BRUCELLOSIS IN ELK IN THE GREATER YELLOWSTONE AREA

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Abstract: Brucellosis is a highly contagious bacterial disease of both animals and humans. Infection of the female reproductive tract may result in abortion. The most common route of transmission is thought to be oral as a result of licking or ingestion of infected fetuses, placentas, fetal fluids, or vaginal exudates. Such transmission can be exacerbated under conditions that artificially congregate infected and susceptible animals, such as winter feedgrounds. A cooperative state/federal brucellosis eradication program began in 1934 with the goal of eliminating brucellosis from the United States by the end of 1998. The presence of brucellosis in wildlife creates a conflict with this goal. Elimination of brucellosis from the Greater Yellowstone Area (GYA) will not be easy. Over 100,000 elk and more than 3,000 bison inhabit the GYA. The rate of seropositivity can be as high as 88% in bison and 67% in elk using winter feedgrounds. Several management alternatives bear consideration in addressing the conflict between potentially infected wildlife and susceptible cattle. The Wyoming Game and Fish Department (WGFD) has vaccinated thousands of elk on feedgrounds with a reduced-dose B. abortus strain 19 vaccine delivered remotely by biobullet. However, eradication of brucellosis in elk and bison will probably require a combination of several management strategies.

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Brucellosis is a highly contagious bacterial disease of both animals and humans recognized since the 19th century. Brucella spp. are small, gram-negative, non-motile, non-spore-forming rods (Mayfield et al. 1990). The current taxonomic scheme recognizes 8 biotypes (biovars); B. abortus, biovar 1 is probably the most common isolate from wildlife in the Greater Yellowstone Area (GYA), but biovar 4 has also been found (Thorne et al. 1978). Brucella spp. are facultative intracellular parasites causing chronic disease, which usually persists for life.

The organism causes high morbidity and low mortality in adults. Infection of the female reproductive tract often results in abortion. Retained placentas and metritis accompanied by excessive vaginal discharge, and occasionally infertility, are also seen with infection. Fetuses delivered near term often are stillborn or fail to thrive due to overwhelming brucellae infection. Infection of the male reproductive tract can cause necrotizing orchitis and epididymitis of 1 or both testicles, seminal vesiculitis, or prostatitis. Brucellae in bone and synovial membranes cause bursitis and synovitis, and infection of the carpal bursa result in hygromata (Enright 1990).

The most common route of transmission is thought to be oral as a result of licking or ingestion of infected fetuses, placentas, fetal fluids, or vaginal exudates. Transmission is exacerbated under conditions that artificially congregate infected and susceptible animals, such as winter feedgrounds (Thorne et al. 1978). Under cool, moist conditions, brucellae can persist up to 100 days (Cook et al. unpubl. data) in the environment and transmission may occur by animals grazing on infected pasture or consuming other feedstuffs contaminated by discharges or fetal membranes.

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Brucellosis is endemic in bison and elk in the GYA, which encompasses Yellowstone National Park (YNP), Grand Teton National Park (GTNP), and surrounding areas in Wyoming, Montana, and Idaho. Brucellosis was undoubtedly introduced into these wildlife populations from domestic cattle around 1900 (Mohler 1917, Rush 1932). Because brucellosis infects both bison and elk in the GYA and it is assumed each species can infect the other, both must be discussed simultaneously.

For economic and health purposes, a cooperative state/federal brucellosis eradication program (Cooperative Brucellosis Eradication Program) began in 1934 with the goal of controlling, then eliminating brucellosis from the United States. This goal was realized in domestic animals in 2001 (Ragan 2002). The presence of brucellosis in wildlife creates a conflict with the goal of eradication by providing a potential source for re-infection of cattle. To address this problem, state and federal agencies formed the Greater Yellowstone Interagency Brucellosis Committee (GYIBC) to protect and sustain the existing, free-ranging elk and bison populations in the GYA while protecting the public interests and economic viability of the livestock industry in the states of Wyoming, Montana, and Idaho. The mission of the GYIBC is to facilitate the development and implementation of brucellosis management plans for elk and bison, and their habitat in the GYA (Hunter and Kreeger 1999).

Elimination of brucellosis from the GYA will not be easy. There are over 100,000 elk (Toman et al. 1997) and more than 3,000 bison in the GYA (Meagher et al. 1997). Elk have extensive annual migrations throughout the GYA between summer and winter ranges. To a lesser degree, bison also migrate out of YNP and GTNP in search of forage during winter. These migrations potentially commingle elk and bison with domestic cattle, thus it is possible for elk or bison to transmit brucellosis to cattle. In 2002, vaccinated cattle in Idaho contracted brucellosis from an aborted elk fetus (Hillman 2003).

Brucellosis is also considered an exotic disease of native wildlife. The rate of seropositivity (presence in blood of antibodies against Brucella) can be as high as 88% in bison (Williams et al. 1993) and 67% in elk using winter feedgrounds (Thorne et al. 1997). It has also been shown that 50–70% of elk (Thorne et al. 1997) and up to 82% of bison lose their first calf after infection with B. abortus (Williams et al. 1997). Although difficult to document, brucellosis could have negative impacts on elk and bison populations as a result of abortions and unthrifty calves.

POSSIBLE SOLUTIONS

Do Nothing

There are several management alternatives that bear consideration in addressing the resolution of brucellosis in the GYA. One option is to simply do nothing. There are some scientists and non-scientists who do not view brucellosis in the GYA as a problem and believe that any attempt to control or eradicate the disease would have unacceptable negative impacts on wildlife. From a wildlife management agency's viewpoint, doing nothing would violate its statutory responsibility to maintain viable and healthy wildlife populations. Elk and bison infected with Brucella are not healthy animals. The loss of offspring from this exotic disease is not a "natural" mortality and should not be tolerated. Doing nothing also poses a perpetual risk to domestic cattle. Cattle producers in and near the GYA would have to continuously vaccinate and monitor their cattle for brucellosis. Brucellosis in cattle not only imposes a financial loss on a given ranch, but it could have negative economic consequences for the entire state's cattle.
industry, and potentially the entire country as a result of beef export restrictions. A disease such as brucellosis should be treated no differently than efforts to stop the spread of exotic plants and animals within this country.

Remove All Elk and Bison

Probably the opposite extreme of doing nothing would be to somehow kill all elk and bison within the GYA, then replace them with elk and bison free of exposure to brucellosis. This undoubtedly would eradicate the disease from the GYA. Killing all the bison would probably not be difficult; the elk, on the other hand, would be problematic. Bison are big, slow-moving targets, which were almost exterminated century ago by early hunters using relatively crude weapons. Elk are furtive, more wary, and far more numerous. Theoretically, with advanced military technology and a concomitant degree of firepower, all of the elk could be located and eliminated. Even with hundreds of brucellosis-free elk and bison imported back into the GYA, it would take decades to recover populations to their previous numbers. And, important historic migration patterns would be lost to the reintroduced populations. Such draconian measures would be enormously expensive with no guarantee of removing all the potentially exposed elk and bison. Such musings are probably academic, because litigation against such measures would undoubtedly prevent the first shot ever being fired.

Test and Slaughter

"Test and slaughter" was a key component in efforts to eradicate brucellosis from domestic cattle in the U.S (Ragan 2002). Cattle were blood tested for exposure to Brucella and those testing positive were sent to slaughter. Coupled with vaccination and repeated testing, brucellosis could be eventually eliminated from a given herd. It is doubtful that test and slaughter would be effective in free-ranging wildlife. It would be possible to physically catch all the bison because of their relatively small numbers (compared to elk) and higher visibility. Few consider catching all the elk in the GYA even a remote possibility because of their numbers and secretive nature. More problematic, however, is that no test provides a 100% accurate diagnosis of infection (MacMillan 1990). Animals can be infected with Brucella, yet have no circulating antibodies or bacteria in the blood that can be detected by either serologic test or culture. Thus, Brucella-infected elk or bison could be captured, tested, found negative, and released only to shed the bacteria and transmit the disease at a later date. Thus, test and slaughter has no guarantee of accurately identifying infected individuals. Animals would either have to be kept in captivity for extended periods for testing, or repeatedly recaptured and tested. Neither of these scenarios is practicable.

Vaccinate Cattle

There are those who believe the only "problem" with brucellosis in the GYA is the threat to cattle. Therefore, if cattle were protected, the wildlife could be left alone. This is almost a variation of the "Do Nothing" option. Most cattle within and around the GYA are currently being vaccinated against brucellosis. Nonetheless, no brucellosis vaccine is perfect and vaccination did not prevent infection in 2002 of an Idaho cattle herd, which wintered near Brucella-exposed elk. Vaccination may provide some protection for cattle, but it does nothing to resolve the issue of infected elk and bison. Leaving elk and bison to live with brucellosis in
perpetuity condemns thousands of animals to suffering, loss of offspring, and increased probability of predation. This is neither humane or responsible wildlife management. Ultimately, vaccination of cattle can only be a buffer, not a shield, against brucellosis.

Remove Cattle from Public Lands

Removing cattle from public lands within the GYA may decrease the probability of disease transmission from elk or bison by some minute degree, but would do nothing about the essential problem of the disease in wildlife nor offer any protection for cattle on the millions of acres of private property within and around the GYA. Oftentimes, cattle grazing allotments are not utilized at a time when elk or bison may abort. Thus, cattle are not present at an appropriate time or place for exposure. Eliminating cattle grazing within the GYA may eventually become part of an overall risk reduction plan, but in and of itself offers little in the way of an ultimate solution. Unfortunately, brucellosis could become a straw man for a larger agenda to end all public lands grazing.

Eliminate Feedgrounds

Another management option is to eliminate winter-feeding of elk. Winter-feeding artificially congregates elk, which probably enhances disease transmission. At the same time, however, feedgrounds provide the only opportunity to vaccinate large numbers of elk. The prevalence of brucellosis in feedground elk is higher than in elk not inhabiting feedgrounds (Clause et al. 2002). Eliminating feedgrounds would also spread elk throughout the GYA, preventing any possibility of vaccination or treatment and subjecting thousands to death by starvation. Hungry elk would depredate cattle feed lines and hay stackyards, causing extensive damage, and increasing contact with and risk to cattle. Currently, feedgrounds appear to provide more benefit than detriment to wildlife. Regardless of differing viewpoints, feedgrounds may have to persist in the GYA.

The Wyoming Game and Fish Department, in collaboration with federal land management agencies and organizations like the Rocky Mountain Elk Foundation, works diligently to create new winter range as a substitute for feedgrounds. But habitat improvement projects take years to accomplish, and the potential for acquisition of new habitat is limited and prohibitively expensive in the GYA. Winter feedgrounds do not maintain artificially high elk numbers as some contend; rather, they help maintain historic numbers of elk. Feedgrounds came into existence because humans insisted on occupying historic elk winter range, thus limiting management options to either feeding elk or letting them starve. Because humans are the cause of this problem, humans are ultimately responsible for its solution. Until a reasonable, humane, alternative to feedgrounds becomes available, feedgrounds will continue to help elk survive the winter. Nonetheless, increasing natural winter range with a concomitant reduction in winter-feeding is part of the ultimate mix of management actions taken for the resolution of brucellosis in the GYA.

Treatment

As stated earlier, treatment of brucellosis in animals is generally unsatisfactory. However, antibiotics are fairly effective in treating brucellosis in humans. These antibiotics need to be taken several times a day for several weeks. Such a regimen for treating free-ranging wildlife
would be problematic, if not impossible. However, newer antibiotics and improved delivery methods may be developed in the future. If so, treatment may become part of the armamentarium developed to control or eliminate brucellosis in the GYA in the future.

Contraception

Contraception is being evaluated as a tool to decrease the prevalence of brucellosis (Rhyam and Drew 2002). The more Brucella-infected animals that become pregnant, the higher the likelihood of abortion and spread of the disease to uninfected animals. Also, the more animals within a given population, the higher the probability of contact with infectious fetuses or birth products. Contraception can not only reduce the number of pregnant animals but also, theoretically, reduce the total population over time. Wildlife contraceptives have been developed and tested for almost 2 decades with varying degrees of success. Present obstacles to widespread use include short duration of efficacy (or conversely, permanent contraception) and administration limited to single animals at a time. To be effective on a population level, contraceptives would probably have to be disseminated as a widespread oral preparation that would be available only to or would only affect the target animal. As with treatment, contraceptives may ultimately become part of the overall management strategy for some jurisdictions as technology improves.

Vaccinate Elk and Bison

Vaccination of elk and bison certainly has received the most attention by those parties working on brucellosis in the GYA. Vaccine research for elk and bison has been conducted by several governmental and academic organizations (Thorne et al. 1997). The Wyoming Game and Fish Department has vaccinated over 45,000 feedground elk with strain 19 vaccine delivered with biobullets (Fig. 1) with variable efficacy in reducing seroprevalence. Brucella vaccines do not last as long as most viral vaccines and do not protect 100% of the population. Some of the newer strains, such as RB51, originally held some promise as effective tools, but failed to protect elk (Kreeger et al. 2002a) or bison (Elzer et al. 2003) from abortion. Ideally, a highly effective, long-lasting and safe vaccine needs to be developed. Although biobullets are effective in vaccinating feedground elk and may prove so for bison, a more universal delivery method, such as oral baits, needs to be developed. Even if a long lasting, 100% effective vaccine were developed, vaccination alone may not eliminate brucellosis from the GYA. Vaccination most likely will have to be combined with other management strategies.

LIKELY SOLUTIONS

Certainly reducing the risk of brucellosis transmission within and among elk, bison, and cattle is a good start. If the numbers of infected animals can be reduced, then the number of abortions is reduced, which reduces the probability of disease transmission. It is also possible the number of infected animals could be reduced to the point the disease could not maintain itself in the wild and would eventually go out of existence. Short of significantly reducing numbers of infected animals, spatial and temporal separations are still a viable “risk management” approach that can be an interim solution pending development of longer-term solutions.
Vaccination

Vaccination still appears to be one of the best short-term tools to decrease the number of brucellosis abortions, although this does not necessarily address vulnerability to other diseases that can be triggered in situations of crowded wildlife populations. Currently, the *Brucella abortus* strain 19 vaccine has demonstrated the best efficacy in elk, but still it only protects 25–30% of test elk from abortion (Thorne et al. 1981, Herriges et al. 1989, Roffe et al. 2003). It also remains to be determined how long strain 19 protects elk. A more efficacious, long-lasting, safe vaccine certainly needs to be developed for both elk and bison.

Coupled with such a vaccine, a thorough understanding of elk and bison immune systems relative to *Brucella* vaccines is required. Preliminary evidence has shown that elk do not respond to these vaccines in the same manner as domestic cattle (Olsen et al. 2002). Such knowledge is crucial to the development of an effective vaccine. New DNA-plasmid vaccines offer promise of more effective, less pathogenic vaccines, but years of research on these remain to be done. Additionally, public unease with the use of genetically-modified organisms needs to be addressed if they are ever to be employed in the wild.

A delivery system that targets and reaches most elk and bison in the GYA would also be ideal. Currently, the only vaccination delivery system proven effective is the strain 19 biobullet system used by the Wyoming Game and Fish Department to vaccinate elk on feedgrounds. The advantages and disadvantages of this system have been discussed previously (Aune et al. 2002a). If the biobullet is considered the best delivery system, then a longer-range version needs to be developed in order to vaccinate animals, primarily bison, not inhabiting feedgrounds.
An oral vaccine, disseminated throughout the GYA, could be an ideal delivery method, but several hurdles would need to be overcome. All current vaccines are living, mutant *Brucella abortus* bacteria, which must be kept alive to remain viable. Keeping these bacteria alive in an oral bait for the extended periods of time needed for the bait to be found and consumed is problematic. These living vaccines also are not as effective orally as they are when administered intramuscularly (Elzer et al. 1998). There could also be large, perhaps insurmountable, regulatory barriers against the uncontrolled dissemination of an infectious organism in the environment. *Brucella abortus*, after all, is classified as a bioterrorist organism! There are legitimate concerns for nontarget species that may consume the vaccine bait. Research on the safety of any oral vaccine needs to be conducted on several representative nontarget species prior to its deployment. Again, the DNA-plasmid vaccines may overcome some of these hurdles because they are non-living and effective orally. Despite the obstacles, oral vaccines have the potential advantage of being more effective and economical than other vaccine delivery methods.

**Improve Habitat**

Continued development and reclamation of good winter range habitat are needed. As stated previously, good winter range reduces elk reliance on feedgrounds and distributes them over a wider area. When spread out, the likelihood of uninfected elk contacting a *Brucella*-induced abortion is reduced (Aune et al. 2002b). The development of habitat, however, takes time and money. Most large land areas targeted for habitat improvement are a mix of private, state, and federal land holdings, requiring agreement, cooperation, and coordination among all parties before development can occur. Nonetheless, getting elk off of feedgrounds and distributing them over large areas of good winter range is a sound long-term management plan that will reduce disease transmission. Studies have continually shown the prevalence of brucellosis in elk on natural range is 10 times lower than in elk wintering on feedgrounds (Clause et al. 2002, Ferrari and Garrott 2002). It may also be possible to alter the current method of feedground operation to spread elk out or otherwise decrease the opportunity for uninfected elk to contact infected aborted fetuses. The National Elk Refuge has been using habitat enhancement measures such as irrigation, fertilization, seeding, and prescribed fire to enhance forage for wintering elk on the refuge. It has shown positive results in reducing brucellosis seroprevalence in wintering elk (Scott Smith, Wyoming Game and Fish Department, unpubl. data).

**Improve Diagnostics**

Better diagnostic tools are also needed, particularly for field use (Philo and Edwards 2002). The standard test for field use has been the rapid card test, but this is a relatively crude test fraught with false positives and false negatives. Ideally, a good diagnostic test would use a small amount of whole blood (or other easily obtainable sample), be simple and foolproof to conduct, and highly accurate (i.e., good specificity and sensitivity). This kind of test could then be used in a variety of situations to monitor the efficacy of a vaccination or other management program, to conduct test and removal if desired, or perhaps to identify and treat individual animals.

**Treatment**

Treatment of infected animals is an action that is rarely discussed. This is because most antibiotic regimens for the treatment of brucellosis require 1 or more antibiotics administered 1
or more times daily for several weeks. At first glance, this would seem impractical for free-ranging wildlife. But perhaps this tool should be re-examined. There are currently no data that indicate treatment for brucellosis would be effective in elk or bison, so such studies would have to be conducted. A delivery system would then have to be developed. As with vaccines, antibiotic-impregnated bait could be used to treat large numbers of animals, but the problems of environmental concerns, nontarget species exposure, and antibiotic resistance are not trivial. Instead of indiscriminate oral delivery, perhaps treatment could be reserved for a small number of animals that have been captured and tested positive for brucellosis. One-time, slow-release, polymer-based antibiotic delivery systems could then be administered to individual animals. If effective, treatment could reduce the number of infected animals without having to kill or otherwise remove them.

Population Management

Another management option would reduce, then maintain populations of elk and bison within the carrying capacity of their habitat, especially winter range, which is the most limiting. Many elk herds exceed population objectives identified for sustainable habitat utilization. Without removal by hunting or other means, elk and bison will continue to exceed desired population levels. Too many animals not only negatively impact the habitat, but also increase the probability of disease transmission. The development and implementation of specific herd unit management plans is crucial. All parties concerned about brucellosis in the GYA should objectively evaluate the roles of hunting, ungulate predators, contraception, and other management alternatives regarding their contribution to population control.

Obviously, the ultimate resolution of brucellosis in elk and bison in the GYA is not going to occur overnight. All of the above-proposed "solutions" will require years of research and implementation before noticeable change will be effected. In the meantime, specific activities, such as strain 19 vaccination of feedground elk, should be continued to decrease the spread of brucellosis and the risk of transmission from wildlife to cattle. Thus, the solution to the problem of brucellosis in elk and bison in the GYA will be more or less along this path (Kreeger et al. 2002b):

1. Continue elk vaccination with strain 19 biobullets on feedgrounds;
2. Continue surveillance of elk to assess vaccine efficacy;
3. Continue vaccinating cattle for brucellosis in the GYA;
4. Continue to minimize commingling of cattle with elk or bison;
5. Continue to develop winter habitat to reduce elk dependence on feedgrounds;
6. Complete herd management plans and achieve the goals of each;
7. Develop the safest and most efficacious vaccine possible for elk and bison;
8. Develop a vaccine delivery system that will vaccinate the maximum number of target animals with the least environmental and biological problems;
9. Develop a rapid and accurate field diagnostic test;
10. Develop, test, and then implement a proven vaccine and delivery system throughout the GYA;
11. Implement widespread surveillance of elk and bison to assess the efficacy of the vaccination program;
12. Continue to engage the public and to collaborate among agencies having responsibility for management of elk, bison and their habitat in the GYA; and
13. Assess the effectiveness of vaccination and other management actions to incorporate adaptive management approaches into planning so that as new information is developed, it can more readily be integrated into elk, bison, and brucellosis management programs of the involved agencies.

LITERATURE CITED


Reviewer: J.C. deVos