Montana Fish, Wildlife & Parks

National Park Service
U.S. Department of the Interior
Yellowstone Center for Resources
Yellowstone National Park

BRUCELLOSIS SCIENCE REVIEW WORKSHOP

PANELISTS' REPORT

2013

Panel participants: (left to right) Merete Aanes, Mary Ellen Wolfe, Michael Miller, Vanessa Ezenwa, Peter Nara, Steve Olsen, John Cox, Terry Kreeger, Anna Jolles, Keith Aune, Dave Hallac, Pat Flowers

2013
Brucellosis in Yellowstone Bison
Science Review & Workshop

FEBRUARY 26-28, 2013 ◆ CHICO HOT SPRINGS RESORT ◆ PRAY, MT

Credits for photos: Where not otherwise indicated, photos are courtesy of the National Park Service.

BACKGROUND

The bison population that resides in Yellowstone National Park is chronically infected with brucellosis (*Brucella abortus*), which may induce abortions or the birth of non-viable calves and can be transmitted between bison, elk, and cattle. In most years, bison will migrate to low elevation habitat outside the park boundaries in Montana to search for forage during winter and spring, where they could potentially come into contact with cattle. The risk of brucellosis transmission from bison to cattle under current conditions appears to be low yet tangible, and is understandably of concern because such transmission could result in economic loss to livestock producers from slaughtering infected animals, increased disease testing requirements, and decreased marketability of their cattle. This risk has reduced tolerance for bison in the greater Yellowstone ecosystem and elsewhere—thereby impeding the conservation of plains bison. Therefore, the primary issue motivating discussions about brucellosis reduction in Yellowstone bison center on the risk of brucellosis transmission to cattle in Montana.

ISSUE & NEED

Bison and elk in the Greater Yellowstone Ecosystem have long been infected with brucellosis. The management of this disease has been a contentious issue for decades, especially for Yellowstone bison. In years when bison migrate to low elevation habitat outside Yellowstone National Park in Montana to search for forage during winter and spring, there is a small but tangible risk of brucellosis transmission from bison to cattle, which could result in economic loss to local livestock producers.

In 2000, the federal government and the State of Montana agreed to a bison management plan that established guidelines for cooperatively managing the risk of brucellosis transmission from bison to cattle. This Interagency Bison Management Plan (IBMP) emphasized maintenance of a wild, free-ranging bison population while protecting the livestock economy in Montana. To date, no documented transmission of brucellosis from Yellowstone bison to cattle has occurred. This success appears due, at least in part, to successful efforts by federal and state agencies to maintain separation between cattle and bison. However, management interventions that have removed large numbers of bison yielded neither a measurable decrease in brucellosis exposure or infection rates within the bison population nor an appreciable change in perceptions about the risk of transmission to cattle. Consequently, management has emphasized spatial-temporal separation of cattle and bison, which has thus far successfully prevented brucellosis transmission between these species.

Vaccination of bison has been proposed as the primary method for reducing the level of brucellosis infection. Because few eligible bison (calves, yearlings) migrate to boundary capture facilities during most winters, little progress has been made on the vaccination efforts envisioned in the bison management plan. Furthermore, a recent evaluation of whether to vaccinate free-ranging bison inside Yellowstone National Park using a rifle-delivered biodegradable bullet with a vaccine payload revealed many uncertainties that would likely limit a significant reduction in disease prevalence and could have unintended adverse effects on bison.

The National Park Service and Montana Fish, Wildlife & Parks remain committed to the suppression of brucellosis in a manner that is aligned with bison conservation. In light of limited and sometimes conflicting information on "best" prospective approaches for managing brucellosis in free-ranging bison, however, these agencies sought an independent evaluation of current scientific knowledge and assessment of suggested management approaches.

APPROACH

To this end, a team of experts that do not work directly on the issue of brucellosis in Yellowstone bison (**Appendix A**) were invited to a workshop to review and evaluate the current science and integrate that science into feasible disease management approaches that consider the interests of all stakeholders. David Hallac (Yellowstone National Park) and Pat Flowers (Montana Fish, Wildlife & Parks) were appointed to serve as co-chairs on the panel, with the role of helping lead discussions among the eight panelists.

The facilitated workshop was held at Chico Hot Springs Resort in Pray, Montana, on February 26-28, 2013. On the first day, presentations were provided to workshop panelists that communicated the perspectives of stakeholders and the relevant science regarding host ecology, brucellosis dynamics, and disease management practices; panelists also reviewed and considered other published materials in the course of formulating their recommendations (**Appendix B**). Panelists spent the second and third days addressing specific questions based on the information presented and developing their recommendations, with deliberations concluding mid-day on February 28. The entire workshop was open to the public. Although the public did not participate in the panelists' discussions, members of the public did have opportunities to offer comments to the panel at the end of each day of the workshop. (**Appendix C**)

The panelists were charged with evaluating current brucellosis science and providing consensus-based conclusions and recommendations in a brief report to be finalized after the workshop. The panelists were also asked to limit their discussions and recommendations to the current areas of the IBMP and management practices within those areas. Specifically, the sponsors requested focused attention on:

- the state of and efficacy of ongoing brucellosis suppression activities
- the feasibility of significantly suppressing the disease in bison
- the likelihood that disease suppression will result in more tolerance for bison and advance bison conservation
- the potential impacts of disease suppression on bison conservation, ecology and wildlife viewing in the park;
- the pros and cons of implementing operational vaccination programs, to include hand vaccination at capture

facilities and remote vaccination (i.e., without capture)
- a recommended course of action regarding research and development to suppress brucellosis in bison.

A workshop charter described the purpose, clarified the responsibilities and authority of various participants, described the role of the public, and proposed a decision making process with preliminary ground rules to guide the process.

The panel arrived at their conclusions and recommendations by consensus. In this context, consensus was defined as a general agreement or outcome of a group decision-making process that most participants could live with. Though the group strove for unanimity, they retained the option of choosing to settle for an agreement that had support of almost all members.

The organizers' intent was that conclusions and recommendations from the panel would be considered by the National Park Service in decision-making on the potential implementation of future vaccination programs, and that the workshop report also would inform short- and long-term adaptive management decisions on and strategies for disease management activities associated with the IBMP. Information provided by the panel and presenters also may be used in the development of future bison management plans.

CONSENSUS PANEL CONCLUSIONS

On the merits and need for remote vaccination of free-ranging bison: Best available data does not support that remote vaccination of bison with the currently available vaccines will be an effective tool for suppressing brucellosis in wild bison to a level that changes the IBMP management strategies. Available data also suggest remote vaccination will be a very cost ineffective tool for preventing brucellosis spillover to cattle.

Our rationale for this conclusion was as follows: Disease dynamic models (e.g., Ebinger presentation) suggest reducing brucellosis prevalence in bison will at best be difficult and expensive – even assuming an ideal (but presently unobtainable) vaccine with 100% efficacy, prevalence might be suppressed to ~30% prevalence over 30 years with an annual investment of $300,000 $500,000. Despite substantial effort and investment, we doubt that this forecasted outcome would change the overall brucellosis management framework because tolerance of bison in the wider landscape would be unlikely to change even with such reduction and thus adaptive spatial-temporal management will have to continue regardless. Moreover, when uncertainties in process data and management (e.g., Hobbs presentation) are taken into account the likelihood of achieving this level of prevalence reduction is low (~3%).

At this time, we do not anticipate that a vaccination program in bison will substantially reduce the need for spatial-temporal separation of the bison and cattle, nor do we believe vaccination of bison would be an efficient use of resources. Our assessment could change with advances in technology (e.g., availability of a much more effective vaccine that could be delivered more practically), but we are not aware of any such advances becoming available to managers in the foreseeable future. To date, adaptive management of contact between cattle and bison in the IBMP area appears to have effectively prevented interspecies transmission of brucellosis. Spatial-temporal separation of these two species has effectively precluded such transmission despite relatively high seroprevalence in bison. Consequently, seroprevalence in bison does not seem to be a good predictor of brucellosis transmission risk from bison to cattle under the present management plan. It appears reasonable to assume that reducing seroprevalence through vaccination (or some other means) would have an effect on the risk of brucellosis transmission among bison, but no experimental field data exist to support that assumption.

On the potential ecological impacts of remote vaccination: In addition to the foregoing main conclusion that an aggressive remote vaccination campaign for free-ranging bison cannot be justified based on available data, we also discussed other potential collateral consequences of such a program. Our distilled summary of this discussion is as follows:

- We anticipate that remote vaccination would have behavioral impacts on bison (e.g., reduced tolerance of people, vehicles, etc.).
- Reduced tolerance for humans and vehicles could lead to shifts in the spatial distribution of bison with resulting effects on landscapes used more or less by bison.
- Reduced tolerance for humans and vehicles also could have impacts on opportunity for visitors to observe bison and could change how bison react to visitors.
- Changes in bison behavior and distribution also could have secondary impacts on predator-prey relationships (e.g., increase pressure on other species) and on scavenger relationships.
- If vaccination were successful in reducing brucellosis in bison, then the net demographic effect would be to increase the bison population (by reducing abortions and increasing annual birth rate). Because it is unlikely that vaccination would eliminate brucellosis completely, we anticipate that such an increase in bison numbers could increase the efforts and fiscal expenditures necessary to maintain effective spatial-temporal separation of bison and cattle.

On the use of culling in disease and bison population management: Control of the bison population size will most likely include culling or removal, along with hunting, as the main management tools. Past and current culling practices (which have been largely nonselective and opportunistic) have not had an apparent effect on reducing overall bison herd seroprevalence (around 50%). We recognize the potential to use culling as a tool for both interspecies disease risk management and bison population control.

On the use of fertility control in disease and bison population management: To achieve the current goals of the disease management plan, intervention with contraception is not needed. However, we acknowledge that fertility control could become a tool for disease control if treated females returning to reproductive status are no longer infectious despite exposure to brucellosis. The available data are insufficient to make a judgment at this time, but we encourage continuation of ongoing research in this area. Experimental results should be combined with modeling to scale contraception effects up to the population level and evaluate this as an alternative disease control approach.

Beyond considering the technical aspects of using fertility control in disease and bison population management, we recognize a number of other questions will remain: Is this approach practical? Cost effective? Ecologically appropriate? Socially and culturally tolerable? We regarded these questions as beyond the scope of our workshop assignment, but recognize the need for further thoughtful discussion. There are insufficient data to determine practicality and cost effectiveness at this time, but these could be revisited once modeling and pilot field applications have taken place. Social and ecological impacts likely will depend on the extent and nature of management application.

On other potential adaptive changes and management considerations: In the course of our discussions, a number of other relevant points on brucellosis and bison population management were raised. We offer these for further consideration or exploration as deemed appropriate:

- In circumstances where culling is primarily intended to lower interspecies transmission risk between bison and cattle, culling efforts could focus on selectively targeting animals most likely to be infectious (e.g., Treanor, et al. 2011). In circumstances where culling is primarily being applied for population control, approaches that minimize genetic and demographic consequences (by emulating randomness with respect to brucellosis exposure status) and do not compromise bison population viability could be emphasized.
- A systems thinking approach to both bison population and brucellosis management may be most beneficial. (Nishi 2010)---a ABS/WCS report available.
- We encourage efforts to improve broader understanding factors changing/affecting brucellosis in the GYA (e.g., the role of elk in persistence and spread).
- A GIS-based risk map of brucellosis could be useful in guiding management efforts.
- In light of recurrent questions about the use and meaning of serology data, a better metric (that also can be applied to elk) is needed for tracking brucellosis epidemic dynamics in bison.
- Where feasible, we encourage working with other government entities to access and test improved remote sensing technologies for assessing winter habitat quality & distribution, risk, mitigation options, or other landscape-level factors that may contribute to success or failure of ongoing disease management efforts.
- Within the Greater Yellowstone Area, consider developing and implementing a survey of users about management of bison (and, where applicable, potentially use some form of fee discount as an incentive for completing the survey).
- A structured scenario exercise (for IBMP managers) involving future changes relating to land use/climate change/societal or economic changes may be beneficial. In particular, we encourage managers to explore the adaptive management part of their plans and look at opportunities for adaptive co-management.
- Managers should (re)examine opportunities to work with agriculture partners to address management and land use issues relating to cattle in the GYA.
- Although some activity in this regard already may have been undertaken, given available data and recurrent suggestions that the role of elk in interspecies brucellosis transmission risk has perhaps been underestimated, IBMP managers may need to further consider the risk from brucellosis in elk. In order to foster more comprehensive adaptive risk management, a relevant plan combining efforts to manage risk for both bison and elk reservoirs appears warranted; such planning may identify logical changes to improve overall management efficacy (e.g., by shifting some resources from bison to elk management).
- Efforts to optimize current management activities should be encouraged. We recognize the benefits of maintaining established quarantine facilities as a means of retaining the option to move bison.
- Given the limitations of traditional vaccines in controlling brucellosis in wildlife, new approaches and insights for vaccination (of either wildlife or livestock) should be encouraged. To be useful at a landscape level, such approaches likely would need to involve more passive or natural delivery, would need to be applicable at landscape levels yet respective of jurisdictional policies and limitations, and would need to be cost-effective. Once fully developed, candidate vaccination strategies meeting such criteria could be considered for adaptive incorporation into ongoing disease management programs at some point in the future.
- If brucellosis eradication in bison remains a long-term goal, then further consideration may need to be given toward creating new herds in other places of the U.S. with "disease-free" animals for use in augmenting or replacing resident bison.
- An incentive-based approach for increasing bison tolerance relating to brucellosis could be explored. Managers could investigate creative incentives for stakeholders to increase tolerance for bison. (Example questions to explore: How can enhancing bison conservation be viewed as being in the best interest of stakeholders? Why are elk and bison viewed differently with respect to brucellosis risk and management in Montana?)
- Business opportunities (e.g., partnerships for bison meat) may deserve exploration by IBMP managers.
- Analyze and change (as indicated) incentives for communities adjacent to conservation areas to give people a stake in conservation (e.g., hunting, bison ranching, ecotourism, etc.).
- Work with other land protection agencies to develop understanding of biologic and social carrying capacity of land adjacent to Yellowstone.

- Explore public attitudes towards tribal hunting of bison within the park.
- Web, paper-based, and more interactive education and communication about brucellosis may be useful in improving public understanding about the issues surrounding this disease and its management.

FUTURE RESEARCH NEEDS

The final area of our discussion focused on potentially beneficial topics for additional research. We used a straw ranking vote to identify a handful of "high"- and "medium"-priority topics from among the more exhaustive list we originally generated, as follows:

HIGH-PRIORITY RESEARCH TOPICS

- A. Cost/benefit analyses of different brucellosis management options and goals (e.g., bison vs. cattle vaccination; risk reduction vs. suppression vs. eradication, etc.).
- B. Cost/benefit analysis of producing a more effective brucellosis vaccine for use in domestic livestock (mainly cattle) vs. a more effective vaccine in wild bison or elk.
- C. Improve understanding of genetic effects of culling bison based on disease management parameters (e.g., serology data).
- D. Characterize and understand human values and attitudes towards conservation of wildlife affected by brucellosis to improve effective exchange of knowledge for collaborative decision making in the GYA.

MEDIUM-PRIORITY RESEARCH TOPICS

- E. Determine efficacy of remote/syringe vaccine delivery in wild bison.
- F. Identify or develop less invasive or disruptive vaccine delivery technologies.
- G. Modeling to evaluate contraception for disease control, incorporating data from the ongoing experimental study regarding contraceptives and brucellosis in bison.
- H. Explore new molecular bacterial genomics & new vaccine science and technology.
- I. Characterize bison behavior and social dynamics and their relationships to brucellosis transmission.

APPENDIX A

PANELISTS

KEITH AUNE
Wildlife Conservation Society

Keith Aune MS.C. is Senior Conservationist, Wildlife Conservation Society. Keith received his Masters Degree in Fish and Wildlife Management from Montana State University. Keith was previ-ously employed by the Montana Department of Fish, Wildlife and Parks (MFWP) where he served for 31 years in various capacities. He conducted field and laboratory research on black and grizzly bears, wildlife diseases, wolverine, lions, and bison. Keith worked on the research and management of Yellowstone bison for 10 years. While at his last post with MFWP he served as the Chief of Wildlife Research and directed multiple research projects across Montana as well as supervising the annual harvest survey and the Wildlife Research Laboratory staff. Since coming to WCS in 2007, Keith has worked on several issues including the WCS Wildlife Corridors Initiative, the American Bison Society Initiative and senior advisor to the Wildlife Action Opportunities Fund. In 2011 he became director for the WCS-North American Bison Program and the American Bison Society initiative. He is currently chair of the IUCN Bison Specialist Group for North America.

JOHN COX
University of Kentucky

John J. Cox is an adjunct assistant professor of wildlife and conservation biology at the University of Kentucky, Department of Forestry. His research attempts to find practical solutions to biodiversity conservation and management problems, and address interesting broader ecological questions where possible. Research topics have primarily focused on the population and disease ecology, conservation and management of terrestrial vertebrates, as well as general biodiversity assessment and monitoring. Other research has included work on invasive and native plant species in Kentucky, human dimensions in wildlife, and conservation planning and implementation. He teaches an undergraduate conservation biology course, graduate field courses about highly biodiverse U.S. ecosystems, and a graduate seminar series in vertebrate ecology and management. He has advised or co-advised nearly two dozen graduate students, coauthored over 40 scientific papers, and served on advisory panels for NGOs and state and federal wildlife agencies.

VANESSA EZENWA
University of Georgia

Vanessa Ezenwa is an associate professor at the University of Georgia with appointments in the Odum School of Ecology and the Department of Infectious Diseases, College of Veterinary Medicine. Her research focuses on the ecology of infectious diseases in wild animal populations. She uses techniques from ecology, parasitology, genetics, immunology and endocrinology to study associations between wild ungulates and their parasites and pathogens in sub-saharan Africa and western Montana. Dr. Ezenwa received a BA in Biology from Rice University and a PhD in Ecology & Evolutionary Biology from Princeton University. She was a postdoctoral research associate studying West Nile virus ecology at the US Geological Survey before moving to the University of Montana, Missoula as an assistant professor in 2005. She joined the faculty of the University of Georgia in 2010.

ANNA JOLLES
Oregon State University

Dr. Anna Jolles is a disease ecologist and epidemiologist at Oregon State University, where she has appointments in the College of Veterinary Medicine and the Department of Zoology. She studied Physics at Freiburg University in Germany and Biology at Oxford University, England. She came to the United States as a graduate student and earned her PhD from Princeton University in Ecology and Evolutionary Biology. Dr. Jolles studies infectious diseases in wild mammals. Her current research investigates questions such as these: *How do gastrointestinal parasites affect TB dynamics in African buffalo? Does feline AIDS mediate what infections occur in African lions? How does intensive forest management affect the prevalence of Hanta virus in small mammals? What factors explain variation among species in their propensity for transmitting infections?* Dr. Jolles and students routinely collaborate with land and wildlife management agencies to conduct their field work, and use mathematical models to interpret the resulting data.

TERRY KREEGER

Wyoming Game & Fish

Terry J. Kreeger, State Wildlife Veterinarian for the Wyoming Game and Fish Department, holds Bachelor degrees in Journalism and Veterinary Science, a Masters degree in Wildlife Biology, a Doctor of Philosophy degree in Wildlife Management and a Doctor of Veterinary Medicine degree. He is an adjunct professor at the University of Wyoming (Veterinary Sciences) and the University of Minnesota (Fisheries and Wildlife). His research interests include wildlife diseases, wildlife capture and anesthesia, physiology and behavior, and animal contraception. He has captured wildlife and trained others to capture wildlife throughout North America and in Russia, Africa, and Asia. He has conducted research in the epidemiology, ecology, and management of brucellosis in elk and bison in the Greater Yellowstone Area (GYA) for almost two decades. This research included surveillance, elk movement and calving patterns, vaccination, contraception development, and diagnostic development.

MICHAEL MILLER

Colorado Parks & Wildlife

Michael W. Miller has served as a wildlife veterinarian and staff scientist for the Colorado Division of (Parks and) Wildlife since 1989. In that capacity, he has studied a variety of infectious diseases and their implications for managing and conserving native wildlife resources in Colorado and elsewhere. Dr. Miller holds a Bachelor of Science degree in Zoology with a minor in Biochemistry, a Doctor of Veterinary Medicine degree, and a Doctor of Philosophy degree in Wildlife Biology. Because his entire career has been spent working for a state wildlife management agency, Dr. Miller's research has emphasized work on applied questions directed toward understanding and controlling (to the extent possible) important wildlife disease problems. Much of his current research is focused on diseases of wild ruminants including respiratory disease in bighorn sheep and chronic wasting disease of cervids, as well as on controlling plague in prairie dogs and associated small mammal species.

PETER NARA

Biological Mimetics, Inc.

Dr. Nara holds the Endowed Eugene Lloyd Chair Professorship in Vaccinology at Iowa State University (ISU). He is also the founding Director of ISU's Center for Advanced Host Defense, Immunobiotics and Translational Comparative Medicine, and the CEO and co-founder of Bio-logical Mimetics, Inc. He holds a combined Doctor of Veterinary Medicine and a Ph.D. (retro-virology/oncogenesis) from the Ohio State University. Dr Nara's scientific contributions include over 21 book chapters and 173 scientifically peer-reviewed publications. His comparative medical interests are to more fully understand how innate and acquired immune systems are sculpted and bias the development of protective long-lasting responses to infectious pathogens. Diverse professional commitments include serving on various national planning and research panels, and a 2007 appointment to the board the National Foundation for Infectious Diseases in Washington D.C.

STEVE OLSEN

Agricultural Research Service

Dr. Olsen is a brucellosis researcher and administrator in the Infectious Diseases of Livestock Research Unit at the National Animal Disease Center in Ames, Iowa. Dr. Olsen has a Doctorate in Veterinary Medicine from Kansas State University, a Ph.D. in physiology from Kansas State University, and is board certified in veterinary microbiology by the American College of Veterinary Microbiologists. For more than 20 years, the focus of Dr. Olsen's research has been on brucellosis in domestic livestock and wildlife, with particular emphasis on development of vaccines and diagnostics, and implementation of control programs. He has contributed to body of work that led to the licensure and initiation of the B. abortus strain RB51 vaccine in the United States and eventual use in many other countries. He is also characterized immunologic differences between species in responses to brucellosis vaccines, and has authored more than 90 peer-reviewed publications on brucellosis.

Appendix B

BACKGROUND MATERIAL

Included below are abstracts or summaries of some of the published literature reviewed by panelists in the course of formulating opinions on the questions addressed during this workshop.

BRUCELLOSIS MANAGEMENT

MANAGEMENT OF YELLOWSTONE BISON AND BRUCELLOSIS TRANSMISSION RISK – EXPECTATIONS AND REALIZATIONS.

WHITE, P.J., WALLEN, R.L., GEREMIA, C., TREANOR, J.J. & BLANTON, D.W. (2011)

Abstract: Yellowstone bison (*Bison bison bison*) are managed to reduce the risk of brucellosis (*Brucella abortus*) transmission to cattle while allowing some migration out of Yellowstone National Park to winter ranges in Montana. Intensive management near conservation area boundaries maintained separation between bison and cattle, with no transmission of brucellosis. However, brucellosis prevalence in the bison population was not reduced and the management plan underestimated bison abundance, distribution, and migration, which contributed to larger risk management culls (total >3000 bison) than anticipated. Culls differentially affected breeding herds and altered gender structure, created reduced female cohorts, and dampened productivity. The ecological future of plains bison could be significantly enhanced by resolving issues of disease and social tolerance for Yellowstone bison so that their unique wild state and adaptivecapabilities can be used to synergize the restoration of the species. We recommend several adaptive management adjustments that could be implemented to enhance the conservation of plains bison and reduce brucellosis infection. These findings and recommendations are pertinent to wood bison (*Bison bison athabascae*), European bison (*Bison bonasus*), and other large ungulates worldwide that are managed using best practices within a risk framework.

Biological Conservation, 144, 1322–1334

APPLYING AND ECOSYSTEM APPROACH TO BRUCELLOSIS CONTROL: CAN AN OLD CONFLICT BETWEEN WILDLIFE AND AGRICULTURE BE SUCCESSFULLY MANAGED?

BIENEN, L. & TABOR, G. (2006)

Abstract: Brucellosis is a hotly debated topic in the western United States. For decades, this disease has pitted conservationists against ranchers, as well as against federal and state government agencies, particularly in Montana and Wyoming. Bison and elk are the primary wildlife disease reservoirs, and cattle the primary species of agricultural concern. Here, we briefly summarize the disease's etiology and ecology in wildlife and discuss recent developments in the sociopolitical landscape and in scientific research that could result in improved management. Applying some key principles of ecosystem management is crucial to improving brucellosis control in wildlife.

Frontiers in Ecology and the Environment, 4, 319-327

BRUCELLOSIS MODELING (FOR DISEASE CONTROL)

SIMULATING STERILIZATION, VACCINATION, AND TEST-AND-REMOVE AS BRUCELLOSIS CONTROL MEASURES IN BISON

EBINGER, M., CROSS, P. WALLEN, R., WHITE, P.J. & TREANOR, J. (2011)

Abstract: Brucella abortus, the causative agent of bovine brucellosis, infects wildlife, cattle, and humans worldwide, but management of the disease is often hindered by the logistics of controlling its prevalence in wildlife reservoirs. We used an individually based epidemiological model to assess the relative efficacies of three management interventions (sterilization, vaccination, and test-and-remove). The model was parameterized with demographic and epidemiological data from bison in Yellowstone National Park, USA. Sterilization and test-and-remove were most successful at reducing seroprevalence when they were targeted at young seropositive animals, which are the most likely age and sex category to be infectious. However, these approaches also required the most effort to implement. Vaccination was less effective (even with a perfect vaccine) but also required less effort to implement. For the treatment efforts we explored (50–100 individuals per year or 2.5–5% of the female population), sterilization had little impact upon the bison population growth rate when selectively applied. The population growth rate usually increased by year 25 due to the reduced number of Brucella-induced abortions. Initial declines in seroprevalence followed by rapid increases (>15% increase in 5 years) occurred in 3–13% of simulations with sterilization and test-and-remove, but not vaccination. We believe this is due to the interaction of superspreading events and the loss of herd immunity in the later stages of control efforts as disease prevalence declines. Sterilization provided a mechanism for achieving large disease reductions while simultaneously limiting population growth, which may be advantageous insome management scenarios. However, the field effort required to find the small segment of the population that is infectious rather than susceptible or recovered will likely limit the utility of this approach in many free-ranging wildlife populations. Nevertheless, we encourage scientists and policy makers to consider sterilization as part of a suite of available brucellosis management tools.

Ecological Applications, 21, 2944–2959

VACCINATION STRATEGIES FOR MANAGING BRUCELLOSIS IN YELLOWSTONE BISON

TREANOR, J.J., JOHNSON, J.S., WALLEN, R.L., CILLES, S., CROWLEY, P.H., COX, J.J., MAEHR, D.S., WHITE, P.J., PLUMB, G.E. (2010)

Abstract: Concerns over migratory bison (*Bison bison*) at Yellowstone National Park transmitting brucellosis (*Brucella abortus*) to cattle herds on adjacent lands led to proposals for bison vaccination. We developed an individual-based model to evaluate how brucellosis infection might respond under alternate vaccination strategies, including: (1) vaccination of female calves and yearlings captured at the park boundary when bison move outside the primary conservation area; (2) combining boundary vaccination with the remote delivery of vaccine to female calves and yearlings distributed throughout the park; and (3) vaccinating all female bison (including adults) during boundary capture and throughout the park using remote delivery of vaccine. Simulations suggested Alternative 3 would be most effective, with brucellosis seroprevalence decreasing by 66% (from 0.47 to 0.16) over a 30-year period resulting from 29% of the population receiving protection through vaccination. Under this alternative, bison would receive multiple vaccinations that extend the duration of vaccine protection and defend against recurring infection in latently infected animals. The initial decrease in population seroprevalence will likely be slow due to high initial seroprevalence (40–60%), long-lived antibodies, and the culling of some vaccinated bison that were subsequently exposed to field strain Brucella and reacted positively on serologic tests. Vaccination is unlikely to eradicate B. abortus from Yellowstone bison, but could be an effective tool for reducing the level of infection. Our approach and findings have applicability world-wide for managers dealing with intractable wildlife diseases that cross wildlife–livestock and wildlife–human interfaces and affect public health or economic well-being.

Vaccine, 28S, F64-F72

WILDLIFE–LIVESTOCK CONFLICT: THE RISK OF PATHOGEN TRANSMISSION FROM BISON TO CATTLE OUTSIDE YELLOWSTONE NATIONAL PARK

KILPATRICK, A.M., GILLIN, C.M. & DASZAK, P. (2009)

Summary: 1. Interactions between wildlife and domestic livestock have created conflict for centuries because of pathogen transmission, competition for space and food, and predation. However, the transmission of pathogens from wildlife to domestic animals has recently gained prominence, including H5N1 avian influenza from wild ducks to poultry, bovine tuberculosis from badgers to cattle, and brucellosis from elk and bison to cattle. The risk of transmission of *Brucella abortus* (the causative agent of brucellosis) from bison (Bison bison) to cattle around Yellowstone National Park (YNP) is a hotly debated topic and an important conservation issue. 2. Here we use a model to integrate epidemiological and ecological data to assess the spatiotemporal relative risk of transmission of Brucella from bison to cattle outside YNP under different scenarios. 3. Our risk assessment shows that relative risk is spatially and temporally heterogeneous with local hotspots, shows a highly skewed distribution with predominantly low risk, and is strongly dependent on climate and the abundance of bison. We outline two strategies for managing this risk, and highlight the consequences of the current adaptive management plan. 4. Synthesis and applications. Our results provide a detailed quantitative assessment of risk that offers several advantages over projections of numbers of bison leaving Yellowstone National Park. They suggest that risk could be effectively managed with lower costs, but that land use issues and the larger question of bison population management and movement outside the park might hinder the prospect of solutions that will please all stakeholders. More broadly, our work provides a model framework for quantifying the risk of wildlife–livestock pathogen transmission to guide management actions.

Journal of Applied Ecology, 46, 476–485

<u>BRUCELLOSIS IN ELK</u>

PROBABLE CAUSES OF INCREASING BRUCELLOSIS IN FREE-RANGING ELK OF THE GREATER YELLOWSTONE ECOSYSTEM

CROSS, P.C., COLE, E.K., DOBSON, A.P., EDWARDS, W.H., HAMLIN, K.L., LUIKART, G., MIDDLTON, A.D., SCURLOCK, B.M. & WHITE, P.J. (2010)

Abstract: While many wildlife species are threatened, some populations have recovered from previous overexploitation, and data linking these population increases with disease dynamics are limited. We present data suggesting that free-ranging elk (*Cervus elaphus*) are a maintenance host for Brucella abortus in new areas of the Greater Yellowstone Ecosystem (GYE). Brucellosis seroprevalence in free-ranging elk increased from 0–7% in 1991–1992 to 8–20% in 2006–2007 in four of six herd units around the GYE. These levels of brucellosis are comparable to some herd units where elk are artificially aggregated on supplemental feeding grounds. There are several possible mechanisms for this increase that we evaluated using statistical and population modeling approaches. Simulations of an age-structured population model suggest that the observed levels of seroprevalence are unlikely to be sustained by dispersal from supplemental feeding areas with relatively high seroprevalence or an older age structure. Increases in brucellosis seroprevalence and the total elk population size in areas with feeding grounds have not been statistically detectable. Meanwhile, the rate of seroprevalence increase outside the feeding grounds was related to the population size and density of each herd unit. Therefore, the data suggest that enhanced elk-

to-elk transmission in free-ranging populations may be occurring due to larger winter elk aggregations. Elk populations inside and outside of the GYE that traditionally did not maintain brucellosis may now be at risk due to recent population increases. In particular, some neighboring populations of Montana elk were 5–9 times larger in 2007 than in the 1970s, with some aggregations comparable to the Wyoming feeding-ground populations. Addressing the unintended consequences of these increasing populations is complicated by limited hunter access to private lands, which places many ungulate populations out of administrative control. Agency–landowner hunting access partnerships and the protection of large predators are two management strategies that may be used to target high ungulate densities in private refuges and reduce the current and future burden of disease.

Ecological Applications, 20, 278–288

VACCINATION STUDIES

EFFICACY OF DART OR BOOSTER VACCINATION WITH STRAIN RB51 IN PROTECTING BISON AGAINST EXPERIMENTAL BRUCELLA ABORTUS CHALLENGE

S. C. OLSEN AND C. S. JOHNSON. (2012)

Abstract: This study characterized the efficacy of the *Brucella abortus* strain RB51 vaccine in bison when delivered by single intramuscular vaccination (hand RB51), by single pneumatic dart delivery (dart RB51), or as two vaccinations approximately 13 months apart (booster RB51) in comparison to control bison. All bison were challenged intraconjunctivally in midgestation with 107 CFU of B. abortus strain 2308 (S2308). Bison were necropsied and sampled within 72 h of abortion or delivery of a live calf. Compared to nonvaccinated bison, bison in the booster RB51 treatment had a reduced ($P<0.05$) incidence of abortion, uterine infection, or infection in maternal tissues other than the mammary gland at necropsy. Bison in single-vaccination treatment groups (hand RB51 and dart RB51) did not differ ($P>0.05$) from the control group in the incidence of abortion or recovery of S2308 from uterine, mammary, fetal, or maternal tissues at necropsy. Compared to nonvaccinated animals, all RB51 vaccination groups had reduced ($P<0.05$) mean colonization or incidence of infection in at least 2 of 4 target tissues, with the booster RB51 group having reduced ($P<0.05$) colonization and incidence of infection in all target tissues. Our data suggest that booster vaccination of bison with RB51 enhances protective immunity against Brucella challenge compared to single vaccination with RB51 by hand or
by pneumatic dart. Our study also suggests that an initial vaccination of calves followed by booster vaccination as yearlings should be an effective strategy for brucellosis control in bison.

Clinical and Vaccine Immunology, 19, 886–890

DNA VACCINATION OF BISON TO BRUCELLAR ANTIGENS ELICITS ELEVATED ANTIBODY AND IFN-γ RESPONSES

CLAPP, B., WALTERS, N., THORNBURG, T., HOYT, T., YANG, X. & PASCUAL, D.W. (2011)

Abstract: *Brucella abortus* remains a threat to the health and well-being of livestock in states bordering the Greater Yellowstone Area. During the past several years, cohabitation of infected wildlife with cattle has jeopardized the brucellosis-free status of Idaho, USA; Wyoming, USA; and Montana, USA. Current livestock B. abortus vaccines have not proven to be efficacious in bison (Bison bison) or elk (Cervus elaphus nelsoni). One problem with the lack of vaccine efficacy may stem from the failure to understand wildlife immune responses to vaccines. In an attempt to understand their immune responses, bison were vaccinated with eukaryotic DNA expression vectors encoding the Brucella periplasmic protein, bp26, and the chaperone protein, trigger factor (TF). These DNA vaccines have previously been shown to be protective against Brucella infection in mice. Bison were immunized intramuscularly at weeks 0, 2, and 4 with bp26 and TF DNA vaccines plus CpG adjuvant or empty vector (control) plus CpG. Blood samples were collected before vaccination and at 8, 10, and 12 wk after primary vaccination. The results showed that bison immunized with bp26 and TF DNA vaccines developed enhanced antibody, proliferative T cell, and interferon-gamma (IFN-c) responses upon in vitro restimulation with purified recombinant

bp26 or TF antigens, unlike bison immunized with empty vector. Flow cytometric analysis revealed that the percentages of CD4+ and CD8+ T lymphocytes from the DNA-vaccinated groups were significantly greater than they were for those bison given empty vector. These data suggest that DNA vaccination of bison may elicit strong cellular immune responses and serve as an alternative for vaccination of bison for brucellosis.

Journal of Wildlife Diseases, 47, 501-510

PATHOGENESIS AND EPIDEMIOLOGY OF BOVINE BRUCELLOSIS

PATHOGENESIS OF BOVINE BRUCELLOSIS

CARVALHO NETA, A.V., MOL, J.P.S., XAVIER, M.N., PAIXÃO, T.A., LAGE, A.P. & SANTOS, R.L. (2010)

Abstract: Bovine brucellosis is one of the most important zoonotic diseases worldwide, and is of particular significance in developing countries. The disease, which results in serious economic losses due to late term abortion, stillborn and weakly calves, is caused by Gram negative coccobacilli bacteria of the genus Brucella. Lesions consist of necrotic placentitis and interstitial mastitis in pregnant cows, and fibrinous pleuritis with interstitial pneumonia in aborted fetuses and newborn calves. This article considers the pathogenesis of Brucella abortus and reviews the ability of the pathogen to invade phagocytic and nonphagocytic host cells, resist the acidified intraphagosomal environment, and inhibit phagosome–lysosome fusion. Significant aspects of innate and adaptive immunity against brucellosis are also discussed.

The Veterinary Journal, 184, 146-155

PATHOGENESIS AND EPIDEMIOLOGY OF BRUCELLOSIS IN YELLOWSTONE BISON: SEROLOGIC AND CULTURE RESULTS FROM ADULT FEMALES AND THEIR PROGENY

RHYAN, J.C., AUNE, K., ROFFE, T., EWALT, D., HENNAGER, S., GIDLEWSKI, T., OLSEN, S. & CLARKE, R. (2009)

Abstract: Our objective in this prospective study was to determine the natural course of *Brucella abortus* infection in cohorts of seropositive and seronegative, female bison (*Bison bison*) and their offspring in Yellowstone National Park (YNP) for 5 yr. We collected specimens from 53 adult females and 25 calves at least once and from 45 adults and 22 calves more than once. Annual seroconversion rates (negative to positive) were relatively high (23% for calves and juvenile bison, 6% in the total sample of adult female bison in our study, and 11% in the adult females that began the study as seronegatives). Antibody was not protective against infection, even for calves that passively received antibody from an infected mother's colostrum. Antibody levels stayed remarkably constant, with only a slow decline over time. We found only two seroconversions from a weak positive status to negative. Infected bison aborted and shed viable bacteria. Risk of shedding infective Brucella was highest for bison in the 2 yr following seroconversion from negative to positive. In one bison, we detected shedding for 3 yr following seroconversion. Regardless of serostatus of dams and neonates, most calves were seronegative by 5 mo of age. There was no relationship between the antibody status of the dam and the tendency of a calf to seroconvert to positive during the duration of the study.

Journal of Wildlife Diseases, 45, 729-739

ENVIRONMENTAL PERSISTENCE OF *BRUCELLA ABORTUS* IN THE GREATER YELLOWSTONE AREA

AUNE, K., RHYAN, J.C., RUSSELL, R., ROFFE, T.J. & CORSO, B. (2012)

Abstract: Bison (*Bison bison*) and elk (*Cervus elaphus*) of the Greater Yellowstone Area (GYA) are the last remaining reservoirs of bovine brucellosis (*Brucella abortus*) in the United States. An important factor in evaluating the risk of transmission to cattle is the persistence of bacteria and infectious birth materials shed on pastures where cattle graze. We selected 2 study areas near the northern and western boundaries of Yellowstone National Park (YNP) to determine the persistence of bacteria on fetal tissue, soil, and vegetation, and scavenging on infectious materials from birth and abortion sites. We performed 3 independent field experiments to determine: 1) persistence of *Brucella abortus* (RB51) purposely applied to fetal tissues, 2) scavenging of fetuses by native scavengers, and 3) natural contamination of birth or abortion sites in the GYA. Results from these field experiments established that Brucella bacteria can persist on fetal tissues and soil or vegetation for 21–81 days depending on month, temperature, and exposure to sunlight. Bacteria purposely applied to fetal tissues persisted longer in February than May and did not survive on tissues beyond 10 June regardless of when they were set out. Brucella abortus field strain persisted up to 43 days on soil and vegetation at naturally contaminated bison birth or abortion sites. Fetuses were scavenged by a variety of birds and mammals in areas near YNP and more rapidly inside YNP than outside the Park boundary. Models derived from our data determined a 0.05% chance of bacterial survival beyond 26 days (95% Credible Interval of 18–30 days) for a contamination event in May. May 15 is the final date for hazing all bison into Yellowstone National Park under the current interagency bison management plan. With these data managers can predict when it is safe to graze cattle onto pastures previously occupied by bison.

Journal of Wildlife Management, 76, 253-261

ESTIMATING PROBABILITIES OF ACTIVE BRUCELLOSIS INFECTION IN YELLOWSTONE BISON THROUGH QUANTITATIVE SEROLOGY AND TISSUE CULTURE

TREANOR, J.J., GEREMIA, C., CROWLEY, P.H., COX, J.J., WHITE, P.J., WALLEN, R.L. & BLANTON, D.W. (2011)

Summary: 1. Disease management along the boundaries of wildlife reserves is a growing conservation problem worldwide, as infected wildlife can migrate outside protected areas and pose a threat to livestock and human health. The bison population in Yellowstone National Park has long been infected with *Brucella abortus*, but culling of Yellowstone bison to prevent transmission to cattle has been ineffective at reducing brucellosis infection. This management strategy is negatively affecting long-term bison conservation because of difficulties in diagnosing actively infected animals. 2. We integrated age-specific serology and B. abortus culture results from slaughtered Yellowstone bison to estimate probabilities of active brucellosis infection using a Bayesian framework. Infection probabilities were associated with age in young bison (0–5 years old) and with elevated antibody levels in older bison (>5 years old). Our results indicate that Yellowstone bison acquire B. abortus infection early in life but typically recover as they grow older. 3. A tool was developed to allow bison management to better reflect the probability that particular animals are infective, with the aim of conserving Yellowstone bison while reducing the risk of brucellosis transmission to cattle. Combining selective removal of infectious bison with additional management practices, such as vaccination, has the potential to advance an effective brucellosis reduction programme. 4. Synthesis and applications. We conclude that active B. abortus infection in Yellowstone bison is age dependent, which allows true infection probabilities to be estimated based on age and quantitative diagnostic tests. These findings have important application to disease management worldwide where accurate diagnostic tests for wildlife are unavailable. Estimation of true infection probabilities can replace culling practices that conflict with wildlife conservation. The ability to identify infective individuals can improve management practices that support conservation, particularly when human health is at risk or endangered wildlife species are involved.

Journal of Applied Ecology, 48, 1324-1332

PREDICTING BISON MIGRATION OUT OF YELLOWSTONE NATIONAL PARK USING BAYESIAN MODELS

GEREMIA, C., WHITE, P.J., WALLEN, R.W., WATSON, F.G.R., TREANOR, J.J., BORKOWSKI, J., POTTER, C.S. & CRABTREE, R.L. (2011)

Abstract: Long distance migrations by ungulate species often surpass the boundaries of preservation areas where conflicts with various publics lead to management actions that can threaten populations. We chose the partially migratory bison (*Bison bison*) population in Yellowstone National Park as an example of integrating science into management policies to better conserve migratory ungulates. Approximately 60% of these bison have been exposed to bovine brucellosis and thousands of migrants exiting the park boundary have been culled during the past two decades to reduce the risk of disease transmission to cattle. Data were assimilated using models representing competing hypotheses of bison migration during 1990–2009 in a hierarchal Bayesian framework. Migration differed at the scale of herds, but a single unifying logistic model was useful for predicting migrations by both herds. Migration beyond the northern park boundary was affected by herd size, accumulated snow water equivalent, and aboveground dried biomass. Migration beyond the western park boundary was less influenced by these predictors and process model performance suggested an important control on recent migrations was excluded. Simulations of migrations over the next decade suggest that allowing increased numbers of bison beyond park boundaries during severe climate conditions may be the only means of avoiding episodic, large-scale reductions to the Yellowstone bison population in the foreseeable future. This research is an example of how long distance migration dynamics can be incorporated into improved management policies.

PLOS ONE, 6, E16848

CARRYING CAPACITY, MIGRATION, AND DISPERSAL IN YELLOWSTONE BISON

PLUMB, G. E., WHITE, P. J., COUGHENOUR, M. B. & WALLEN, R. L. (2009)

Abstract: The conservation of bison in Yellowstone National Park, from near extinction in the late 19th century to a recent high of 5000, has led to long-term societal conflict regarding perceived overabundance, transboundary movements, and potential transmission of brucellosis from bison to livestock. We synthesized available information to address two central questions in this debate: (1) has the Yellowstone bison population surpassed numbers that can be supported by the forage base in the park; and (2) why do some bison move outside the park during winter, even when numbers are below food-limited carrying capacity? A spatially-explicit model of the system that integrated abiotic variables with biotic processes indicated bison have not reached a theoretical food-limited carrying capacity of 6200 in Yellowstone National Park. However, more bison began to migrate earlier to lower-elevation winter ranges as numbers increased and climatic factors interacted with density to limit nutritional intake and foraging efficiency.

A gradual expansion of the winter range as bison numbers increased enabled relatively constant population growth and increased food-limited carrying capacity. Current management actions attempt to preserve bison migration to essential winter range areas within and adjacent to the park, while actively preventing dispersal and range expansion to outlying areas via hazing and removals (i.e., dispersal sink). A population of 2500–4500 bison should satisfy collective interests concerning the park's forage base, bison movement ecology, retention of genetic diversity, brucellosis risk management, and prevailing social conditions.

Biological Conservation 142, 2377-2387

A REVIEW OF BEST PRACTICES AND PRINCIPLES FOR BISON DISEASE ISSUES: GREATER YELLOWSTONE AND WOOD BUFFALO AREAS (ABS WORKING PAPER NO.3)

NISHI, JOHN S. (2010)

EXECUTIVE SUMMARY: ***Background:*** The American bison (Bison bison) reflects the resiliency of a species that was brought to the brink of extinction at the turn of the 19th century due to widespread market hunting and the accumulated years of systematic slaughter. The creation of Yellowstone National Park in 1872 played a pivotal role in the conservation of plains bison (B. b. bison), while in northern Canada, Wood Buffalo National Park was established in 1922 to protect wood bison (B. b. athabascae). Although today we may consider that bison have been saved from extinction, there is a significant amount of work yet to be done to achieve ecological restoration of bison in North America. Future success will ultimately be defined by the unfolding relationships between humans and bison over the next century. A key challenge that will influence restoration efforts for bison is our collective ability to manage current and future disease risk at a landscape scale. The greater Yellowstone (GYA) and Wood Buffalo areas (GWBA) in the US and Canada are focal points of intense controversy because the wild bison are infected with "reportable" zoonotic pathogens of livestock origin. Yellowstone bison are infected with brucellosis (Brucella abortus) and represent a disease risk to cattle herds around the park in Montana, Wyoming and Idaho. Bison in the GWBA are infected with brucellosis and bovine tuberculosis (Mycobacterium bovis) and primarily represent a risk of pathogen transmission to healthy conservation herds of wild wood bison in neighboring jurisdictions of Alberta and the Northwest Territories. Our collective ability (or inability) to develop successful management processes to address the current disease issues in Yellowstone and Wood Buffalo will affect our future capacity to address complex management issues that will inevitably arise with new bison restoration projects in North America.

Goals and Objectives: The goal of this paper was to conduct an objective, strategic level review of diseased bison issues and management approaches in the GYA and GWBA. The aim is to provide a conceptual framework for understanding the issues and illustrate linkages to management options. Specific objectives were twofold: 1. Describe and summarize case studies in the Greater Yellowstone Area and Greater Wood Buffalo Area to highlight current management issues and explore possible strategies for engaging stakeholders and moving issues forward, and 2. Develop strategic-level recommendations for diseased bison management with implications for bison restoration.

Methodology: The methodology included an extensive search of scientific journals and available 'grey' literature produced primarily by government agencies and non-government organizations. The main purpose was to review studies on the disease ecology of bovine brucellosis and tuberculosis in bison and the history of disease management within the GYA and GWBA. The process also included two site visits to interview wildlife disease experts in the United States and Canada who have been involved in various aspects of research and management of the diseased bison issues in the GYA and GWBA.

The Focus on Best Practices: This paper reviews and contrasts the disease management processes in the GYA and GWBA, and suggests that management of the issue in the GYA is further advanced compared to the GWBA. A major shortcoming in the GWBA has been the lack of a consistent management process with stakeholder engagement over a period that extends for more than a few years at a time. In the GYA, governments and stakeholders have been more involved in implementing management options, but there are still fundamental challenges associated with implementing adaptive management as it applies to brucellosis in the GYA. A key similarity between the GYA and GWBA has been the focus of research programs to improve scientific knowledge and develop effective best practices. One approach to improving the reliability and value of best practices is to develop and apply them within a broader context of a defined, goal-oriented disease management process. By matching best practices to specific disease management objectives (ie., laissez faire, prevention, control, or eradication), the expected effect or contribution of a best practice can be compared to its observed performance, which can then lead to selection of the most reliable and effective best practices. The best practices developed through research and management activities in the GYA and GWBA fit within the following broad categories:

- Passive and active monitoring
- Surveillance
- Education, training, and consultation
- Directed activities against disease
- Mopping up and preventing reintroduction

However, continued focus on improvement of science-based best practices will be insufficient for achieving sustainable long-term management of brucellosis in the GYA, and of brucellosis and tuberculosis in the GWBA. To develop potentially useful recommendations that might apply to these extremely complex problems, this paper focuses on outlining best principles and then possible strategic actions.

Best Principles and a Way Forward: A principle is defined as a basic generalization that is accepted as true and that can be used as a basis for reasoning, conduct, or action. The following principles frame the discussion:

- Focus on measurable goals that specify future (long-term) processes and outcomes necessary for sustainability;
- Recognize that complexity and connectedness are inherent properties that impart resilience to ecosystems;
- Recognize that ecosystems are dynamic and adaptive, and that humans are an important ecosystem component and play an active role in achieving sustainable goals;
- Apply the full range of knowledge and skills from the natural and social sciences as required to address problems;
- Understand and take account of the motives, interests, and values of all users and stakeholders, but not by simply averaging their positions; and
- Facilitate effective communication that is interactive, reciprocal, and continuous.

A conceptual framework suggests how systems thinking and other principle-based strategies may be used to chart a way forward to improve collaborative and adaptive management initiatives on the diseased bison issues.

Conclusions and Recommendations:

• The diseased bison issues in the GYA and GWBA are 'wicked' problems that have eluded resolution because of their dynamic epidemiology, and the diverse and conflicting mandates and values held by various government agencies and stakeholders. Although the issues are beset by significant technical challenges and knowledge gaps, the human dimensions – a key driver in social-ecological issues – have received comparatively less formal attention than the scientific studies addressing knowledge gaps and the improvement of best practices. The current research and management emphasis on disease ecology could be improved by broadening the scope and collaborating with researchers in the social sciences, including sociologists, economists, and political scientists. Other non-traditional collaborators may include policy makers, planners, managers, community and aboriginal groups, and citizens.

• Development of science-based best practices is useful and should continue, but is not sufficient on its own to contribute meaningfully to resolving the diseased bison issues. Best practices should be considered and applied within a risk framework because risk analysis methodologies can provide logical and quantitative rigor. Development and application of best practices should be considered as one component of a multi-scale, three-point strategy that also includes a formalized collaborative and adaptive management process, and an ongoing evaluation and refinement of livestock and wildlife policy.

• Adaptive management provides the overall framework for developing and implementing strategies to address the diseased bison issues in the GYA and GWBA. Although adaptive management has been identified as the preferred management approach and it has been specified in a myriad of official government agency documents and records of decision, the principal challenge has been to effectively implement the concept on the front lines of these real world 'wicked' problems. One area for improving adaptive management strategies is to clearly define objectives, working hypotheses, assumptions, and predictions of prospective management actions. Only then can an appropriate active or passive implementation design be developed along with a suitable monitoring program.

• A way to move forward from the current situation, which is characterized by recurrent patterns of conflict and controversy centered on the diseased bison issue, is to focus on ways of improving collaborative relationships and adaptive management processes. Several key strategies should be considered: – providing a forum, funding and mandate for a long-term process to address the issue; – developing and using systems thinking skills; – working across boundaries; – engaging stakeholders and citizens; – developing and using diverse (modeling) tools; and – institutionalizing adaptive management.

• At a continental scale, the opportunity for shared learning between the US and Canada should be developed through directed and continued dialogue between the governments and stakeholders involved in the diseased bison issues of the GYA and GWBA. Shared learning would be enhanced through informal and formal collaboration, for example, through workshops and committees.

• Failure to address the bison disease issues by letting outcomes be determined through inaction is an inappropriate management strategy for these valuable wildlife resources. Political, public, and stakeholder support for the development and implementation of disease management strategies is essential. While working towards a long term solution to both issues, initiatives to contain and mitigate disease risk need to be continued and enhanced.

ABS Working Paper No. 3;
www.americanbisonsocietyonline.org/resources/ABSWorkingPapers

Appendix C

WORKSHOP AGENDA

• 2013 •
Brucellosis in Yellowstone Bison
Science Review and Workshop
February 26-28, 2013 Chico Hot Springs Resort Pray, MT
Program Agenda

Tuesday, February 26

8:00-8:15	Welcome Dan Wenk Superintendent, Yellowstone National Park
8:15-8:30	Introduction & Charge to Panelists Dave Hallac & Pat Flowers Co-chairs, Brucellosis Science Committee, Mary Ellen Wolfe Facilitator
8:30-10:00	Morning Session 1: Stakeholder Perspectives
8:30-9:00	Interagency Bison Management Plan (IBMP) Overview P.J. White, Yellowstone National Park
9:00-9:30	Citizen Working Group Matthew Skoglund, NRDC
9:30-10:00	Native American Tribes Jim Stone, Inter Tribal Buffalo Council; Keith Lawrence, Nez Perce
10:00-10:20	Break
10:20-noon	Morning Session 2: Stakeholder Perspectives (continued)
10:20-10:40	Montana Fish, Wildlife & Parks Sam Sheppard, MT FW&P
10:40-11:00	Montana Department of Livestock Martin Zaluski, MT DOL
11:00-12:00	Panelist Questions & Discussion
12:00-1:00	Open Lunch
1:00-5:30	Presentations: Brucellosis Science, Management, & Disease Suppression
1:00-1:30	Ecology of Yellowstone Bison Chris Geremia, Yellowstone National Park
1:30-2:00	Ecology of GYA Elk Paul Cross, USGS
2:00-2:40	Adaptive Management Model Tom Hobbs, Colorado State University
2:40-3:00	Break
3:00-3:30	Disease Suppression: Immunocontraceptives Jack Rhyan, USDA-APHIS
3:30-4:00	Disease Suppression: Vaccination David Pascual, Montana State University
4:00-4:30	Brucellosis in Yellowstone Bison John Treanor, Yellowstone National Park
4:30-5:00	Panelist Questions & Discussion
5:00-5:30	Public Comments

Wednesday, February 27

8:00-10:15	Panelist Meeting/ Discussion
10:15-10:30	Break
10:30-12:00	Panelist Meeting/ Discussion
12:00-1:00	Open Lunch
1:00-3:00	Panelist Meeting/ Discussion
3:00-3:30	Break
3:30-5:00	Panelist Meeting/ Discussion
5:00-5:30	Public Comment