designated crucial winter yearlong range, 55 mi^2 considered winter yearlong range, and 118 mi^2 are considered elk parturition range. There are two feedgrounds in the HEH, and two elk hunt areas (HA, Fig. 2). Dell Creek feedground (HA 87) is located at the mouth of Riling draw, north of Dell Creek, east of the Hoback River on USFS land. McNeel feedground (HA 86) is located about three miles south of US Highway 191 on the east side of the Hoback River on private land, which the WGFD leases. Both Dell Creek and McNeel feedgrounds are intended to prevent damage, co-mingling, and winter starvation of elk. McNeel feedground also serves to keep elk away from US Highway 191 and prevents an excessive number of elk from otherwise attending the Franz feedground (in the Piney elk herd unit) to the south.

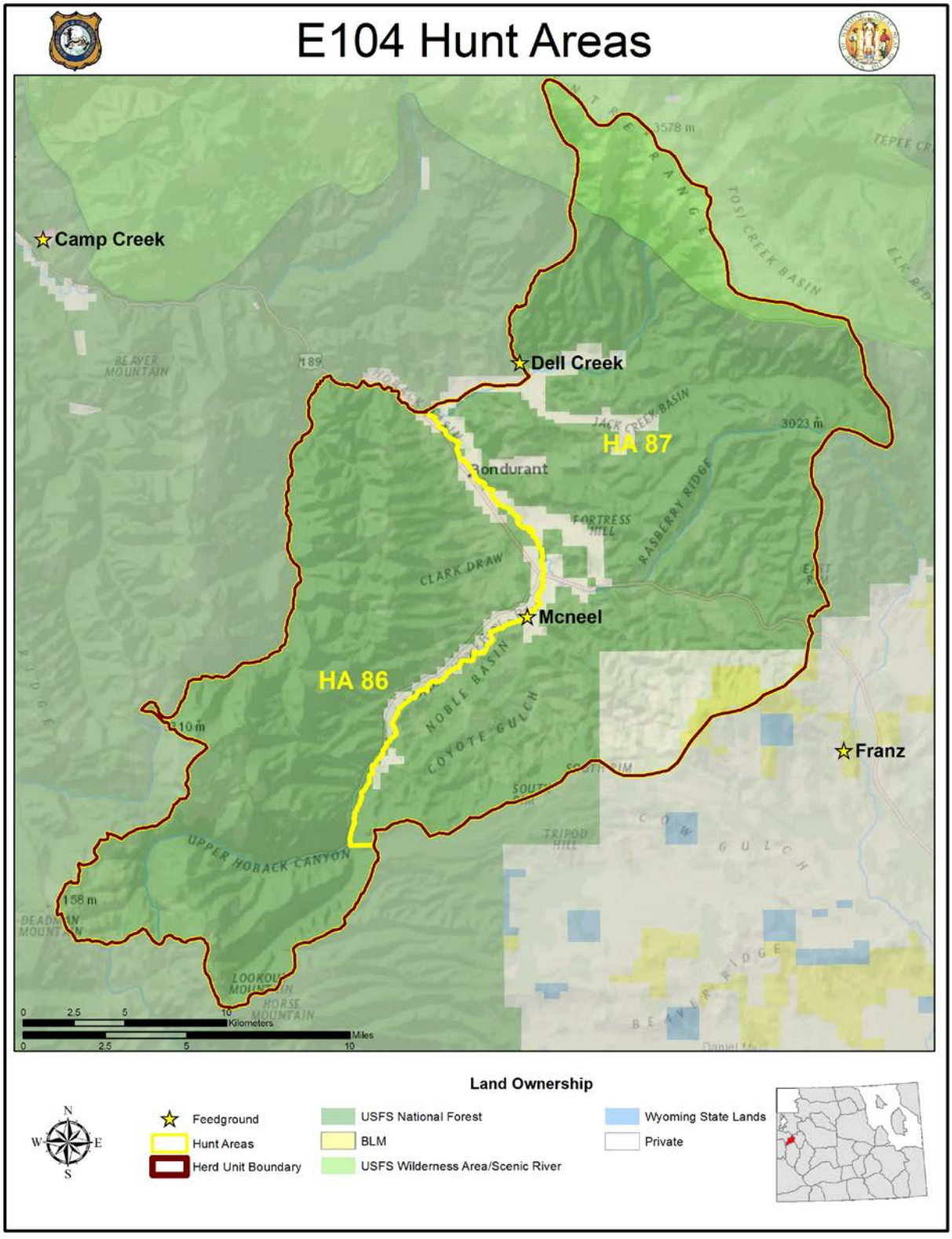

Figure 1. Land ownership, feedground locations, and hunt areas within the HEH.

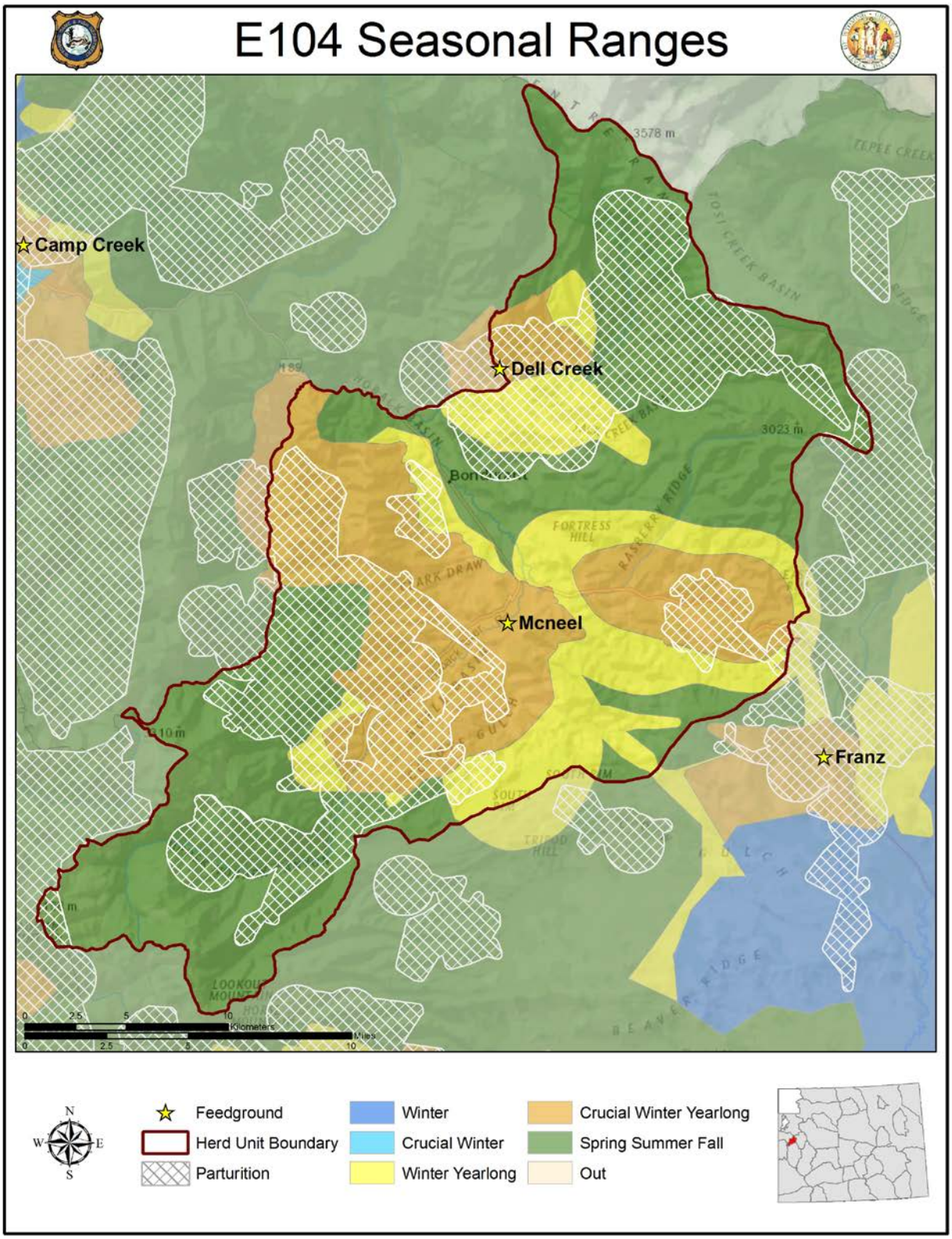

Figure 2. Seasonal elk ranges, elk feedgrounds, and hunt areas within the HEH.

B. Brucellosis Management Options

Listed below are potential options for managing brucellosis on the two feedgrounds in the HEH. 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 Ecosytem (GYE) if determined to be technically feasible, maintain livestock producer viability, reduce or 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.

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

Phasing out feedgrounds in the HEH is probably unfeasible at this time. Yet if current conditions and herd objectives change, through implementation of one or more of options 2 – 8, this option might become more realistic. The WGFC has the authority to make this decision.

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 occurs 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

Reducing the feeding season length on the Dell Creek and McNeel feedgrounds is difficult given typically persistent deep snow, limited availability of native forage, and close proximity to livestock and stored hay. Minor reductions to length of feeding season (early end date) may be possible within the HEH depending on annual snow conditions and a favorable long-term forecast, yet end date of feeding (1998-2007 vs. 2008-2016) on Dell Creek and McNeel have increased by 3 and 4 days, respectively. Implementation of one or more options 3-8 would make this option more possible. The WGFC has the authority to make this decision.

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. 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 HEH. Dell Creek feedground lies on USFS lands and McNeel feedground resides on private lands (25-year lease). USFS lands adjacent to both feedgrounds do not provide suitable space, slope, and other attributes to warrant relocation. For Dell Creek feedground, relocating to private lands more distant from wintering cattle could reduce the potential for elk to mingle with livestock, and similar to the McNeel feedground, using elk to fertilize hay meadows would be an added benefit.

4. Elk Reduction

Reducing elk numbers on feedgrounds in the HEH through liberalized hunting seasons could allow more flexibility to pursue options 1-3 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

Since 2011, hunting seasons in the HEH have been designed to increase elk numbers as population counts have been below the post-hunt population objective of 1,100 elk. The 2010 post-hunt population of elk in the HEH was 850 elk, falling to 787 in 2012, and rising steadily to 1,104 in 2015 (WGFD 2016). Since 2011, the number of elk on Dell Creek has been below the

WGFC quota of 400, and the population attending McNeel feedground has been at or above the quota of 600.

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.

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

Where fencing stackyards is considered beneficial (e.g., prevent damage to stored crop), the WGFD provides fencing materials and suggested schematics to landowners. Fencing projects around feedgrounds would require favorable decisions by the landowner (private or federal). Since 2011, the WGFD has provided stackyard fencing to 3 producers in the HEH that will help alleviate most of the traditional elk conflicts in the herd.

6. Elk Test and Slaughter

This option was conducted on the Muddy, Fall and Scab Creek feedgrounds in the Pinedale elk herd 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 compared to populations at Greys River and Dell Creek feedgrounds, brucellosis prevalence was reduced most significantly. However, prevalence at Muddy Creek rebounded from 5% in 2010 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 HEH 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. Affected permittee or 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

Little opportunity currently exists for developing significant acreages of winter range in the HEH. Historically, it is believed that few elk wintered within the HEH due to deep snow conditions (Anderson 1958, WGFD 1990), and this trend, in addition to increased recreational snowmobile activity, continues today (WGFD 2007, WGFD 2010). However, the Monument Ridge project has enhanced spring and fall range. To date, about 800 acres of aspen and sagebrush have been burned, and livestock management and vegetation response have been excellent. An additional 1,000 acres in the upper Hoback River area have been categorized for treatment. Increased quantity/quality of native forage in spring resulting from treatment of aspen and/or sagebrush may entice elk off of feedgrounds, reducing risk of intraspecific brucellosis transmission. Furthermore, using elk to enhance the nutritional quality/quantity of vegetation produced on hay meadows could also be a beneficial treatment. The increased forage quantity/quality in fall may entice elk onto the feedgrounds and away from damage situations, without an earlier initiation of feeding in some years.

8. Acquisition/Conservation Easements

With adequate intact, healthy, and accessible elk winter habitat available, elk feeding may 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 stability and health of all wildlife populations. Decision authority is between the seller and buyer.

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 all feedgrounds within the HEH may decrease by managing lands adjacent to, or connected with, native elk winter ranges. Cost of land and lack of funding for conservation easements in the HEH make this option unfeasible at this time.

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 NER. 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 they 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 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

Elk populations on both feedgrounds in the HEH are appropriate to test a new vaccine. However, it is unlikely that Gonacon would be appropriate to test on any HEH feedground at this

time as these populations have been below (Dell Creek) or at to slightly above (McNeel) WGFC quotas, and abundant public lands within the herd unit allow sufficient access for harvest.

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 and land managers can 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

Livestock producers and land managers in the HEH would benefit from refined maps of brucellosis risk from elk.

D. Coordination Meetings

1. Producer & Interagency Meeting

A meeting was held December 15th, 2015 in Daniel to discuss the ten options among livestock producers and associated land and resource management agencies within the HEH and Piney elk herds. Twenty-six producers, one USFS employee, three BLM personnel, eight WGFD personnel, two USDA-APHIS VS personnel, and one representative from the WLSB attended the meeting. A presentation was given by WGFD that summarized management and research regarding brucellosis and elk in relation to the ten options. Questions, comments and suggestions (oral and written), and refreshments were provided throughout the meeting.

About 10% of attendees had heard of low-density feeding and were supportive. Specific to the BMAP options, there were no comments regarding elk population reduction, habitat enhancements, acquisition/easements, vaccination research, or mapping risk areas. There was no support to phase-out all feedgrounds, yet it was suggested that WGFD consider trapping and relocating elk to Rock Springs to re-establish migration routes. Reduced feeding seasons was supported with continued flexibility in dates based on weather, but also cautioned that it should not be done in places with deep snow like the feedgrounds in the HEH. Although there was no support to relocate Dell Creek (or McNeel) feedground, the WGFD was encouraged to investigate relocating feedgrounds from USFS to private land to reduce cost of litigation. Fencing of haystacks was fully supported, but not fencing in livestock winter feeding operations

because of disease concerns (e.g., scours). Most discussion revolved around test & slaughter, and it was suggested that test & slaughter be incorporated on high risk feedgrounds (i.e., high prevalence and in close proximity to cattle). Additional ideas/suggestions included WGFD manage wolves to prevent spread of brucellosis, encourage ranchers to booster-vaccinate cattle with strain RB51 and blood test prior to shipping, and compare seroprevalence of elk commonly captured vs. elk that are very difficult to capture

2. Public Meeting

A meeting was held March 24th, 2016 between WGFD and concerned members of the public to discuss the ten options as they pertained to the Pinedale, Upper Green River, Big Piney and Hoback elk herds. Three interested publics, one producer and four WGFD personnel attended the presentation which summarized WGFD brucellosis management and research strategies and their relation to the ten options. The options of feedground phase-out, reduced feeding season length, and vaccination as well as other aspects of brucellosis were discussed throughout the presentation.

For the option of phase-out, it was noted that this should be considered an option as the USFS conducted a study in the 1950's indicating that feedgrounds could be closed if livestock grazing were eliminated in the foothills (native winter ranges) around Pinedale. However, a follow-up comment cautioned that closing feedgrounds could negatively impact other big game herds via competition. Regarding the option of reduced feeding season length, a producer commented that this option makes sense yet noted an apparent increase in elk near Willow Lake in spring in recent years and is concerned that elk are near cattle during the high-risk period. It was also suggested that the WGFD close gates on the Soda Lake elk fence and notify affected landowners when managers decide to end feeding. For the option of vaccination, there was a comment cautioning the reporting of high vaccination coverage (97%) as a 'success' of the program because the biobullet is a poor drug delivery system, and questions about delivery methods of oral vaccines and effectiveness of strain RB51 in elk. Additional questions and comments touched on several aspects of brucellosis including: ecology (weather-dependent environmental persistence of *Brucella abortus*, limited population effects); management (Hunter Management Areas prevent elk presence on private land, need for interagency collaboration and surveillance); economics (impacts to livestock trade, profits, and compensation); funding (eliminate feedground stamp, derive funding from agricultural interests); and politics (described as a 'political football').

E. Proposed Management Actions

1. Feedground Phase-Out

The WGFD will not pursue this option in the HEH at present time given existing elk brucellosis seroprevalence, inability or low opportunity to implement one or more of options 2-8, and the utility of elk feedgrounds at manipulating winter distributions of elk and maintaining current elk population objectives.

2. Shortened Feeding Seasons

The WGFD will pursue this option on both feedgrounds in the HEH depending on availability of native forage, snowpack, a favorable long-term forecast, and risk of elk commingling with livestock.

3. Feedground Relocation

McNeel feedground is located optimally for current management with no plan to relocate at this time. The WGFD will investigate the feasibility of relocating the Dell Creek feedground to nearby private lands, further in distance from wintering livestock, and off of USFS lands to reduce potential for litigation.

4. Elk Population Reduction

The WGFD will continue to manage for the current, WGFC-established, elk herd unit population objective of 1,100 elk in the HEH.

5. Fencing

The WGFD encourages cattle producers in the HEH to fence areas where hay is stored (stackyards) for winter-feeding operations and will continue to deliver fencing materials for stackyard construction where appropriate. The WGFD will not erect large-scale, game-proof drift fences in the HEH in the foreseeable future due to potential undesirable impacts to other migratory ungulates. As opportunities arise for additional fencing projects (e.g., winter cattle feeding exclosures), the WGFD will assess those situations 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 JEH in the foreseeable future.

7. Habitat Enhancement

The WGFD will continue to coordinate with private landowners, federal land managers, livestock permittees, and NGO's (i.e., RMEF) to develop and implement habitat improvements that may reduce elk dependency on supplemental feed in the HEH.

8. Acquisition/Conservation Easements

The WGFD will attempt to identify and pursue all 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. (2012) 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^{TM}: model impacts to feedground elk populations and seroprevalence.
11. Comparison 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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