# A Decision-Support Tool for Managing the Risk of Tuberculosis and Brucellosis Infection in Northern Canada


Jonathan A. Mitchell
Faculty of Environmental Design, University of Calgary
2500 University Drive N.W., Calgary, AB, T2N 1N4, Canada
jmitche@ucalgary.ca

C. Cormack Gates
Faculty of Environmental Design
University of Calgary
2500 University Drive N.W.,
Calgary, AB, T2N 1N4, Canada

Rick Rowell
AXYS Environmental Consulting Ltd.
Suite 600, 555 - 4th Avenue S.W.
Calgary, AB, T2P 3E7, Canada

Kevin Lloyd
AXYS Environmental Consulting Ltd.
Suite 600, 555 - 4th Avenue S.W.
Calgary, AB, T2P 3E7, Canada



## ABSTRACT

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) lists the wood bison (*Bison bison athabascae*) as Threatened (a species likely to become endangered if limiting factors are not reversed). Recovery efforts have been planned and implemented by the National Wood Bison Recovery Team (WBRT) and its partners. One of the greatest obstacles to the recovery of wood bison is the presence of introduced cattle diseases, specifically bovine tuberculosis and brucellosis, in some northern herds. Approximately 2,500 bison remain in infected herds, while the number of bison in noninfected free-ranging herds has increased to 4,700 (2,700 wood bison and 2,000 plains bison [*B. b. bison*]). In addition, the diseases are of grave economic concern to the burgeoning commercial bison industry in the region. While the agricultural industry and governments currently support the recovery of free-ranging herds of bison, support would diminish if the diseases spread to the healthy wild herds. In response to these concerns, the Animal, Plant and Food Health Risk Assessment Network (APFRAN) conducted a risk assessment at the request of the Canadian Bison Association. We have undertaken a project to add to the utility of the APFRAN model by incorporating biophysical factors and local and traditional knowledge of bison movements into the risk assessment. An approach called friction modelling will be used to define a resistance landscape for bison. The product will be expressed as a digital map of friction values, or spatial patterns of resistance to bison movements. The underlying invasion probability generated by the APFRAN model will be adjusted using a function of the friction value. The models and associated maps will serve as a decision-support tool for the development of management actions and guidelines to reduce the risk of infection of susceptible populations. This, in turn, will serve the continued recovery of wood bison in Canada.



**Key words:** *Bison bison*, brucellosis, risk assessment, tuberculosis, wood bison.


Wood Buffalo National Park (WBNP) and the surrounding area, located in the northeast corner of the province of Alberta and the southern Northwest Territories, supports the largest metapopulation of wood bison (*Bison bison athabascae*) in existence. Unfortunately, herds in this area are infected with 2 cattle diseases introduced during the 1920s, resulting from a massive release of infected plains bison (*B. b. bison*) imported from east-central Alberta. *Mycobacterium bovis* and *Brucella abortus* are the causative agents of the 2 reportable diseases, bovine tuberculosis and bovine brucellosis. The role of the diseases in the population ecology of free-ranging bison is the subject of current research programs in Wood Buffalo National Park (BRCP 1996) and Yellowstone National Park (NPS 1998). The pathobiology of each disease is considered similar in bison and cattle (Tessaro 1988). The main clinical features of brucellosis are a high incidence of abortion during the first pregnancy following infection (Davis et al. 1990, 1991), and a low incidence of bursitis leading to arthritis and reduced joint mobility (Tessaro 1988). Tuberculosis in bison and cattle is primarily a pulmonary disease, although any organ system may be affected. Advanced tuberculosis is generally fatal (Tessaro 1988). Owing to the importance of brucellosis and tuberculosis as zoonoses, these diseases have been the subject of intensive, long-term eradication programs in livestock populations in Canada and the United States. The Canadian livestock population was declared free of brucellosis in 1985. Tuberculosis continues to occur sporadically in livestock herds throughout Canada, but the incidence of the disease is extremely low. The last outbreak occurred in a cattle herd in Manitoba in 1997 (D. Scott, Canadian Food Inspection Agency, pers. comm.). Bison in the Greater Wood Buffalo National Park area represent the last known reservoir of these diseases in Canada.

## MANAGEMENT ISSUES

The issue of disease management was the subject of a controversial proposal to eradicate infected bison in the region (EAP 1990). Although the government of Canada rejected the proposed action, concern about the persistence of the diseases has not diminished. Indeed, the reasons for concern have increased since 1990 in 2 main areas, namely the risk to the conservation of recovering disease-free, free-ranging bison, and the risk to a rapidly expanding commercial bison industry in the region.

### CONSERVATION

Since the termination of interventive bison management in WBNP and the adjacent Slave River Lowlands around 1970 (Carbyn et al. 1989), the Greater WBNP (GWBNP) bison population has declined by >80%, from 16,000 in 1971 to 2,500 in 1998 (Gates et al. in prog.). This stock represents a mix of original wood bison and introduced plains bison (van Zyll de Jong et al. 1995) and was the source of 3 salvage projects undertaken to establish brucellosis- and tuberculosis-free herds representing as close as possible the wood bison phenotype (Gates et al. in prog.). There have been no management initiatives undertaken to promote growth or recovery of infected herds since the 1960s. During the past 3 decades, 6 wild populations of noninfected bison have been reestablished in northern Canada, and now number approximately 4,700 bison in aggregate. They include 5 wood bison populations and 1 plains bison herd (Fig. 1). Should any of these herds become infected, management support would likely diminish as it has for existing infected populations. Managing the risk of infection of the herds nearest to WBNP is the focus of initiatives in the Northwest Territories and Alberta and is a concern for 3 herds in British Columbia (Harper and Gates 2000). The Yukon population is

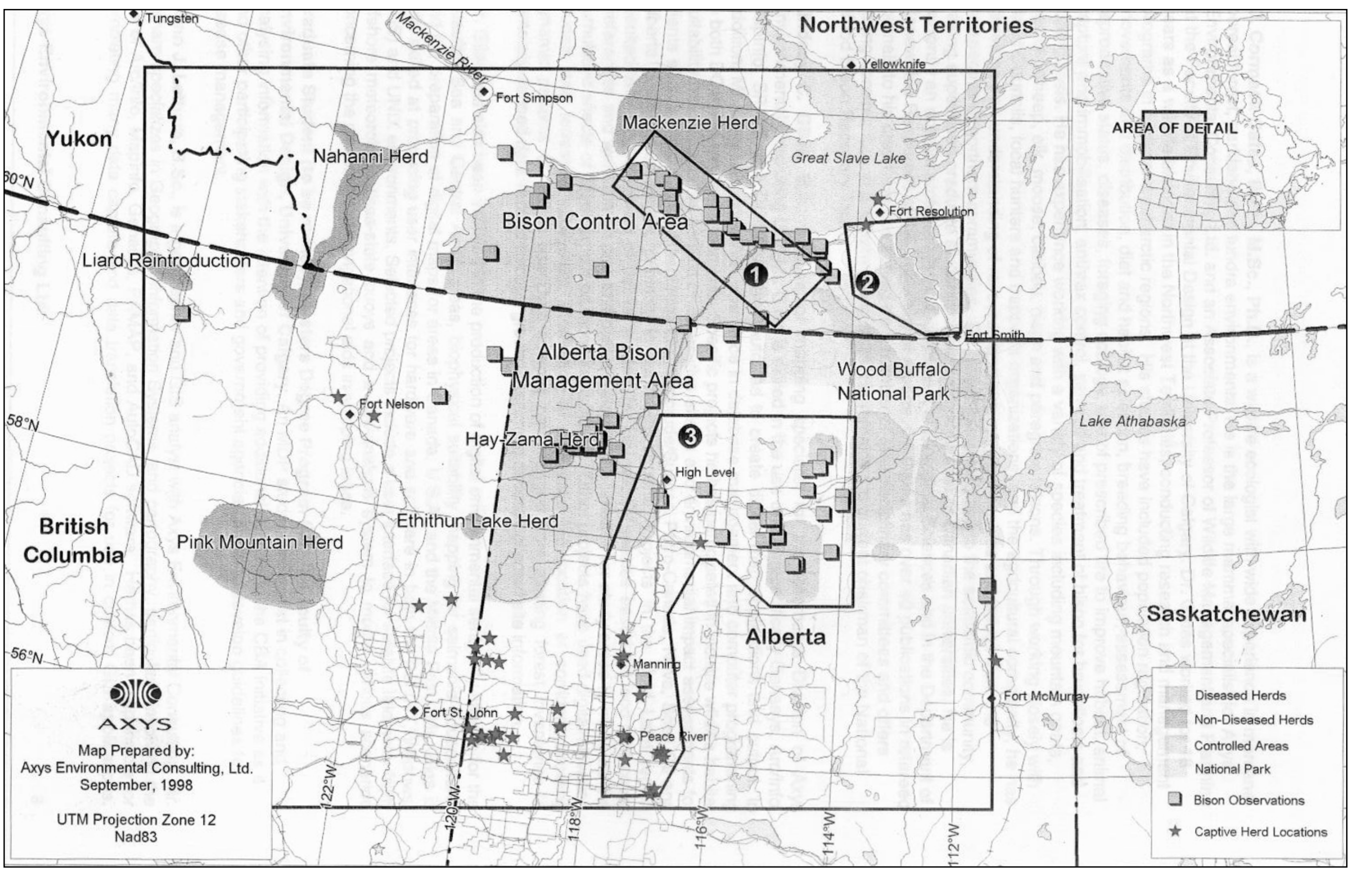


**Figure 1.** Disease risk management region illustrating 3 proposed study areas for disease risk modeling.

sufficiently remote that diseases would only be of concern if closer herds became infected.

Other considerations in the management of diseased bison include the status of wood bison under COSEWIC (listed as Threatened), and the designation of WBNP by the United Nations Educational Scientific and Cultural Organization (UNESCO) as a World Heritage Site in 1983, predominantly because of wildlife populations that inhabit the park (Parks Canada 1997). A national program for conservation of wood bison has existed in various forms since the early 1970s. Currently, the Recovery of Nationally Endangered Wildlife (RENEW) program provides direction for a National Recovery Team, which provides advice to jurisdictions and coordinates recovery actions in Canada. This team has drafted a national recovery plan that identifies 4 primary goals to guide recovery efforts (Gates et al. in prog.):

1. Reestablish viable, healthy, free-roaming wood bison populations in original range, thereby contributing to the maintenance of ecological processes and biological diversity.
2. Ensure the genetic integrity of wood bison is maintained without further loss as a consequence of human intervention.
3. Restore healthy wood bison herds for long-term sustained use, thereby contributing to the aesthetic, cultural, economic, and social well-being of rural communities and society in general.
4. Encourage the establishment of long-term, cooperative management programs for wood bison, in which rural communities, aboriginal people, and public agencies play an integral role.

In addition, a Research Advisory Committee (RAC) was established in 1995 by the WBNP administration to provide advice for the park's Bison Research and Containment Program (BRCP 1996). The long-term goal of the program is to "maintain a viable, free-ranging bison population in the Park."

### Commercial Bison Production and Conventional Livestock

In the Peace River country of British Columbia, Alberta, and the Northwest Territories there are approximately 250 commercial bison herds that hold about 20,000 bison (D. Patten, Peace Country Bison Association, pers. comm.). The farms are located mainly in the agricultural zones in the 2 provinces. However, there are 2 farms in the Northwest Territories near WBNP, 1 of which is stocked with wood bison, and plans are being developed to stock the other. Two bison farms are located in the agricultural area west of WBNP in Alberta and another is proposed. The number of farms in the region has been increasing at a rate of 15% annually and the number of bison on farms has been increasing at a rate of 25% annually (Hussey 1997). Under the National Captive Ungulate Regulations, bison herds testing positive for either of the reportable diseases are subject to slaughter. The economic cost to producers of such an action is high, since losses due to condemnation are not compensated at full market value. Furthermore, access to national and international markets may be affected if a disease outbreak occurs. The Canadian Bison Association (CBA) formed a committee in 1996 to develop an approach to disease risk management. In 1997 the CBA asked the Animal, Plant and Food Health Risk Assessment Network (APFRAN) to conduct a risk assessment for disease-free, free-ranging bison, captive commercial bison, and cattle in the region around WBNP.

## APFRAN'S DISEASE RISK ASSESSMENT

The risk assessment conducted by APFRAN (1998) estimated the probability of invasion by bison, contact, and disease transmission to an individual animal in each risk group, and the economic consequences of disease transmission. Risk was calculated by combining the probability of invasion with the probability of contact once invasion had occurred; then, contingent upon invasion and contact, the risk of transmission was factored in to define an overall risk of infection. Once that risk was defined, the assessment determined the economic consequences of infection.

The risk assessment for the year 1998 considered the 95% probability of at least 1 animal becoming infected in an "At Risk" group (Table 1). Free-ranging (wild) healthy bison were at the highest risk of infection, at 1 in 6 years for tuberculosis and 1 in 8 years for brucellosis.

A temporal model of infection probabilities for commercial bison was developed and projected 5 and 10 years into the future (APFRAN 1998). The model assumed that the rate of increase in the number of farms and the number of commercial bison would remain constant over the 10-year period. The risk of brucellosis infection increased to 1 in 64 years and the risk of tuberculosis infection increased to 1 in 44 years over the 10-year period (Fig. 2).

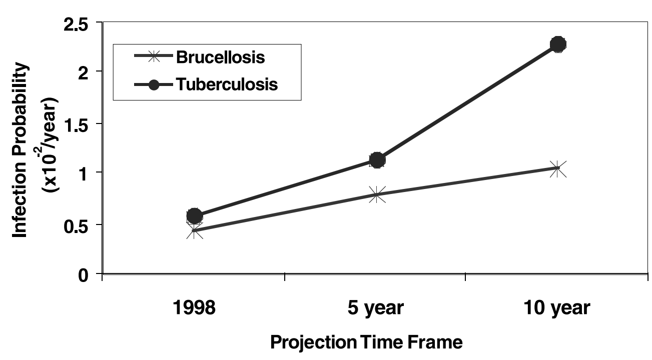


**Figure 2.** Temporal projections of the probability of infection for commercial captive bison (data from APFRAN 1998).

**Table 1.** Risk assessment results indicating infection probabilities and economic consequences based on conditions in 1998 (APFRAN 1998).

| Disease | Risk parameter | Wild bison | Commercial bison | Cattle |
|---|---|---|---|---|
| | Probability of invasion | 1/10 yrs[a] | 1/29.9 yrs | 1/2.7 yrs |
| Brucellosis | Probability of infection | 1/8 yrs | 1/229 yrs | 1/1,276 yrs |
| | Cost per outbreak | $5,400,000 | $6,500,000 | $632,000 |
| | Annual cost | $668,750 | $28,384 | $495 |
| Tuberculosis | Probability of infection | 1/6 yrs | 1/173 yrs | 1/1,764 yrs |
| | Cost per outbreak | $5,400,000 | $8,200,000 | $832,000 |
| | Annual cost | $891,667 | $47,399 | $472 |

[a] Annual probability of 1 bison from GWBNP meeting a free-ranging bison from another population based on bi-directional movement.

### Information Gaps

Bison movements and distribution are influenced by a number of biophysical characteristics of the landscape, such as habitat structure and mosaic pattern, topography, hydrography, physical barriers, and movement corridors such as cutlines, logging sites, trails, and roads. Management factors also influence distribution patterns, (e.g., bison are not protected from hunting outside of WBNP in Alberta, except in a designated wildlife management zone in the northwest corner of the province). The risk assessment conducted by APFRAN acknowledged the need for considering these factors; however, they were not included in the model due to “a lack of time and resources” (APFRAN 1998).

Local ecological knowledge (LEK) of bison movements and landscape features was not incorporated into the assessment and could be used to improve the application of the assessment for developing management recommendations. The area around WBNP is occupied by several First Nations, whose members still practice traditional subsistence, land-based lifestyles to some extent. Biologists, foresters, farmers, and hunters also possess knowledge of the area and could contribute information for interpreting likely bison distribution patterns.

Furthermore, bison are already present in low numbers in the area west of WBNP. The origin of these animals is unknown. They may originate from infected herds inside WBNP or from the disease-free, free-ranging Hay Zama herd in northwestern Alberta. Continued growth of the disease-free, free-ranging populations of bison was not considered in the risk assessment, nor was a scenario in which the disease-free herds became infected. The disease status of the free-ranging bison regularly reported in the area west of WBNP is poorly documented. Limited sampling (11 bison) detected *Brucella*-positive titres in 2 bison, and lesions, suspicious of tuberculosis, were seen in another bison (Tessaro 1988). Further testing of bison west of WBNP has been identified as a need by the Little Red River and Tall Cree First Nations.

These deficiencies were recognized by the CBA Disease Risk Management Committee (CBA–DRMC meeting, 6 October 1998, pers. comm.) and the Bison Research and Containment Program (BRCP)–Research Advisory Committee (RAC) for WBNP (D. Armstrong, RAC member, 1998, pers. comm.).

We have undertaken a project to address some of the deficiencies and to contribute to planning risk management guidelines and actions for the region. In particular, the project will develop a spatial model that incorporates biophysical factors from conventional data sources, such as digital remote sensing data bases, and from LEK sources, to define the resistance of the landscape to bison movements and distribution.

## METHODOLOGY/PROJECT APPROACH

### Development of a Digital Resistance Landscape

The risk assessment assumed equal distribution in every direction without biophysical or LEK considerations. We will incorporate biophysical and LEK data in a model that will define the resistance of the landscape to bison movements using a method known as friction modelling. This method has been used previously to model the potential for movement of wolves in the Banff and Bow Valley area of Alberta (Page et al. in prog.), and the movement of barren-ground caribou in the Northwest Territories (Gates et al. 1998). Friction modelling allows quantitative integration of biophysical and management factors that interact in dynamic and complex ways. Model development involves the following steps:

- identifying biophysical and management factors (variables) that influence bison movements through the landscape;
- measuring and digitally mapping the variables within the study area;
- developing and assigning significance weightings to each variable;
- assigning friction indices (ranging from 0 to 10) to the conditions described by each variable; and
- preparing mathematical statements to calculate an overall friction value from a unique set of friction indices for each pixel in the modelled landscape.

Biophysical and management factors (variables) that influence seasonal movements will be identified based on the following lines of evidence:

- a review of available literature and published and digital biophysical data;
- participatory research methods: LEK obtained through discussions in formal and informal meetings with knowledgeable hunters and elders, foresters, biologists, and landowners; and
- a formal workshop on model assumptions with the CBA Disease Risk Management Committee and other partners.

Factors identified as being potentially important in influencing bison movements are:

- habitat type (vegetation and terrain);
- major water bodies;
- agricultural and urban areas;
- linear features (roads, seismic lines, fencing);
- management regime (protection, bison control, open hunting); and
- known presence of bison.

The relative influence of the variables affecting bison movement varies; some are more influential than others. Therefore, variables will be subjectively ranked for relative influence and will be assigned a weighting value. We will use Saaty's (1977) pairwise comparison matrix to develop linear weighted values of importance for each criterion used in the model. In Saaty's procedure, weights are derived by taking the principal eigenvector of a square reciprocal matrix of pairwise comparisons between criteria (Saaty 1977). This can be accomplished through the use of a 9-point continuous scale and a matrix where each variable is compared independently with other variables to determine their relative importance to each other. Each of the model's components is rated relative to the others and assigned 1 of 9 possible "relative importance" values that range from "extremely unimportant" to "extremely important." Weighting values are assigned separately for variables that influence movement across land as opposed to across water or ice. Friction indices ranging from 0 to 10 are assigned to the conditions described by each variable, where a friction index of 1.0 corresponds to no impediment. A value of <1.0 indicates that movement is facilitated, while a value of >1.0 indicates that the variable impedes movement. A friction value is calculated for each pixel comprising the study area. The computation is based on the assigned parameter value modified by the variable weighting. A special condition is applied to pixels that are impassable by bison (e.g., steep cliffs or urban areas).

Once the resistance surface has been constructed, the probability of invasion will be recalculated to reflect local variations in friction.

### Model Development and Verification

LEK will be incorporated through a stakeholder involvement process. There are 2 committees currently dealing with the disease issue. The CBA's Disease Risk Management Committee (CBA–DRMC) has participants from the bison and cattle industries, the federal agriculture ministry (Canadian Food Inspection Agency [CFIA]), the Alberta, British Columbia, and Northwest Territories agriculture and wildlife agencies, and 2 First Nations. The Research Advisory Committee (RAC) for WBNP's Bison Disease Research and Containment Program has representatives from the governments of the Northwest Territories and Alberta, 4 First Nations, and non-government environmental organizations. A list of stakeholders and their interests will be developed based on the constituents involved with these committees. A method known as "participatory action research" (PAR; Smith et al. 1997) will be used to incorporate local ecological knowledge and traditional indigenous knowledge into analysis of factors that influence the movement and distribution of potentially infected bison in relation to susceptible ungulate populations. PAR has been developed as an effective technique for researchers to collect epidemiological information at the community level, particularly for identifying and priorizing information relevant to animal health problems (McCorkle and Mathias-Mundy 1992, Mariner 1998). An application of this approach, termed Participatory Rural Appraisal (PRA), shifts the paradigm from the researcher as an extractor of information, to the researcher as a facilitator of community participation in problem solving (Mariner 1998). This technique was pioneered in the international sustainable development forum as a rapid and economically feasible method for integrating locally available information with scientific data to produce a semi-quantitative product for statistical analysis (Mariner 1998). The flexibility of this technique allows participants to express their interests and contribute information in a qualitative manner that is consistent and meaningful within their conceptual frameworks and knowledge systems. Application of this technique will allow participants to provide information in a visual format on a map surface. Information sought through this process will include the parameters identified for the friction model and others that participants think may influence bison distribution and movements.

Landscape resistance to bison movements will be mapped using a colour scheme or 3-dimensional graphics to represent spatial variations within the areas of interest; areas of greatest risk of invasion will be graphically highlighted. The mapping products, representing integrated scientific and LEK data, will be used to focus discussions among participants on possible alternatives to manage the risk of infection of susceptible populations. Stakeholder involvement will be enabled through the CBA–DRMC and the RAC. Management guidelines will be cooperatively developed for application at the community, industry, and government levels.

## MANAGEMENT IMPLICATIONS

The project will provide a focus for clearly defining the interests of participants, including government agencies, the agricultural industry, wildlife and park managers, and First Nations. The methods utilized will provide a forum for bringing these interests together and for integrating scientific and rural appraisal information relevant to the epidemiology of cattle diseases in northern Canada. The models and mapping products produced will serve as a decision-support tool that can be used to:

- assist with rapid evaluations of changes or proposed changes in the distribution and abundance of bison or cattle in the region;
- provide an easily understandable overview of the current or future situations in map form;
- improve the capability of stakeholders to predict the most likely areas where disease could spread so that preventative measures can be planned;
- assist in developing guidelines for management purposes; and
- provide additional insight into the epidemiology of the diseases.

This project will contribute to achieving specific goals and high priority objectives of the Draft National Recovery Plan for Wood Bison, and will contribute to maintaining the disease-negative status of free-ranging bison, commercial bison, and cattle in the region.

## LITERATURE CITED

Animal, Plant and Food Health Risk Assessment Network (APFRAN). 1998. Risk assessment on bovine brucellosis and tuberculosis in Wood Buffalo National Park and area. Canadian Food Inspection Agency.

Bison Research and Containment Program (BRCP). 1996. Wood Buffalo National Park Bison Research and Containment Program Newsletter. Summer 1996, Vol.1(1).

Carbyn, L. N., D. Huisman, E. Street, and D. Anions. 1989. An analysis of the decline of bison in Wood Buffalo National Park from 1971 to 1981 and a review of the status to 1989. Can. Wildl. Serv., Edmonton, AB. Unpubl. rep. 268pp.

Davis, D. S., J. W. Templeton, T. A. Ficht, J. D. Williams, J. D. Kopec, and L. G. Adams. 1990. *Brucella abortus* in captive bison. I: Serology, bacteriology, pathogenesis and transmission to cattle. J. Wildl. Dis. 26(3):360–371.

_____, _____, _____, J. D. Huber, R. D. Angus, and L. G. Adams. 1991. *Brucella abortus* in bison. II: Evaluation of strain 19 vaccination of pregnant cows. J. Wildl. Dis. 27(2):258–264.

Environmental Assessment Panel (EAP). 1990. Northern diseased bison. Fed. Environ. Assessment Rev. Office, Minist. Supply and Serv. Can., Ottawa, ON. 47pp.

Gates, C. C., J. Wierzchowski,, R. Rowell, and J. Green. 1998. Barren-ground caribou. Section IV *in* AXYS Environmental Consulting Ltd., eds. Environmental effects report for wildlife. Diavik Diamonds Ltd., Yellowknife, NWT.

_____, H. Reynolds, M. Hoefs, C. G. van Zyll de Jong, N. Cool, H. Schwantje, S. Brechtel, R. Larche, and R. O. Stephenson. In Progress. National recovery plan for the Wood Bison. Recovery of Nationally Endangered Wildlife Committee (RENEW), Ottawa, ON.

Harper, W., and C. Gates. 2000. Recovery of wood bison in British Columbia. Pp. 915–923 *in* L. M. Darling, ed. Proc. Conf. Biology and Management of Species and Habitats at Risk, Kamloops, BC, 15-19 Feb. 1999. Vol. Two. B.C. Minist. Environ., Lands and Parks, Victoria, BC, and Univ. College of the Cariboo, Kamloops, BC. 520pp.

Hussey, G. 1997. Value of bison production 1997 estimates for Alberta. Alberta Bison Association, Edmonton, AB.

Mariner, J. C. 1998. Participatory epidemiology: methods for the collection of action-oriented epidemiological intelligence. Food and Agricultural Association, Rome, Italy.

McCorkle, C. M., and E. Mathius-Mundy. 1992. Ethnoveterinary medicine in Africa. Africa 62:59–93.

National Parks Service (NPS). 1998. Environmental impact statement for the Interagency Bison Management Plan for the state of Montana and Yellowstone National Park [draft] Available from: www.nps.gov/planning/yell/eis/summary.htm.

Page, R., S. Bayley, J. D. Cook, J. E. Green, and J. R. Brent. In Progress. Banff-Bow Valley Study, 1996. Banff-Bow Valley: At the Crossroads. Tech. rep. of Banff-Bow Valley Task Force, Ecological Outlooks Project – Banff-Bow Valley Study, Minist. Can. Heritage, Ottawa, ON.

Parks Canada. 1997. Available from: http://parkscanada.pch.gc.ca/unesco/WOOD/WOOD.htm.

Saaty, T. L. 1977. A scaling method for priorities in hierarchical structures. J. Math. Psychol. 15:234–281.

Smith, S. E., D. G. Willms, and N. A. Johnson. 1997. Nurtured by knowledge: learning to do participatory action research. Apex Press, New York, NY. and Internatl. Dev. Res. Cent., Ottawa, ON.

Tessaro, S. V. 1988. A descriptive and epizootiologic study of brucellosis and tuberculosis in bison in northern Canada. Ph.D. thesis, Univ. Saskatchewan, Saskatoon, SK. 320pp.

van Zyll de Jong, C. G., C. Gates, H. Reynolds, and W. Olson. 1995. Phenotypic variation in remnant populations of North American bison. J. Mammal. 76(2):391–405.