THE ECOLOGY OF BISON MOVEMENTS AND DISTRIBUTION IN AND BEYOND YELLOWSTONE NATIONAL PARK

A Critical Review With Implications for Winter Use and Transboundary Population Management

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EXECUTIVE SUMMARY

Collaboration is necessary to define what is acceptable;
science is necessary to define what is possible;
organizing people to use knowledge to design and implement
management in the face of uncertainty is fundamental

In 1968, Yellowstone National Park (YNP) moved from a 33 year (1934-1967) period of culling ungulate populations for achieving predetermined stocking levels to a regime of ecological management under which populations of bison and other ungulates are allowed to fluctuate in the park without human intervention. With growing numbers of bison, management has become dominated by two major linked controversies; namely, the risk to livestock of transmission of brucellosis from bison moving beyond the park boundary, and criticism of the effects of winter use by snowmobiles on bison movements and range expansion, including transboundary movements, bison condition and population dynamics.

This project was initiated to: 1) provide a thorough, independent assessment of the state of knowledge of the ecology of bison movements and distribution within the context of current published concepts and theories; 2) provide recommendations for adaptive management of uncertainties and gaps in reliable knowledge within an adaptive environmental assessment and management framework, which involves organizing people to link science to management.

The principal investigators, based at the University of Calgary, Faculty of Environmental Design, were chosen because of their lack of previous association with issues related to YNP bison ecology or winter use management, allowing them to assess the state of knowledge and adaptive management from an unbiased perspective. The project was commissioned by the National Park Service. The research contract was administered by the Rocky Mountains Cooperative Ecosystems Studies Unit (RM-CESU) at the University of Montana.

The assessment entailed review of 1) literature on ungulate distribution, including Yellowstone National Park publications and planning documents, 2) key informant interviews for gaining rapid understanding of the system and unpublished knowledge, 3) development of a strategic level bison population and winter distribution model, and 4) key informant technical workshops to refine the model. In addition, 5) a workshop was held with environmental non-government organizations to review the concepts and knowledge upon which the assessment and model are based.

The assessment is summarized below. We first present key findings derived from key informant knowledge and interpretation of empirical data on population and spatial ecology. Secondly, we provide a summary of key findings derived from a systems model. Then we summarize key uncertainties and data gaps that may be addressed through monitoring and basic research. To be effective, adaptive management requires learning from key management experiments defined with the agreement of stakeholders and carried out under scientifically rigorous experimental designs. We identify key challenges for adaptive management, including how agencies are organized to collaborate on and coordinate policy development, management experiments, and procurement of scientific research and monitoring data in the long term. Finally, we offer recommendations for addressing these challenges.

Key Findings

History

- Distribution, movements and population dynamics of large mammal populations need to be viewed at spatial scales significantly larger than Yellowstone National Park itself in the context of historic spatial patterns, habitat composition, and landscape configuration and connectivity. Also, ecological processes play out over many decades so management actions cannot be fully comprehended at shorter time scales.
- Yellowstone National Park is the only area in the lower 48 States where bison have existed in a wild state since prehistoric times.
- Bison occupied the region encompassing the park from shortly after recession of the last glaciers 10,000 to 12,000 years ago, until they were nearly extirpated by market and subsistence hunting, and poaching by 1900.
- The Lamar Valley and the Yellowstone River Valley north to Livingston was an important area for bison and Native peoples throughout Holocene prehistory. This system can be considered the original Northern Range of Yellowstone bison.
- A resident population in the central interior in the Hayden Valley and the Firehole valley was extirpated by the late 1800s.
- The expansive grasslands of the Madison Valley and Snake River Plains were likely the source of some bison moving into the central interior of the park in summer.
- Yellowstone National Park is not a self contained ecosystem, covering only 8,983 km^2 or slightly more than 10% of the Greater Yellowstone Ecosystem (80,503 km^2).
- Historical records for 1902 indicate the persistence of a small remnant bison population in the eastern central interior of the park (22-30 individuals). The foundation stock for Yellowstone bison also included 18 cows imported from Montana and 3 bulls from Texas.
- Northern Range bison were restored in YNP through captive breeding (1902-1915), followed by gradual release and eventual elimination of husbandry by 1952.
- Interchange between Central Range bison in the Pelican Valley and Northern Range bison was suspected as early as the 1920s, related to common summer range in the Mirror Plateau and western slopes of the Absaroka Mountains (Upper Lamar Valley).
- Bison were reintroduced to the central interior of the park in 1936; 35 were released in the Fountain Flats and 36 in the Hayden Valley.

- Interchange between bison in Hayden Valley and the Firehole via the Mary Mountain Trail was first documented in winter 1945 but probably occurred earlier. The bison using the two areas became known as the Mary Mountain herd.
- Movements in winter between the Pelican Valley and Hayden Valley historically occurred when wintering populations were high in the Pelican Valley and Hayden Valley, e.g. in winter 1956.
- The Northern Range herd was managed more consistently by population reductions during the 1920s to the 1960s than Central Range populations. Management reductions of the Central Range herd began in the early 1950s and ceased in 1967.
- Culling of bison in interior YNP for population and brucellosis management ceased with the advent of the 'ecological management' in 1968.
- The risk of brucellosis transmission to cattle from bison exiting the park has influenced bison management in YNP since the 1920s.

Population Ecology

- Ecological conditions are different on the Northern and Central bison ranges, requiring separate assessment of population and spatial ecology.
- Significant areas of geothermally-influenced habitat in the Central Ranges provide refugia for bison in severe winters and reduce snow cover, resulting in reduced costs for accessing forage, travel, and possibly thermoregulation.
- Extensive grasslands and typically low snow cover in the Gardiner basin (the Yellowstone River Valley from Gardiner to Yankee Jim Canyon) provides winter refuge habitat on the Northern Range outside the park. The importance of this area for ungulates in winter has been recognized since the 1920s and perhaps earlier.
- Bison in Yellowstone attempt to compensate for declining per capita food resources by range expansion, thus maintaining a relatively stable instantaneous density. However, compensation is not exact; population growth rate declines with density because high quality foraging patches are limited in overall area, are patchily distributed, and depleted first, forcing bison to shift to poorer quality patches as density increases. The likely demographic responses are decreased fecundity and increased juvenile mortality.
- In the absence of culling, all YNP bison ranges provide environmental conditions supporting long term growth and persistence of bison populations.
- At low to moderate densities, observed growth capacity was highest for the Mary Mountain herd (13% to 16% annually), and was lower for the Pelican Valley and Northern Range herds (5% to 6% annually).
- Based on data collected since 1970, population rate of increase was significantly inversely related to population density for Central Range bison (population growth decreased with increasing population size), but not for the Northern Range population. Northern Range bison may be unresponsive until now because of the dominant effect of forage competition by a large elk population.

- There was no evidence to suggest that groomed roads have changed population growth rates relative to what may have happened in the absence of road grooming.
- Culling of bison exiting the park in the Gardiner MT area sporadically reduced the Northern Range population, but boundary removals did not begin to affect the Central Range population until the mid 1980s.
- YNP is a forage-limited system. As the bison population increases, they compensate for declining per capita forage availability through range expansion, thus maintaining a relatively stable instantaneous density in winter.
- Predation may become increasingly important as wolves learn how to kill bison. We suggest that wolf predation on bison will continue to increase in the Central ranges, but not on the northern range as long as elk are relatively more abundant there. In systems where wolves show a numerical response to an abundant prey species that is difficult to kill, predation rate on easier prey can be inversely proportional to their density. Non-migratory elk may therefore be reduced to very low abundance in the Central Range.

Distribution and Movements

- Key informants defined five winter ranges. The Central herd uses Pelican Valley (55 km^2), Mary Mountain (e.g. Hayden/Madison-Firehole, 152 km^2), and West Yellowstone (80 km^2). The Northern herd occupies Lamar Valley (234 km^2), and Gardiner Basin (98 km^2).
- As defined by key informants, these ranges are inter-connected by five primary movement corridors including Firehole-to-Mammoth (59 km), Firehole to West Yellowstone (21 km), Gardiner Basin to Lamar (river route 15.2 km; road route 11.4 km), Mirror Plateau (Pelican to Lamar, 30 km), and the shortest corridor Pelican to Hayden (8 km).
- The Mary Mountain Trail (19 km) connecting the Hayden and Firehole Valleys has been used by bison since the mid 1940s and is considered by key informants an integral part of the Mary Mountain Range rather than a corridor in the sense of other corridors. The authors deduced that the Mary Mountain Trail is a corridor maintained in winter by bi-directional movements of large numbers of bison.
- When population subunits were small, there were four semi-isolated primary wintering areas: the Pelican Valley, Hayden Valley, Firehole Valley, and the Lamar Valley.
- Apparent isolation of bison in separate winter ranges when populations were small likely reflected high per capita availability of forage, low pressure to move or expand, fewer animals to break and maintain a trail.
- Exploratory movements by mature bulls, which subsequently establish annual migration paths to and from peripheral ranges, likely precede range expansion by cow/juvenile groups.
- Range expansion was gradual, rather than pulsed as described for another erupting bison population in northern Canada. Differences in landscape composition and configuration between YNP and the Mackenzie Bison range is offered to explain the near absence of pulsed expansion in YNP.

- Learning the presence of destination habitat (familiar areas) likely played a significant role in the development of calculated migration and increasingly fluid movements of bison between ranges.
- Anecdotal information suggests that bison can break trail for considerable distances through deep snow (> 1 m), but in addition to forage limitation, knowledge of destination is likely an important condition.
- The density of bison in adjacent ranges likely determines the ability of bison to maintain trails that connect them in winter.
- Dispersal (one way movements from natal ranges) of cow/juvenile groups to unoccupied ranges rarely occurs in the YNP system. Cow/juvenile dispersal would likely be more prevalent in the absence of culling on boundary ranges.
- Mid winter survey data provide strong evidence that range expansion is density driven; more bison use more space. This holds for both the Northern and Central bison ranges.
- As populations increased, the area used expanded, and distributions eventually coalesced.
- Movements between winter ranges in central YNP have become increasingly fluid in recent years with bison moving between Pelican Valley and the Madison/ Firehole.
- Presently, YNP supports 2 bison subpopulations (Central and Northern herds) reflecting differences in ecological conditions and use of space between ranges, genetic differences, fetal growth rates, and tooth wear patterns.
- Interchange between the Central and Northern Ranges occurred historically since the 1920s, primarily via a movement corridor over the Mirror Plateau.
- Movement between the Pelican Valley and Lamar Valley in winter via the unroaded Mirror Plateau is likely constrained in most winters by snow depth, steep terrain and the long distance between these winter ranges.
- Since the early 1990s Central Range bison have migrated in increasing numbers north to Blacktail Deer Plateau and the Gardiner basin in winter using a new route associated with the road allowance between Madison Junction and Mammoth. It was speculated that most migrants return to the Hayden Valley for the rut.
- The calculated migration of Central Range bison to the Northern Range would likely not have developed in the absence of the groomed road between Madison Junction and Mammoth.
- Other groomed road segments facilitate movements within and among winter range units, but inter-range movements in winter in the Central Ranges would likely have developed in the absence of road grooming as the density of bison increased, because road segments are aligned with natural movement pathways.
- There is no documented movement of Northern Range Bison to the Central Range via the road corridor.
- Yellowstone bison are most widely dispersed in late winter then return to one of three rutting areas by mid July. The largest rutting aggregation is in the Hayden Valley, the second largest in the eastern Lamar Valley, and a small aggregation occurs in small high elevation grasslands on the Mirror Plateau and Cache/Calfee Ridge.

- Most movements are confined within Yellowstone National Park, except in winter when large numbers of bison may move into Montana near West Yellowstone and Gardiner.
- The level of boundary removals (representing transboundary movements) is strongly related to population size above 1500 bison for the Central Range and 550 for the northern Range.
- Snow pack had a smaller contributory influence on the level of boundary removals than population size, except in the unusually severe winter of 1996-1997 when an exceptionally deep and hard snow pack forced > 1000 bison to western and northern boundary ranges.
- Bison move beyond park boundaries in winter in response to forage limitation caused by interactions between population density, variable forage production (driven by spring/early summer precipitation), snow conditions, and herbage removal primarily by bison and elk.
- The Gardiner basin has been considered important winter range for bison since at least the 1940s and is an important component of the Northern winter range. In contrast, the Hebgen Lake area north of West Yellowstone offers no unique ecological value as winter range. It can be considered an expansion area for the Central subpopulation with the capacity to support 100 to 130 bison at the instantaneous density typical for Central Range bison (approximately 4 per km^2).

Key Findings Based On Systems Modeling

- Based on the systems dynamics paradigm, a strategic-level model was developed to facilitate collaborative learning about bison population, range use dynamics, and management alternatives.
- The systems model was based on empirical data and key informant knowledge. The model identifies key knowledge gaps and easily accommodates new empirical data and relationships emerging from existing and future research.
- Bison population and spatial dynamics are expressions of complex interactions best understood using a systems approach.
- Forage availability was a sensitive driver of bison movements in the model. The three key variables determining winter forage availability were previous summer precipitation, snowpack characteristics, and elk and bison density (i.e., forage demand).
- Inter-range movements of bison were generally not constrained by winter snowpack in non-road grooming scenarios during most winters. The notable exception to this rule was the Firehole-Mammoth corridor that was a barrier during all non-road grooming scenarios.
- Road grooming had a greater influence on movement of bison between interior ranges (Lamar-Mary Mountain, Mary Mountain-Pelican) than to the boundary ranges (West Yellowstone, Gardiner Basin). Therefore, grooming of winter roads may reduce the variation in and total numbers of bison departing for boundary ranges during winters of inadequate forage.
- Bison movement between winter ranges was projected to range from 100 to 4,000 animals, influenced most by per capita forage availability. An average movement

of ~1,000 bison occurred in non-road grooming scenarios, and 1200 in road-grooming scenarios.

- Average simulated annual winter mortality was ~180 bison (5%) for the non-road grooming and 225 for the road-grooming scenario (7%) of the YNP herd. However, mortality during occasional extremely harsh winters exceeded 25% of the population.
- The predicted maximum cull under current boundary management policies periodically exceeded 500 animals, and rarely exceeded 750 animals.
- Culls exceeded 10% of the total YNP herd in 15% of years in non-road grooming scenarios and 6% of the herd during road grooming scenarios.
- Cumulative culls during ten 100-year stochastic runs ranged between annual average culls of 50-90 bison for the non-grooming scenario, and 60-100 for road grooming scenarios. On average, 75 bison would be culled each year from boundary ranges with or without road grooming.
- Increasing bison habitat exterior to YNP is an effective strategy to increase the total regional population, but would not reduce the number of bison that would need to be culled annually in the regional landscape surrounding the park. Although the number of bison to be culled at the boundary of YNP was significantly reduced in a "repatriation" scenario, a greater number of bison were culled in the surrounding region. For example, the annual culls at the margins of the expanded range were projected to be as follows: (2,500 km^2 = 1,250 bison, 5,000 km^2 = 2,500 bison, 7,500 km^2 = 3,750 bison, 10,000 km^2 = 5,000 bison).

Key Uncertainties

Bison population and spatial dynamics are sensitive to variation in several key variables and interactions between variables. Among them is a subset for which the least amount of empirical data are available. They are, therefore, characterized as Key Uncertainties deserving further research:

- Threshold depth/density of snow at which low and high density forage-limited bison cannot move through corridors in search of better foraging conditions.
- Terrain characteristics (slope, ruggedness) that affect the above snow depth/density threshold preventing movements.
- Snowpack characteristics in the Pelican Valley in relation to other ranges.
- The relationship (shape and scale of the curve) between winter forage availability, bison density and bison over-winter mortality.
- The relationship (shape and scale of the curve) between winter forage availability and probability of bison movement.
- There was contradictory opinion whether the unroaded Mirror Plateau Corridor is a functional barrier to movements in winter between the Pelican Valley and the Lamar Valley when bison numbers are high and per capita forage is limited.
- Inter-range variability in forage productivity in response to precipitation and growing season length. In particular, one key informant suggested the growing season is shortest in the Pelican Valley range because of a long period of snow cover typically followed by spring flooding.

- Relationship between incidence of sero-positive bison and proportion of the herd that has been vaccinated.
- Systematic research has not been carried out on the ability of bison to move through snow under the variety of circumstances present in Yellowstone National Park.
- Snow conditions in the Pelican Valley are limited to subjective observations rather than consistent records from strategically-placed snow stations. Two modeling efforts thus far have not been able to precisely model the dynamic of snow conditions in this isolated valley of the park. Calibration of models in one location of the park does not allow large scale inference.
- The future role wolf predation plays in bison population dynamics is uncertain in Central Yellowstone ranges and is likely increasing at present. Mechanisms underlying how YNP wolves limit bison abundance and distribution have received limited attention.
- There is uncertainty of the extent of the interchange between the Northern and Central bison herds. This information is important for understanding how to conserve the spatial and genetic structuring of this population and maintenance of bison on the Northern Range under current boundary management.
- Data now being obtained from GPS collars will allow key questions about movement ecology to be addressed, including the timing and extent of movements in relation to plant phenology, snow conditions, forage production and utilization. In addition, with this technology research is now possible to address questions about the effects of roads and other anthropogenic or natural features on movements about which some uncertainty remains.

The YNP bison population will continue to experience wide long term fluctuations providing opportunities to study ecological dynamics at varying densities. A systems-based approach to understanding the dynamics of the YNP bison subpopulations can exploit environmental and management perturbations to learn about key uncertainties.

Key Challenges

- Empirical data on the effects of snow pack on bison movements and foraging in YNP is weakly represented in available literature.
- The two snow models developed for YNP yield discordant results.
- Herbivory (bison and elk), primary productivity and plant community structural responses have been poorly studied on ranges in central YNP.
- Competition and antagonism among some scientists and research groups impede data sharing, collaboration and research coordination.
- The YNP bison monitoring program is poorly defined and has been inconsistent since 1997, making it difficult to analyze changes in vital rates, population structure, and spatial responses in relation to environmental variation and management interventions since then.
- Migration of Central Range bison north to the Gardiner basin could result in management actions (removals) that jeopardize the viability of the Northern Range population.

- The humaneness of mechanized hazing of bison back into the park in winter is strongly challenged by some environmental non-government organizations and some park personnel.
- Government agencies compete for influence over bison management based on differences between individual agency mandates, disciplinary biases and institutional cultures.
- The USDA and Montana Department of Livestock remain deeply committed to eradication of brucellosis from wildlife and eliminating all risk to the livestock industry, and appear unresponsive to public interests in bison conservation and ecosystem management.
- The singular focus of these agencies on bison as a vector of brucellosis is poorly understood by the public, which sees a much larger reservoir in elk associated with feed grounds in Wyoming and inconsistent policies by which agencies deal with bison emigrating from the park.
- Efforts to deal with the linked issues of bison/brucellosis management and winter use/bison movements suffer from fractured governmental jurisdiction, inefficient and ineffective policy processes, and have been unable to define the common interest.
- Existing organizations and decision processes addressing the two issues have not been effective in defining the common interest or producing stable, broadly supported management plans.
- The agency-based planning processes used to address the issues and the low level of public involvement required under NEPA, have generated conflict and reduced public trust in governance.
- Decision processes followed by federal and state agencies to develop the Joint Management Plan appear a divisive, deeply-rooted power-balancing struggle to protect fragmented and overlapping jurisdictions and avoid risk.
- Many publics are frustrated with their low level of participation in decision processes but are willing to collaborate with government agencies to define common interests and to participate in decision-making.
- There is confusion about the appropriate role of science in value-based decision-making.
- There is resistance within some agencies to increasing public involvement in decision-making.
- Previous decision-making documents, formal assessments and environmental planning documents have not improved policy processes or provided organizational structures necessary to achieve enduring solutions acceptable to a broad range of affected stakeholders.
- Both the bison/cattle/brucellosis issue and the winter use issue are highly charged conflicts with public interests having no mechanism for meaningful participation. The affected publics are willing to use the courts and sometimes more extreme actions to be heard. The result is ongoing conflict, substantial annual and incremental costs for the agencies in time and resources, and promotion of the notion that more science, more information, will somehow result in wiser outcomes.

Recommendations

Monitoring and Science

1. Yellowstone National Park should implement an internally funded bison population monitoring program that collects and manages data on population size, vital rates, and winter distribution in the long-term.
2. Yellowstone National Park should define a minimum viable bison population for the Northern Range.
3. Yellowstone National Park should encourage and coordinate research focused on reducing key uncertainties over a full range of densities as the population fluctuates in response to environmental stochasticity or management actions.
4. An adaptive management experiment should be designed to test permeability of the Firehole to Mammoth corridor under varible snow conditions with a specific focus on the road section between the Madison Administrative Area and Norris Junction.
5. Yellowstone National Park should install a SNOTEL or Snow course station in the Pelican Valley, monitor snow conditions in the Pelican-Hayden Corridor, and re-evaluate the two existing snow models.

Adaptive and Collaborative Management Structures and Processes

6. Engage the U.S. Institute for Environmental Conflict Resolution in an independent situation assessment that includes advice on designing an integrated agency and public planning strategy to represent the common interest.
7. The Yellowstone Center for Resources should play a lead role among agencies and researchers in coordinating data sharing, research and monitoring of bison and other research relevant to bison ecology and management, by developing a stable collaborative science and management framework.
8. Develop or refine appropriate systems models and other decision support tools to help agencies and other stakeholders to understand key uncertainties and system properties, and to evaluate outcomes of management scenarios defined through value-based decision processes.
9. The National Park Service should increase its support for the appropriate agencies to secure agreements for key winter range for bison and other wildlife adjacent to the park in the Northern Range.

GLOSSARY OF TERMS

AEAM Adaptive Environmental Assessment and Management
AM Adaptive Management
AHP Analytical Hierarchical Procedure
APA Administrative Procedure Act
APHIS Animal and Plant Health Inspection Service
BTNF Bridger-Teton National Forest
CEQ Council on Environmental Quality
CMP Comprehensive Management Plan
DFWP Department of Fish, Wildlife and Parks
DOL Montana Department of Livestock
EA Environmental Assessment
EIS Environmental Impact Statement
ENGO Environmental Non-Government Organizations
ESA Endangered Species Act
FACA Federal Advisory Committee Act
FMC Firehole to Mammoth Corridor
FWC Firehole to West Yellowstone Corridor
GAO General Accounting Office
GIS Geographic Information Systems
GLC Gardiner Basin to Lamar Valley Corridor
GTNP Grand Teton National Park
GYA Greater Yellowstone Area
GYCC Greater Yellowstone Coordinating Committee
GYE Greater Yellowstone Ecosystem
GYIBC Greater Yellowstone Interagency Brucellosis Committee
IBMP Interagency Bison Management Plan
IENR Institute for Environmental and Natural Resources
IHD Impact Hypothesis Diagram
ISMA International Snowmobile Manufacturers Association
JBEMP/EIS Jackson Bison and Elk Management Plan and Environmental Impact Statement
MOU Memorandum of Understanding
MPC Mirror Plateau Corridor
OSV Over snow vehicle
PHC Pelican Valley to Hayden Valley Corridor
NAS National Academy of Sciences
NEPA National Environmental Policy Act
NER National Elk Refuge
NPS National Park Service
NOI Notice of Intent
RM-CESU Rocky Mountain Cooperative Ecosystem Research Unit, University of Montana
SWE Snow Water Equivalence

USDA United States Department of Agriculture
USDOI United States Department of Interior
USFS United States Forest Service
USFWS United States Fish and Wildlife Service
USGS United States Geological Survey
USGS-BRD United States Geological Survey – Biological Research Division
USIECR United States Institute for Environmental Conflict Resolution
WGFD Wyoming Game and Fish Department
YNP Yellowstone National Park