Chapter 6

Brucellosis in Cattle, Bison, and Elk: Management Conflicts in a Society with Diverse Values

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Paul Cross and his colleagues have studied not just the biology of brucellosis but the politics as well – the two seem to be inseparable. Before coming to Montana, Paul worked with bovine tuberculosis in the African buffalo of the Kruger National Park in South Africa but nothing prepared him for the agenda-driven politics of cattle ranching, bison, and big game hunting in states like Montana and Wyoming.

Not all threats to the ecology and integrity of the park are as easily visible as fire or human population growth. The issue of brucellosis in the park is a good example. Brucellosis is a bacterial pathogen found in bison, elk, and domestic cattle that can cause the host to abort its fetus. USDA successfully eradicated brucellosis in the U.S. cattle industry in 2000. Today, bison and elk are vectors that could return the disease back to domestic herds. Needless to say, the politics of cattle production and wildlife management pervade any discussion of controlling or managing the disease. If brucellosis is consistently found in cattle herds in the region, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) amends its brucellosis regulations and require cattle producers to test their animals for brucellosis prior to interstate movement. This adds cost and logistics to their business.

Cascades of issues follow the brucellosis debate. Bison are a dominant symbol of the West yet; government officials kill them as if they were vermin. At the same time, elk, a high value public commodity, receive preferential management treatment by state fish and game agencies. Public feeding grounds are proven sources for disease but continue to be funded by the State of Wyoming, the entire debate is framed as an "old west/ new west" lifestyle choice.

Paul and his team of collaborators combine field data with mathematical modeling and statistical analysis to bring a better understanding of the pathogens to policy makers. In a cultural setting where cattle production and free roaming native species are held in equally high esteem, the science will always be political but that doesn't exclude the need for rational and effective management strategies. Paul has his work cut out for him.

J. Johnson



Mature bull bison in YNP (Steve Hinch)

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Paul C. Cross, Mike R. Ebinger, Victoria Patrek, and Rick Wallen

Paul C. Cross, U.S. Geological Survey, Northern Rocky Mountain Science Center,
Bozeman, MT 59715; Email: pcross@usgs.gov

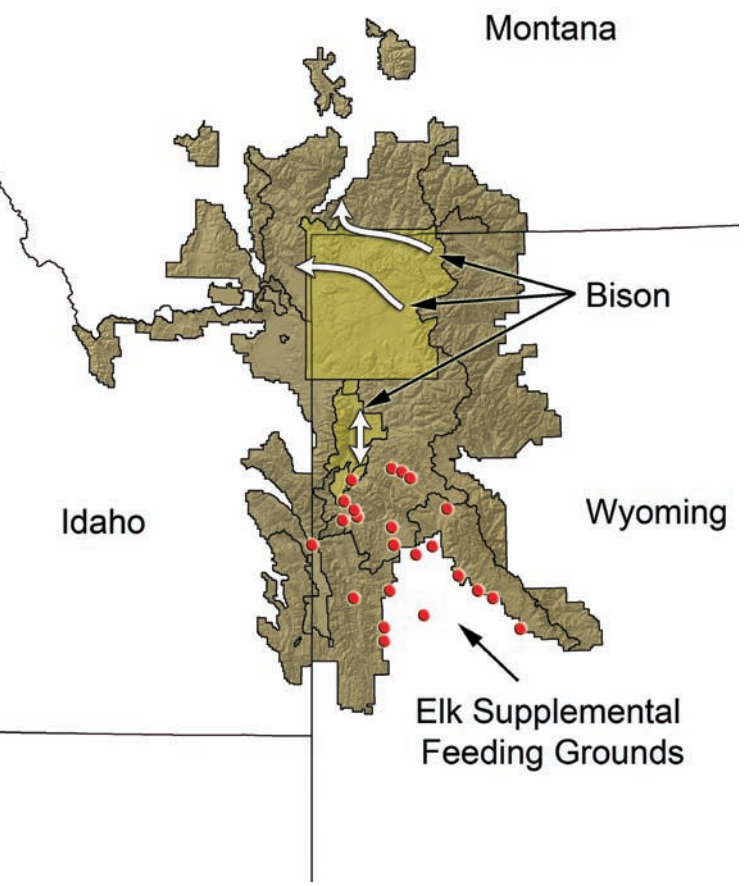
Mike R. Ebinger, Big Sky Institute, Montana State University,
Bozeman, MT 59717; Email: mrebinger@hotmail.com

Victoria Patrek, Department of Ecology, Montana State University,
Bozeman, MT 59717; Email: vickipatrek@hotmail.com

Rick Wallen, National Park Service, P.O. Box 168,
Yellowstone National Park, WY 82190; Email: rwallen@nps.gov

Paul's work is highlighted on the USGS site at: http://www.nrmsc.usgs.gov/staff/pcross/research

The Greater Yellowstone Ecosystem (GYE) abounds with charismatic wildlife, picturesque landscapes and long-standing controversies. The management of brucellosis, a disease caused by a bacterial pathogen of bison, elk and cattle that can cause the host to abort, is one such example.



▲ FIGURE 6.1 Map of the Greater Yellowstone Ecosystem. While the brucellosis issue is frequently framed as an ecosystem-wide problem, the overlap of bison and elk on private grazing land is actually quite small. Yellow arrows show annual migrations of bison from Yellowstone and Grand Teton National Parks shown in green to public lands (brown). The 23 supplemental elk feedgrounds are shown as red circles. (Paul Cross, USGS)

The national goal of eradicating brucellosis from the livestock industry evolved in the 1930's and was formally established by law in the 1950's. Since that time the eradication program made impressive progress, and by 2000 only a small number of infected herds remained. In February 2008, the U.S. Department of Agriculture announced that, for the first time in history, the United States cattle herd was brucellosis free. The excitement was short-lived however, because cattle in both Montana and Wyoming were subsequently infected. Both states lost their brucellosis-free status, resulting in additional testing requirements and interstate movement restrictions.

The brucellosis controversy is jurisdictionally complicated, involving a variety of federal and state agencies with very different mandates. State wildlife agencies have jurisdiction over wildlife, while state livestock agencies regulate livestock movements among landowners to control the spread of infectious diseases. However, the U.S. Forest Service and Bureau of Land Management (two federal agencies that reside in different departments—the U.S. Department of Agriculture and U.S. Department of Interior) control most of the public lands that are used by wildlife and livestock in the West. On these lands the Forest Service and Bureau of Land Management must balance the interests of livestock grazing with wildlife protection and outdoor recreation. To make things even more complicated the U.S. National Park Service and U.S. Fish and Wildlife Service have complete autonomy over their lands and most wildlife management within national parks and national refuges, respectively.

Since wildlife move freely across jurisdictional boundaries, management responsibilities are shared among state and federal agencies, and conflicts arise due to their differing mandates and management philosophies. With respect to brucellosis the stakes are high, and a cutthroat atmosphere arises as the wildness and conservation of a species is pitted against the livelihood of an industry and way of life. Ultimately, the conflict revolves around the cultural and scientific suitability of management actions. The efficacy of different management strategies is usually unknown, and

for some people the implementation of those strategies (e.g. capturing and hazing bison) diminishes the wild aesthetic of the species and landscape. As long as elk and bison are infected with brucellosis they represent a disease risk to cattle, but the magnitude of those risks and whether the management actions are justifiable are intensely contested.

Research in the Greater Yellowstone Ecosystem is often driven by the scientific, economic, and political context of the time. So, to understand why researchers are tackling particular issues we first develop some of the background around the brucellosis issue prior to delving into active research projects. Research is about solving mysteries, and in that spirit we raise a number of conundrums throughout the chapter. Some of these we attempt to answer, but many are open questions that researchers continue to work on.

Discovery and Detection of Brucellosis

Brucellosis has a long history with humans and their domestic counterparts. The first known record of brucellosis in humans dates back to 1859 by Jeffrey Allen Marston. His accounts were of a mysterious disease, now believed to be brucellosis, infecting soldiers of the Crimean War. In fact, during the same year Florence Nightingale returned unwell to England from the Crimean War where she had set up a hospital to treat sick soldiers. She remained chronically infected until her death, and it is believed to have been brucellosis, then called Mediterranean fever.

Captain David Bruce was sent to the island of Malta to study the mysterious fever. By chance Bruce (and others) discovered that it was the goats' milk fed to patients that was responsible for the transmission to humans. Bruce and his coworkers isolated a bacteria and ultimately it was Bruce's name that was forever attached to the causative agents. It was Danish professor L.F. Benhard Bangs who isolated a different causative organism in cattle in 1895, giving it the name *Brucella abortus*. Nomenclatures shifted, and for a brief period brucellosis was referred to as Bang's disease.

Accurate diagnosis of disease is tricky, even for human diseases. For example, recall your last tuberculosis test. The doctor probably injected a small amount of fluid into your arm. You then returned to the doctor's office 48 hours later. If there was swelling, then your immune system reacted to the injection indicating that you were previously exposed to tuberculosis. The test does not indicate the extent of the infection, when it may have occurred, or whether you have already recovered. Many tests for other diseases are similar in that they are often based upon the presence or absence of antibodies. If antibodies are present then your immune system has seen the particular pathogen in the past.

In the case of brucellosis, researchers sacrifice elk and bison that have *B. abortus* antibodies in order to determine the relationship between positive test and the extent of the infection. Tissue samples from the slaughtered individuals are taken into the laboratory, and placed into petri dish environments that promote bacterial growth. If *B. abortus* appears in the petri dish, then the animals are referred to as "culture positive." Roughly one half of the elk and bison that test positive for *B. abortus* antibodies are actually culture negative. Individuals may be culture negative because they have recovered from a previous infection or because the researcher did not capture the *B. abortus* bacteria in the tissue samples. Either way, most researchers believe that these culture negative individuals are unlikely to pass the disease to others either because they are truly recovered or because the infection was not very severe.



▲ PHOTO 6.1 Bison roam large distances in herds that vary from tens to hundreds. This herd, in the Lamar Valley, YNP, is feeding on grass and sedges in the sagebrush meadows. When bison migrate out of the park in search of winter forage, the brucellosis problem increases in complexity as bison move onto private property where state agencies have regulatory jurisdiction. (NPS, Yellowstone National Park)

Brucellosis Biology

Brucellosis in the GYE is the result of infection by the bacteria *Brucella abortus. Abortus* refers to the way that this bacteria gravitates towards the reproductive tissues of an infected host where it multiplies and sometimes causes a host to abort a pregnancy. If an infected female aborts, or even if she has a live birth, the fetus and/or associated fluids and tissues are highly contaminated with infectious bacteria. If other animals investigate those infected materials they may also become infected and pass on the infection during their next pregnancy. From a management and epidemiological perspective, brucellosis is only of concern with females as males are not considered effective transmitters of infection. Although *Brucella abortus* pathology differs among cattle, elk, and bison, generally newly infected individuals are likely to abort their calves in the first few years after the initial infection. Afterwards they recover and presumably raise successful offspring.

Brucellosis probably causes a minor decrease in the population growth rates of elk and bison, but it is not currently considered a threat to their long-term survival. In fact, many (but not all) of the bison and elk populations in the GYE are larger than they have been in the past 30-100 years. Brucellosis also does not appear to threaten the survival of individual cattle, but it can infect people and infected cattle produce fewer viable calves so the USDA judged it more beneficial to control/eradicate the disease by depopulating infected ranches. These management-related depopulations can have large impacts on the small number of affected farms (less than 10 on the Montana side of the GYE) that also serve to maintain open-space in an area of rapid human development.

Bison and Elk as Wildlife Disease Hosts

Brucellosis remains a problem in the GYE despite the overwhelming success of the brucellosis eradication program in cattle because the disease is maintained independently in both elk and bison. Brucellosis was first detected in the Yellowstone bison population around 1917 when blood collected from two female bison that aborted their pregnancies at the Buffalo Ranch tested positive for the disease.

Yellowstone bison had numerous opportunities to contact the disease from potentially infected cattle during the early historic period of the park. Prior to 1917 cattle were routinely kept in the park for milk and beef production to feed park visitors and staff. Early bison caretakers used milk from domestic cattle to feed orphaned bison calves before they were released to mingle with the rest of the herd. Yellowstone bison currently have a brucellosis seroprevalence of around 50%.

Every year in late winter as the snow piles up in Yellowstone National Park (YNP), bison migrate to low elevation winter ranges outside the Park boundary where less snow makes foraging easier. Bison that migrate out of the park encounter a landscape where cattle ranching activities conflict with bison conservation near West Yellowstone and Gardiner, Montana. Once bison have left YNP they enter the jurisdiction of Montana Fish Wildlife and Parks (MFWP) and the Montana Department of Livestock (MDOL), which have different constituencies and mandates. MFWP treats the animals as a game species, while the MDOL view them as threats to the livestock industry. To manage bison in the conflict zone, these agencies, along with YNP, the Gallatin National Forest and the U. S. Animal and Plant Health Inspection Service developed an

Interagency Bison Management Plan (IBMP) in 2000. The intention of this plan is to "maintain a wild, free-ranging population of bison and to manage the risk of brucellosis transmission from bison to livestock in Montana". The plan is focused on making sure that bison and cattle are separated during the late winter and early spring when the transmission of brucellosis is most likely. The IBMP allows for some bison in designated management areas during portions of the year that risk of brucellosis transmission is low. The plan calls for more aggressive control and culling of the population as the risk increases. Managing for a population abundance of about 3000 bison was determined to minimize the risk of bison migrating beyond the park boundary and thus reduce the risk of brucellosis transmission from bison to cattle. To keep bison within designated management areas and to keep abundance in these areas within accepted limits the agencies use a variety of tactics (riders on horseback, snowmobiles, helicopters) to haze bison away from cattle occupied areas. If necessary, they use corral traps located in the Madison Valley and Gardiner Basin to capture bison and remove them from the population.

In 2008, 1729 bison were removed from Yellowstone through hunting and management actions, roughly 40 percent of the pre-winter population estimate. This was the largest removal in the history of YNP. Conservation groups vary in their approach and philosophy, but most objected to this level of removal and the way in which it occurred. Part of the controversy revolves around the appropriate use of public lands outside of YNP. Some believe that bison, like other wildlife species, should be allowed access to public land, but this potentially brings them into close proximity with cattle herds. The extensive press coverage of bison management activities suggests that bison are a major risk of transmission to cattle. In fact, as is often mentioned by the press, there are no confirmed cases where bison have transmitted brucellosis to cattle in the wild. This is true, but not because bison are unable to transmit the disease to cattle, rather it is because the current management practices of hazing, boundary quarantines, and removal effectively separate cattle and bison. The management regime is unpalatable to many conservation groups, but it is highly effective.



▲ PHOTO 6.2 In order to manage the bison population and prevent the spread of brucellosis to livestock, public lands agencies frequently haze bison away from cattle grazing areas using aircraft, snowmobiles, and horses. If the animals cannot be kept away from cattle they are often trapped and removed from the wild population. (Buffalo Field Campaign)

Determining the source of infection when cattle test positive is a difficult problem. The events are extremely rare and detection can be anywhere from months to years after the infectious event occurs. State wildlife veterinarians use information on cattle and wildlife commingling, as well as genetic tools to determine the most likely cause of an infectious event. In all the recent cases of cattle that tested positive for brucellosis in Montana, Idaho, and Wyoming experts have pointed to elk as the most likely source of infection.

Elk are ecologically, behaviorally, and epidemiologically different from bison, and these differences present substantial challenges from a disease management perspective. Elk require an alternative set of tools than those used for bison disease management. For example, elk numbers and behavior prevent managers from using hazing as a management tool. Elk show lower disease prevalence than bison, but the prevalence in elk varies geographically. The prevalence of brucellosis in elk is higher in the southern regions of the GYE than in the north. This geographical difference in elk prevalence is due to another controversial management strategy – supplemental feeding.

In the Jackson and Pinedale regions of Wyoming, state and federal wildlife managers feed elk during the winter at 23 sites to control the spread of brucellosis from elk to cattle. The supplemental feeding program cost the

Capturing Elk and Bison

Blood samples are necessary to determine brucellosis seroprevalence, getting these samples require that elk be captured. The two capture methods used on elk and bison are the corral trap and remote delivery darting. Corral traps are used to capture a large number of animals whereas darting is used when only a few individuals are targeted. Elk are baited into corral traps with hay. After after several dozen elk are in the corral a door is released, trapping them. Bull elk are excluded from the corrals by vertical bars that are too narrow for their antlers to pass through. Bison are more easily herded using horseback riders to direct groups of animals through the opening in the corral trap. The captured animals are then coerced through a series of progressively smaller pens to a series of chutes until a single animal is contained in very tight quarters. At this site age, sex and morphology information along with a blood sample is collected.

When using darting techniques, the target individual is identified and shot with a tranquilizer dart from a CO_2 powered gun. Within a few minutes the animal succumbs to the sedation process and lies down on the ground. The capture team monitors the breathing and heart rate of the animal while data such as sex, age, weight and tissue samples are collected; a reversal drug is administered and shortly thereafter the animal is up and walking (or running in some cases) back to the safety of the herd.

Research is also being done on the feedgrounds that does not entail capture. Remote cameras are being used by Wyoming Game and Fish Department to look at how often elk come in contact with non-infected fetuses, and how quickly scavengers remove these fetuses from the feedground. This is providing managers with information on how changes in the feeding regime may decrease contacts with infective tissues and how an intact scavenger community may help reduce transmission. Researchers also use fecal samples collected off the ground to look at stress hormones. They have found that stress hormone levels in elk on feedgrounds are much higher than free-ranging elk. However, they were unable to determine what caused these high stress hormone levels. Currently researchers are investigating what factors contribute to these high stress hormone levels and are addressing how management may mitigate these high stress levels by altering feeding procedures.

state of Wyoming $1.5 million in 2007. Unfortunately, the feeding also appears to increase the prevalence of brucellosis among the portion of the elk population that frequent the feeding grounds. This leads us to another riddle. Why do managers spend time and money on a policy that increases the prevalence of a disease in one host in order to decrease the chances that it infects another?

Elk on native ranges are less effective hosts for brucellosis than bison because they often have their calves in seclusion and clean up any afterbirth as an anti-predator strategy. This makes it unlikely that other elk contact the infectious material. However, the supplemental feedgrounds create dense aggregations of elk during late pregnancy and into the spring calving season thereby allowing brucellosis to more easily persist. As a result, the prevalence of brucellosis on the feedgrounds is much higher than in other elk populations around the GYE. Outside the GYE, brucellosis is not known to persist in elk populations. Unlike elk, bison are aggregated year-round and have their calves in closer proximity to one another, thus increasing the number of potential transmission events.

With this background we can now return to an earlier question about why managers spend time and money on a policy that increases brucellosis prevalence in elk



▲ PHOTO 6.3 Darting elk on the Wyoming feedgrounds is sometimes the only way for public land managers to collect blood samples to test for pathogens that threaten wild populations. (Vicki Patrek, MSU)

in order to decrease the chances that elk infect cattle. Essentially, managers are caught in a cycle—supplemental feeding helps to separate elk from cattle, but also increases transmission and prevalence of brucellosis in elk, requiring the continued feeding of elk.

The Wyoming Governor's Brucellosis task force acknowledged that decommissioning the elk feedgrounds would likely lead to a decrease in brucellosis seroprevalence among elk, but were concerned that reduced feeding would lead, particularly during the first few years, to increased transmission from elk to cattle. Wyoming's Game and Fish Department has not yet been willing to accept these short-term risks which would likely reap long-term reductions in elk brucellosis, perhaps due, in part, to conflicting interests to support high elk populations for hunting.

Management Strategies

Not all of the constituencies involved in the brucellosis debate have the same management goals, and the most 'effective' strategies depend upon where one sits. Strategies that reduce livestock risk may not effectively protect wildlife species and vice versa. In fact, some people argue that the best management of bison and elk would be none at all. However, regardless of disease risks, concerns about private property damage would ultimately lead to some level of bison containment within a delineated conservation area. Thus, even if managers



▲ PHOTO 6.4 Wyoming Game and Fish personnel test elk samples for brucellosis. Blood testing shows the proportion of animals that have been exposed to brucellosis and developed antibodies. A positive test doesn't necessarily mean that the animal can transmit the disease only that it harbors the bacteria and may be able to transmit to other animals. (Mark Gocke, Wyoming Game & Fish)

were able to eradicate brucellosis from the GYE, there would still be some form of bison management activity necessary. There is a suite of management options that focus on maintaining spatial and temporal separation of bison and cattle (e.g. conservation easements, fencing, and alternative grazing strategies), which are important for the conservation of bison but generally do not protect livestock from the risk of brucellosis transmission from elk.

There are several reasons for the very different treatment of elk and bison in this ecosystem. First, bison congregate in large numbers more so than elk do and are thought to be more controllable. There are substantially fewer of them within the GYE compared to elk and they tend to remain in valley bottoms during much of the year. Thus, an aggressive management program to vaccinate, and/ or capture and test a high proportion of bison is believed to present a greater probability for success than the same management strategy for GYE



▲ PHOTO 6.5 Feeding time at the National Elk Refuge. Established in 1912, the refuge is the winter home of the largest elk herd in North America. Elk are supplementally fed alfalfa pellets and hay throughout the long winter. The federal and state feedgrounds were established as a partial solution to loss of habitat loss and conflicts with ranchers but have created other dilemmas. When animals are crowded together on feedgrounds they often have higher rates of disease. Closing feedgrounds could reduce the prevalence of brucellosis, but it would likely result in a different set of problems. (Paul Cross, USGS)

elk. The proposition of keeping tens of thousands of elk away from cattle is certainly more difficult than controlling a few thousand bison. Second, an established hunting constituency actively lobbies for increasing elk population sizes and hunting opportunities.

Despite the relative success of eradication efforts in cattle as well as in the bison of Wind Cave National Park and Custer State Park, eradication of brucellosis from the GYE seems unlikely. All of these successful eradication programs have involved capturing large portions of the populations repeatedly, vaccinating young females that test negative for the disease, and removing infected individuals. Such an effort may be feasible with bison, but the logistics of capturing tens of thousands of elk scattered across the rugged terrain of the GYE is hard to imagine. Reductions in the total number of bison and/or elk may reduce the total number of infectious individuals on the landscape, but are unlikely to lead to outright eradication.

Compared to removing bison or feeding elk, vaccination is an aesthetically appealing control strategy. However, the effectiveness of vaccination at eliminating pathogens, or even controlling them, is limited, particularly in wildlife species. In fact, the elimination of *Brucella abortus* from elk and bison through vaccination alone is not an expected outcome. This should not be surprising given that, even in humans, we have only successfully eradicated smallpox. Since wildlife species do not present themselves for vaccination like people do, the delivery of a vaccine becomes an important component of any control strategy.



▲ PHOTO 6.6 Elk, bison, and most other ungulates lick newborn young, whether it is one of their own offspring or not. If elk, bison and cattle mix during the birthing season, this instinct is a potential vector to transmit brucellosis to another animal. (NPS, Yellowstone National Park)

One benefit of the supplemental feedgrounds is that the aggregation of elk facilitates a vaccination program that began in 1985. Nearly all calves are vaccinated annually on all feedgrounds except Dell Creek using Strain 19 *B. abortus* vaccine encapsulated biobullets. These biobullets are hard, plastic, 0.25 caliber projectiles that penetrate the skin, dissolve in muscle tissue and deliver the vaccine dose. The Strain 19 vaccine reduced abortion events in captive elk from 93% to 71% during the first pregnancy, but did not reduce infection rates. Over the longer term, reduced abortion rates should translate into reduced transmission and thus lower prevalence. Unfortunately, this vaccination effort does not appear to have resulted in a major reduction in brucellosis seroprevalence on the feedgrounds.

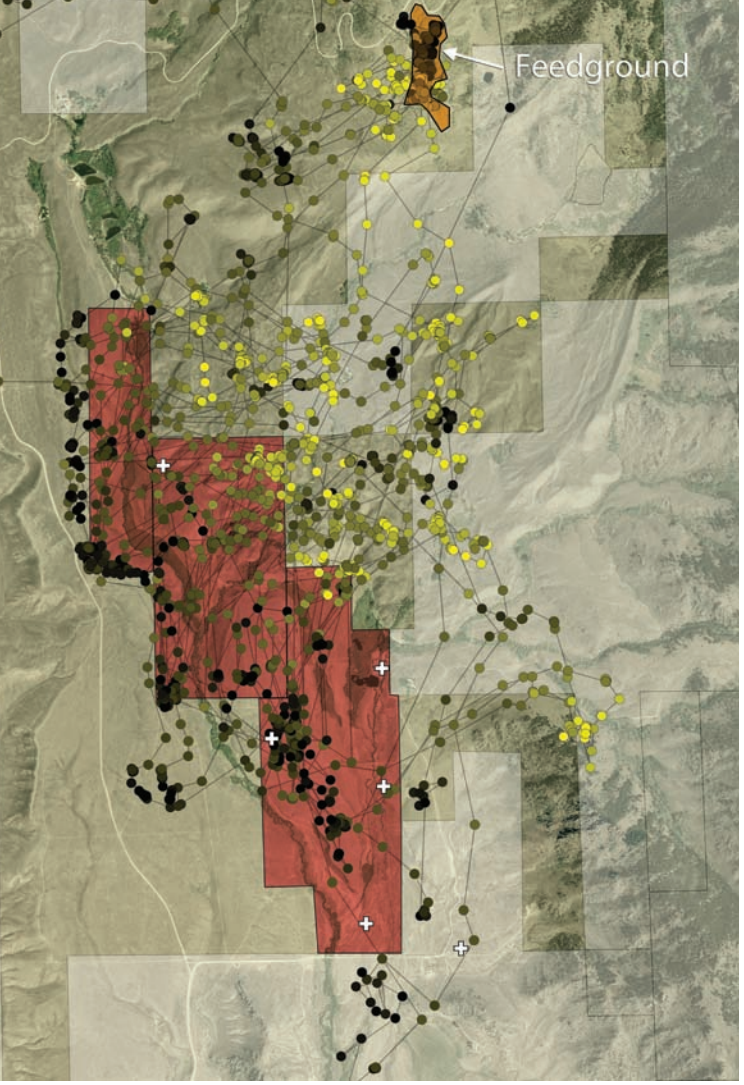
Research on the development of more effective vaccines for wildlife and livestock is ongoing, but the chances of developing a *"silver bullet"* in the near future remain slim. The amount of research effort conducted on livestock and wildlife vaccines is relatively small compared to humans. Second, since several *Brucella* species were among the first pathogens to be developed into biological weapons they are highly regulated. Researchers must pass security clearances and the facilities used to house the pathogens must meet biosafety requirements. These requirements become increasingly difficult and expensive to satisfy when large animals are involved and only a few facilities in the U.S. can run these experiments.

Obviously it would be easier to vaccinate cattle than either bison or elk. However, there is an interesting disconnect between how vaccines typically work and the current livestock regulations. Most vaccines help individuals mount a strong immune defense after they have been exposed to a pathogen. They do not reduce the probability that an individual is exposed to an infection. So, vaccinated cattle are equally likely to be exposed to *Brucella abortus* (and test positive), but vaccinated cattle may be less likely to abort their calves following exposure to the disease. However, protecting the cattle from future morbidity does not help the rancher with respect to the state agencies who are still required to quarantine or slaughter the exposed (but less infectious) herds.

History of Bison in Yellowstone and Grand Teton National Parks

After the bison slaughter of the late 1800's, an active bison restoration program was initiated in YNP in 1902 when 21 animals were released into the Park from two semi-domestic herds. Brucellosis was first detected in YNP bison in 1917, and it is likely to have been introduced from cattle to bison just prior to that time around the Buffalo Ranch area of the Lamar Valley where a few milk cows were kept until 1919. The bison population grew from the initial couple dozen individuals in 1902 to over 1000 bison by 1930. From 1930 to 1950 Yellowstone bison were translocated to many sites throughout North America. In 1936, park managers relocated 71 bison from the northern range of YNP to the central region to redistribute bison to formerly occupied range within the park. The central herd then increased until the late 1950's. Between 1950 and the mid 1960's an active brucellosis eradication program was implemented in concert with a program to actively reduce abundance.

By the mid 1960's biologists felt that the brucellosis eradication program would nearly eradicate the bison population and made recommendations for YNP to switch to an ecological process management policy. By the mid 1990s the bison population was over 4000 individuals and increasingly likely to be moving outside the boundary of the National Park during the winter resulting in the reinstitution of bison removals, but this time the actions occurred along the borders. Several large-scale removals have occurred affecting over 1000 individuals in 1996, 2006 and 2008. Bison were also reintroduced to the Grand Teton National Park (GTNP) in 1948. This small herd was found to be infected with brucellosis in 1963, but through testing and removing positive individuals and vaccinating calves the herd was determined to be brucellosis-free in 1967. After an initial escape of these bison from a captive area nine of these bison were allowed to roam-free in 1970. In 1990 the herd numbered 123. By 2008 the herd was over 800, and managers were attempting to increase the hunting pressure on bison to reduce population abundance. Most of these bison spend the winter months on the National Elk Refuge just outside of Jackson, Wyoming where they are supplementally fed.



▲ FIGURE 6.2 Elk-cattle interactions may occur mostly at night. Points represent GPS locations from one elk every 30 minutes. Dark circles are during the night. Yellow circles are during the day. Red areas and white crosses are historic cattle properties and haystacks, respectively. (Paul Cross, USGS)

Current Research

Despite the importance of understanding the contact patterns of elk and cattle, very little work has been done on the issue until recently. In collaboration with Wyoming Game and Fish Department, we have been deploying collars on elk around the Wyoming feedgrounds. These collars use Global Position Systems (GPS) to communicate with satellites and record locations at specific time intervals. In our case these collars record a position every 30 minutes; after a year the collars are programmed to automatically release from the neck of the individual allowing us to collect the collar without recapturing the individual. GPS collars allow us to look at fine scale patterns in both space and time. For example, preliminary data show that elk may be going onto private land at night and concentrating on irrigated pastures indicating that elk-cattle contact may be more frequent than we might have guessed based upon daytime observations. We are also using satellite imagery to investigate how snowpack affects the artificial feeding season for elk. In previous studies we found that feedgrounds that feed longer into the spring have a higher prevalence of brucellosis. Meanwhile, the population size at the feedground appears to explain very little about the seroprevalence on the site. For example, the elk on the National Elk Refuge have the lowest seroprevalence of any feedground (around 10%) but have around ten times more elk than most of the Wyoming feedgrounds. The NER probably has a low prevalence of brucellosis because it stops feeding before most transmission occurs. Using this information Wyoming Game and Fish Department is trying to end the feeding season earlier than normal on several feedgrounds. However, there is a concern that shorter feeding seasons may result in elk moving from the feedgrounds to private properties where they may infect cattle. By combining satellite imagery data with GPS collar data we hope to generate a picture of which areas melt first and where the elk are likely to go once the feeding season ends.

The substantial support for a vaccination program within the GYE has directed much of the recent research regarding brucellosis in bison. To date, researchers have focused on three related aspects of vaccination: whether the use of strain RB51 *Brucella abortus* vaccine is safe for use in bison, whether it is safe if non-target species were to encounter the vaccine in the wild, and in quantifying any differences between vaccinates and non-vaccinates regarding their ability to mount an effective immune response to brucellosis. Research has shown that this vaccine is safe when used in bison and will not present any unusual clinical symptoms for non-target species that may encounter vaccine indirectly through exposure to vaccinated bison. However, there are differing results and professional opinions among brucellosis

experts regarding the level of protective immunity that a vaccinated Yellowstone bison would exhibit. With clinical experiments completed, the next step is to conduct some experimental trials to measure the response to vaccination by Yellowstone bison in the field.

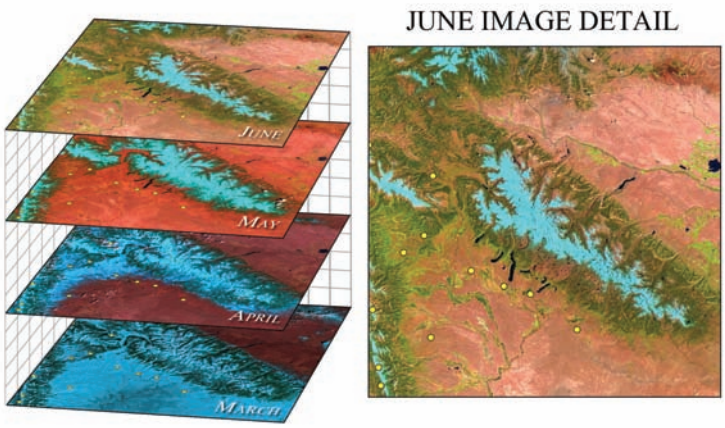
Unanswered Questions and Future Directions

"There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know." (Donald Rumsfeld Feb. 12, 2002, Department of Defense news briefing)

Although Mr. Rumsfeld was cryptically describing issues of national defense, his statement is applicable to many ecological and wildlife management issues. It is the unknown connections in ecological systems that often result in unintended consequences. For example, the release of an insect in Montana to control spotted knapweed (a non-native weed) resulted in elevated levels of hantavirus in mice. These 'unknown unknowns' are pervasive in ecology, but also troubling are the 'known unknowns'.

There are many uncertainties about how brucellosis is maintained in the wildlife of the GYE, how best to manage the risk of interspecies transmission, and whether elimination of the disease from the wildlife reservoir is technically feasible. These issues are all topics of ongoing research. In particular, transmission is very difficult to estimate in either human or wildlife systems. For brucellosis it remains unclear how often bison transmit brucellosis to neighboring elk and vice versa. If transmission between the species is rare, then the dynamics of brucellosis infection in each species are likely to be independent of one another. In other words, a decrease in the prevalence of brucellosis in bison may not result in a corresponding decrease in elk. Research on the genetic composition of *Brucella abortus* strains in elk and bison may help to unravel this question.

The management of brucellosis, like so many other issues in the Greater Yellowstone Ecosystem, is complicated by political, ecological, and economic factors. In addition to biological uncertainty, the social tolerance for ongoing intensive management through mass wasting of wildlife resources (whether elk or bison) is also uncertain. Testing to identify seropositive individuals so that they could be eliminated from populations is a proven strategy in domestic stock. Applying this type of management in a wildlife conservation arena is unlikely to occur for logistical, financial, and sociological reasons. Consequently, the social and political debate will have to resolve the issue of whether brucellosis elimination is worth the price or whether an effective risk management strategy could be acceptable with changes in the disease regulations. Such changes could benefit both the agricultural and conservation communities. The GYE is one of the fastest growing regions on the US and one where most constituents have a common goal of maintaining open space and healthy wildlife populations. Researchers and decision makers will need to continue to ask focused questions that systematically resolve scientific uncertainties. To fail to do so places the ranching and conservation constituencies arguing their own ideology unchecked by a common science based reality.



▲ FIGURE 6.3 Images of vegetation and snowcover from the Landsat 5 satellite sensors. Blue indicates snow. Red indicates soil moisture, and green indicates chlorophyll absorption (i.e. vegetative growth). Elk feedgrounds are represented by yellow circles. Images like these allow researchers to investigate how snowcover and vegetation affect the timing and routes of elk migration to and from summer ranges. (Paul Cross, USGS)