

Robustness Analysis of the Jackson Hole Valley: the Bison Management Case

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1. Introduction

Throughout the United States, many pristine environments are recognized as Iconic places, based on their unique and emblematic biophysical features. Abundant wildlife, a verdant natural environment, and recreational opportunities for a variety of constituent groups characterize these iconic places. Due to these characteristics, many such places lie within the jurisdictional boundaries of national parks and national forests as mandated by the National Parks Organic Act. Other iconic places include the national parks within Yellowstone, the Grand Canyon, Yosemite, Glacier, Everglades and others.

The Jackson Hole Valley (JHV) is a prime example of an iconic place. The natural environment surrounding the town of Jackson, Wyoming, is the resource system upon which wildlife and human settlements rely. This natural environment provides numerous streams of goods and services to all wildlife and many interested subgroups (Righter, 1982). Subgroups include recreationalists, sportsmen, residents and governance agencies. For many of these subgroups, the natural beauty of the JHV brings substantial tourism to enjoy the natural ecosystem.

Today the natural ecosystem within the JHV is subject to multiple anthropogenic and natural pressures. There has been a substantial increase in the human settlement throughout the JHV. Therefore, there is greater competition for habitat between humans and wildlife. As settlements encroach on the boundaries of protected areas, competition for natural resources between humans and wildlife occur. Management of the natural resource has narrowly focused on wildlife population sizes rather than the dynamics of the natural system. This management structure has generated unintended spillover effects. One major unintended spillover effect has been the reduction of winter forage habitat for Elk. This has resulted in the management decision to initiate supplemental winter-feeding, which has in turn supported the growth of the Bison population from approximately twenty individual in 1948 (Record of Decision, 2007) to more than a thousand in 2013. One of the primary causes of this population explosion is reduced winter mortality for Bison. Well-fed bison are well suited to withstand even the harshest Wyoming winters. Consequently, the large Bison population has increased the cost and limited

the effectiveness of supplemental winter-feeding for the Elk population. The JHV has a limited carrying capacity for the number of large ungulates that it can support; artificial means of supporting a population inhibit the natural ecosystem from self-organizing.

Competition between different constituents for natural resources poses a ‘commons dilemma’. In the most general sense, the ‘commons’ can be understood as a set of resources, natural or cultural that are shared through the collective action of constituent groups. In 1968, biologist Garret Hardin wrote an article entitled: ‘Tragedy of the Commons’, which argued that the only way to prevent degradation of shared resources by self-interested parties was through privatization and state control. However, research by Elinor Ostrom, a Nobel Prize of Economics recipient, points in a different direction. By examining multiple case studies of shared resources around the world, Ostrom concluded that in collective action situations, communities were able to maintain a shared resource effectively over time. She later developed the Institutional Analysis and Development (IAD) framework as an option to analyze in more depth the dynamics of shared resources. Based on the IAD framework the Robustness framework was developed to examine the interactions among the external variables of the IAD (e.g. biophysical context, attributes of the community, and rules in use) that influence the dynamics of shared resources (Anderies, Janssen, and Ostrom, 2004).

The aim of this paper is to analyze the appropriation of limited natural resources as the commons dilemma present in the JHV. We applied the Robustness framework through stakeholders’ interviews and external research to capture the complexity of the Socio-Ecological System (SES) within the JHV. Through the use of the Robustness framework, we will examine the commons dilemma in relation to the shocks, vulnerabilities and capacity of the SES within the JHV; associated to the Elk and Bison management strategies and supplemental winter feeding this framework will provide an alternative lens to examine the interactions among stakeholders within the JHV.

2. Methods

2.1. IAD and Robustness Framework

The IAD framework is best thought of as a conceptual map. The IAD framework focuses on the “action arena”, where social choices and decisions take place. This social arena is influenced by three external variables which are: the biophysical context, attributes of the community, and the rules in use. The rules relevant to the IAD framework include boundary, position, scope, choice, aggregation, information and payoff rules (Ostrom, 2011). Attributes of the community describe factors such as; diversity, values, beliefs and norms. The biophysical context include natural factors that affect the availability of the resource.

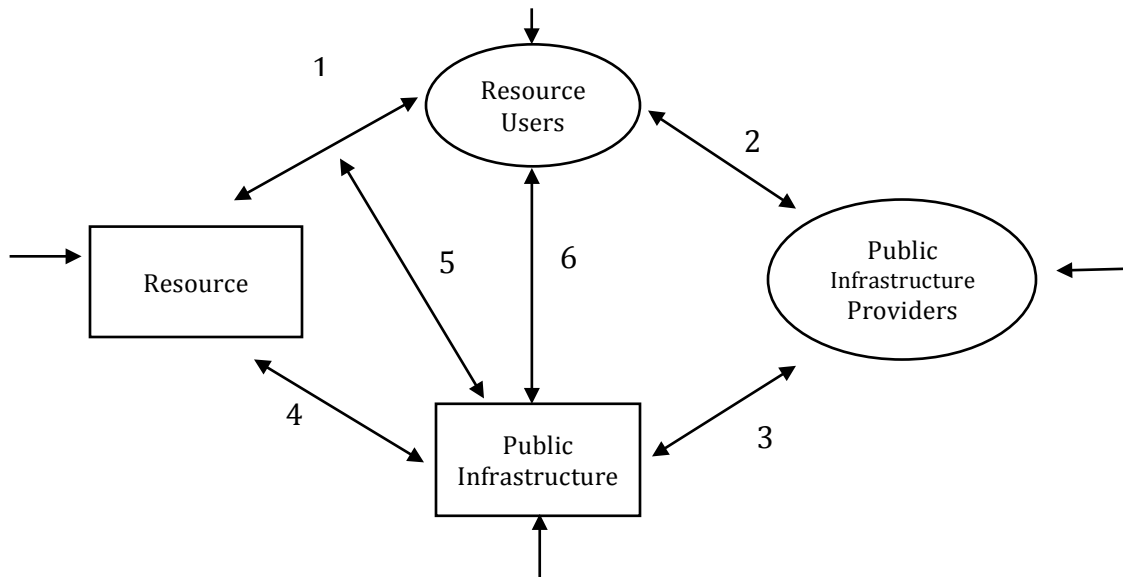


Figure 1. System Representation: Robustness Framework (Adapted from Anderies et al., 2004).

Each set of resource users is not exclusive in this case study, and many individuals receive multiple streams of goods and services that reflect their preferences. Also, the natural infrastructure and opportunities for RU vary seasonally. Public infrastructure providers (PIP) can be categorized as formal and informal agencies. Formal agencies govern the Resource (R), whereas, informal agencies educate the RU about the Public Infrastructure (PI). A table in the supporting information section illustrates the PIP that governs the R and the organizations that they are nested within. The management structure of the PI is complex, and involves several agencies, with different missions and goals that govern the R. For example, the Wyoming Game

and Fish Department (WGFD) is responsible for ‘wildlife,’ but do not manage the habitats on which they forage.

The Robustness framework expands the external variables of the IAD framework. The robustness of a SES is defined by Anderies et al. (2004) as systems “[...] in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units”. By employing the Robustness framework, we have examined the SES’s ability to maintain structure and function in the face of disturbances. Throughout this applied research, we used the Robustness framework to examine the entities and links within the SES of the Jackson Hole Valley

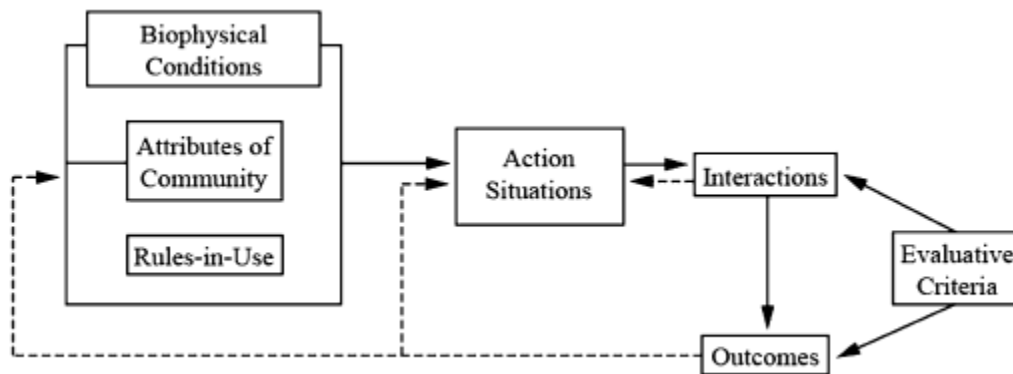


Figure 2. System Representation: Robustness Framework (Anderies et al., 2004).

2.2 Data collection process

In order to determine which stakeholders would be fruitful to interview, we conducted a literature review of Bison Management in the JHV. Representatives from various agencies were interviewed on two separate trips. The first trip took place from October 7 - 9, 2013 and the second trip in November 15 - 19, 2013, in and around Jackson, WY. The interviews conducted were designed to elicit information relevant to the Robustness framework and the entities involved; namely, the resource, the resource users, the public infrastructure, and the public infrastructure providers.

3. Current State of the Jackson Hole Valley

The JHV is a part of the Greater Yellowstone Ecosystem (GYE), which is well known for its game-rich valleys. The GYE is approximately 19 million acres and its watershed contains the headwaters of the Missouri-Mississippi, Snake-Columbia, and Green-Colorado rivers (Lynch et al., 2008). There are numerous jurisdictional boundaries within the GYE including: two national parks, seven national forests, private land, state land and Native American Reservations (Lynch et al., 2008).

The JHV exhibits similar complexity with respect to jurisdictional boundaries; however, there are other aspects that compound the complexity of the system. Within the JHV, lay the Grand Teton National Park (GTNP), the National Elk Refuge (NER), and the Bridger-Teton National Forest (BTNF) (see Figure 3). These areas are adjacent, but the jurisdictional boundaries delineate which actions are permissible. Each of these areas is governed by different agencies, which are bound by organizational directives and missions. Not only is the governance structure complex, so too is the natural environment. Within the JHV there is a complex interplay between ecosystems and the habitat they provide for numerous species; there are alpine, forest, rangeland, sagebrush, wetland and riparian ecosystems within the Valley (Matson, 2000; Smith, Cole & Dobkin, 2004).

Within these ecosystems, the most prominent and visible wildlife species are large ungulate species; namely, Moose, Mule Deer, Elk and Bison. The boundary between the NER and the GTNP is an important boundary for both Elk and Bison. The complexity of the situation is further compounded by the attributes of the community within the JHV. There are a variety of constituent groups who have vested interests in the flows of goods and services from the natural environment. The community within the JHV is vocal, active and heterogonous in beliefs. These subgroups consist of sportsmen, recreationalists and artists. An engaged constituency is a valuable asset in wildlife conservation, however there are tradeoffs of this aspect. The attributes of the community in the JHV increase the complex of the decision making process and inhibits rapid response measures.



Figure 3. The jurisdictional boundaries of the NER, GTNP and the BTNF ("Map of Grand")

3.1 National Elk Refuge and Bison Management

The NER, adjacent to the town of Jackson, was established by Congress 1912 in an effort to reduce winter mortality of Elk by protecting winter rangeland. The largest remaining Elk herd in North America was in need of sanctuary. Much of their winter rangeland was appropriated for other uses or became inaccessible due to “changes in land use and development” in the late 1800’s (U.S. Department of the Interior, 2007). Thousands of Elk winter in the NER. The process of “supplemental feeding” was initiated to provide adequate forage for the large Elk population (U.S. Department of the Interior, 2007) to keep winter mortality to socially acceptable levels. However, over the years, Bison too have found sanctuary and the supplemental feeding in the NER during the winter.

The present Bison herd in the JHV originated from a herd of about twenty individuals that were re-introduced in 1948. After nearly two decades of physical confinement, the small Bison herd escaped and was allowed to roam free throughout the JHV (Leopold et al. 1969; U.S. Department of the Interior, 2007). Several interviewees indicated that the Bison herd maintained a relatively stable population prior to their discovery of supplemental winter feeding in the NER, in 1975. The growth of the Bison population has interfered with the NER goals of reducing

winter Elk mortality. They found Bison to be dominant and aggressive toward Elk on the feeding grounds. In order to meet their objective, the NER needs to feed Bison first and away from the Elk. Bison are hearty animals. A well-fed Bison population exhibits little to no winter mortality and has led to substantial population growth. Since the discovery of supplemental feeding, the Bison population has been growing at a rate of about 13% per year (U.S. Department of the Interior, 2007).

In addition, the growth of the Bison herd was supported by the 1998 litigation process between the Fund for the Animals and the U.S. government (Fund for Animals v. Clark, 1998). The litigation required “additional National Environmental Policy Act (NEPA) compliance” to understand the impact of supplemental winter feeding on the Jackson Bison population (U.S. Department of the Interior, 2007; Schumaker, Peck & Kauffman, 2012). A better understanding of the herd response to feeding would better inform sound population control measures for the herd (U.S. Department of the Interior, 2007). Throughout the litigation process, the harvest of bison was not substantial enough to curb population growth supported by supplemental winter feeding. A Record of Decision was submitted on April 2007, which indicated that the Alternative 4 was selected as the desired management approach. Alternative 4 states that the populations and habitats will be “adaptively managed [...] to achieve the desired conditions over 15 years” (U.S. Department of the Interior, 2007). The desired populations for Bison and Elk, are 500 and 5,000 respectively (U.S. Department of the Interior, 2007). A number of interviewees corroborated this information.

3.2 Rules in Use (IAD)

The rules-in-use denote attempts to capture characteristics of human-made infrastructure as they relate to the commons dilemma. There are a range of rules in relation to the management of the bison population, these rules consist of: boundary, position, scope, choice, aggregation, information, and payoff rules. These rules are established as a part of the Public Infrastructure within the Robustness framework.

The rules affect the interactions between entities within the Robustness framework. Many rules also indirectly affect other components of the action situation via the interactions among the components involved in the action situation (Anderies & Janssen, 2004). The followings are example of the rules in use related to bison in the JHV.

Boundary Rules

- Members of the general public wishing to hunt on the refuge must have a valid State of Wyoming Bison Hunting License, and a valid Hunter Safety Card (or certification) or a current Hunter Safety Instructor Card issued by a state.

Position Rules

- The bison hunting program for the general public is administered by the National Elk Refuge, which is licensed by the Wyoming Game & Fish Department (WGFD).

Scope Rules

- Population objective of approximately 500 animals for the Jackson bison herd. WGFD sets the objective levels for the herd.

Choice Rules

- Hunters with a hunting tag permit will be required to hunt the wildlife defined by that hunting tag on hunting permitted areas.

Aggregation Rules

- Population objective levels are set by WGFD after review and public hearing process.

Information Rules

- Hunters will be provided instructional materials on identification of sex and age of bison in the field to enhance selection of the type of animal that their permit specifies.

Payoff Rules

- The CFR contains all the generally applicable rules with current and future effects as it pertains to bison and elk management at the National Elk Refuge and Grand Teton National Park.

4. Robustness framework.

The application of SES Robustness into the system provides the understanding of the relationship between society and natural environment in the JHV. In the figure below we applied the framework into the system:

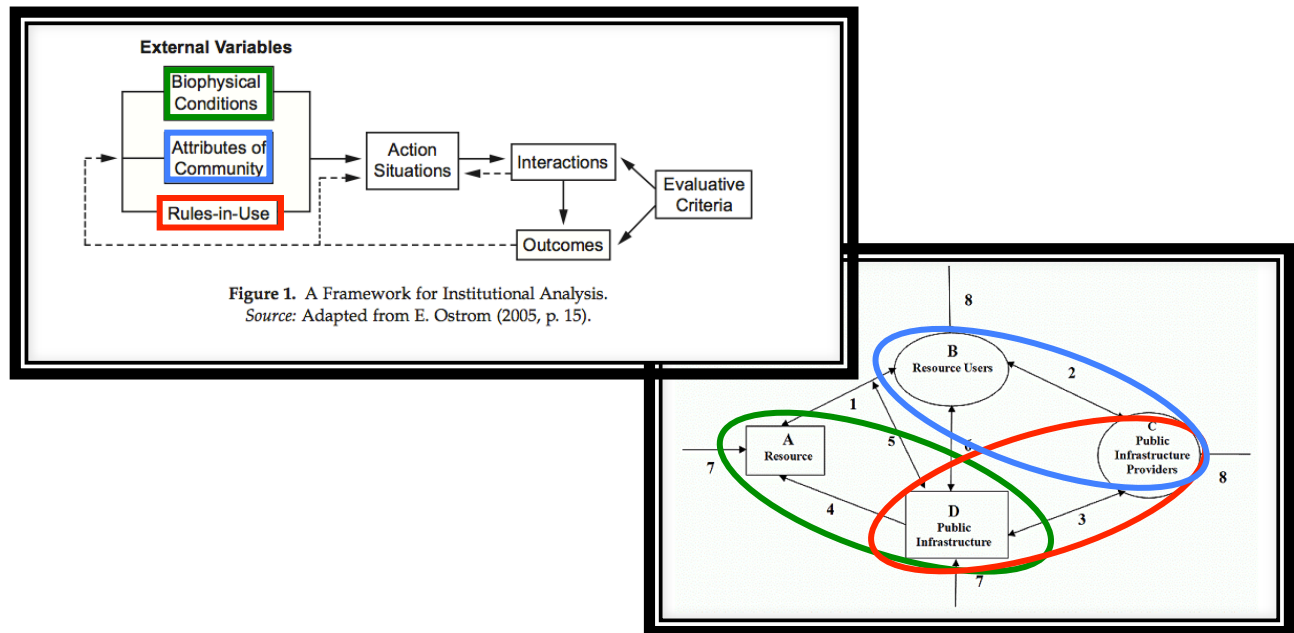


Figure 4. Robustness demonstration relationships human and natural systems.

Adapted from (Ostrom 2005; Anderies et al., 2004).

Resource

The resources in the JHV is the natural environment that sustain the wildlife and the wildlife. The natural environment is the JHV ecosystem including GTNP, NER, and BTNF. The wildlife in this case are aquatic, avian, and mammalian (ungulates, etc.) living in the natural environment of the JHV. These two resources provide streams of goods and services to the heterogeneous resource users and are managed by public infrastructure providers with various missions.

Resource Users

The resource users are artists, bikers, conservationist, fishermen, hikers, hunters, photographers, residents, tourists and tribal nations who benefit from the resources. We organized the resource users into the following subgroups: recreationalists, sportsmen, and residents. These subgroups represent a heterogeneous and engaged community.

Public Infrastructure

There are soft and hard public infrastructures in the system. The laws that commit the valley for preservation under the USFS, NPS, and NER are soft infrastructure developed in the late 19th century. Hard infrastructure administered by various governance agencies and facilitated by NGO. These include wildlife hunting and fishing programs, the supplemental winter feeding program, recreational and irrigation infrastructure, and wildlife conservation and hunting community forum.

Public Infrastructure Provider

There are a number of agencies that work to manage the land resources on which Bison and other wildlife roam. The WGFD manages the wildlife species within the State of Wyoming. The USFWS manages the NER and the winter feeding program. The man made infrastructures are managed by different governance agencies each with a separate mission, activities and focus. The NPS manages the land and boundaries of GTNP. The USFS manages the national forests that surround GTNP and the NER. The Wyoming Department of Transportation is responsible for the transportation system that connects these land management agencies. Non-governmental agencies also provide a soft infrastructure in community forum and also organize wildlife management and education projects together with the governmental agencies.

The relationship within the system describe the interaction, challenges that could be encountered, and shocks that can has the potential to disrupt the system as we see today. Examples of these are presented in the table 1 below.

	Description	Potential challenges	Potential outcomes
Relationship #1 [R] to [RU]	Streams of goods and services from wildlife through hunting, recreation, etc.	Over popularity of the resource benefit	Increase the number of resource users
[RU] to [R]	Harvesting (hunting and fishing) Habitat encroachment / ecological disturbances	Under harvesting of bison Residential development encroachment	Natural environment to be degraded due to overgrazing Reduction in winter forage, Wildlife on private property issues
Relationship #2 [RU] to [PIP]	Public hearing on management direction	Vocal and heterogeneous resource users	PIP decision making is slow due to consensus building
[PIP] to [RU]	Recreation, hunting and fishing permits Education and outreach	Complex and costly hunting permit Complex information	Reduction in number of hunters leads to reduction in predation Uninformed subgroups
Relationship #3 [PIP] to [PI]	Management towards Natural Infrastructure. Ex. Forest ecosystem Management towards Human Made Infrastructure: - Supplemental winter feeding - Recreational infrastructure - Community forum for wildlife harvesting and ecosystem	Abundant forage leads to more wildlife Reduction on winter mortality Increase human use of the natural environment Reduction in participation of the forum due	More animal leads to degradation of forest ecosystem High growth rate of bison. Wildlife encroachment Reduction management capacity of the community
Relationship #4 [PI] to [R]:	Management of wildlife and of forest habitat and infrastructure	Slow management due to heterogeneous values Complex objective and goals	Explosion of population due to slowness of management
Relationship #5 [PI] to [R]&[RU]:	Seasonal closure Hunting restrictions Activity Boundaries	Reduction in tourism Reduction in anthropogenic predation Continuing harvest target short comings due to wildlife safe zone	Local economy decline Wildlife growth rate not reduced

	Description	Potential challenges	Potential outcomes
Relationship #6 [PI] to [RU]: [RU] to [PI]:	Monitoring and sanctioning related to: Hunting and fishing by WGFD and USFWS Recreational infrastructure by NPS and USFS Conservation investment in natural ecosystem Investment in manmade infrastructure	Not enough enforcement officials for the vast area	Poaching and food storage hazards to other resource users
Disturbance #7 Shock to [R]	Diseases: Ungulate (Chronic Wasting Disease (CWD) and Brucellosis) Excess of Conservation and Hunting activities Depredation of wildlife and natural environment [R] by humans [RU] or predator [R]		
Disturbance #7 Shock to [PI]:	Divestment and investment of manmade infrastructure (supplemental winter feeding & Recreational Infrastructure). Ecological conservation activities		
Disturbance #8 Shock to [RU]:	Changes in resource users due to the change in town demography and (inter)/national economy. Changes in transportation method to Jackson (airport and road closure)		
Disturbance #8 Shock to [PIP]:	Governmental agencies disturbances (financial restriction, mandate, or mission changes) Community forum break down which reduces stakeholder cooperation in decision making		

5. Discussion

The issues related to wildlife management (i.e. large ungulates, Elk and Bison) are based on natural and social pressures. The natural environment in the JHV is subject to ungulate disease and is governed by a complex jurisdictional management system. The land use (social) pressures from the town, ranching, and tourism surrounding the natural environment confine Elk and Bison to the BTNF, GTNP and NER. Larger ungulate outside this area have the potential to damage private property and transmit disease to cattle. One of the many strategies to keep the bison and elk in the area is through supplemental feeding in the NER. This strategy increases Bison and Elk population density in the valley.

Issue	Shocks	Vulnerability	Capacity
Elk, mule deer & moose die-off	Chronic wasting disease	High density of elk & bison	Society cares highly of wildlife
High density of elk & bison	Brucellosis outbreak	Overgrazing and rancher's damages	EIS address this issue
Complex bison hunting	N/A	Jurisdictional boundaries limits bison hunting	Moves towards Changes hunting tag and boundary
Wildlife management slow reaction	N/A	Bison population explosive growth	Multi-departmental adaptive management
Heterogeneous values	N/A	Gridlock in decision making	Society cares highly of wildlife

5.1 Disease

A major issue of concern is the high density of ungulate species. Both Elk and Bison populations are more vulnerable to disease transmittal under these circumstances. Supplemental winter feeding has come under scrutiny for causing increased density of the Elk and Bison populations. A major concern is the transmittance of brucellosis, which is a bacterial infection. Brucellosis can cause reproductive failure in ungulates and is commonplace in the Jackson Elk and Bison herds. Studies had shown that brucellosis can be transmitted between species through oral contact with infective tissues and fluids associated with aborted fetuses. Cattle ranchers have eradicated brucellosis from their herds, however the potential for infection is a contentious issue that can impact a rancher's ability to export cattle out of the state, and therefore poses an

economic risk to the cattle industry (Economic Analysis Division, 2004). At present, there is the high propensity of infected elk and bison hindering eradication of the disease and have been linked to cattle outbreaks since 2002 (Ragan, 2002). The supplemental winter-feeding of elk at NER is of great concern, because of the increased potential for disease transmission at higher densities of elk on feeding grounds.

A big shock to the system is the effect of a fatal transmissible disease called Chronic Wasting Disease (CWD), on the JHV population of deer and elk. Animals contracting this die within several months. Since 2000 this epidemic have spread from southwest Wyoming and northeast Colorado towards two direction: towards northeast into Nebraska and South Dakota; and towards southwest into northwest Colorado and northeast Utah (Belay et al., 2004). Locals have voiced concerns of this disease and its effect on the valley and some voiced their incredulity towards the disease's fatal effect (Interviews 2013).

5.2 Community

The community within the JHV is both vocal and heterogonous. This represents both a vulnerability and a capacity. The community values wildlife and the conservation of large ungulates within the valley. Therefore they have a vested interest in ensuring governance of the natural resources within the JHV. There is substantial input from the community concerning outcomes and actions of an effective governance strategy. However, there are many different views concerning how to govern these resources. The high participation levels slow the decision making process and reduce the capacity of public infrastructure providers to take prompt action. For example, the 1998 litigation process inhibited the active management of the resource for nearly a decade.

5.3 Complexities in Bison Reduction

The reduction of bison through hunting is undermined by current regulations that limit hunting to specific locations. The hunting of Bison is only allowed within the jurisdictional boundaries of the NER and the BTNF, and prohibited within the GTNP. In turn, Elk can only be hunted outside the NER. After several hunting seasons, the Bison population began to spend more and more time within the jurisdictional boundaries of the GTNP. This has limited the capacity to use hunting as an effective population management tool. Numerous interviewees have expressed that the Jackson Bison herd has come to recognize that the GTNP provides safety from hunters. In order to avoid hunting within the park hunters are advised to be cognizant of the exact park boundaries. However, in 2011 a hunter was charged for hunting within the boundaries of the GTNP ("Hunter charged for," 2011).

Another aspect that leads to the complexity of bison reduction is the hunter's difficulty of getting a bison tag because of limitation for tags and high fees. Wyoming state legislators have recently introduced two bills that would reduce the cost for bison tag and also lift limitation of one bison in a lifetime (Hancock, 2013).

6. Conclusion

This research has utilized the Robustness framework as a 'lens' to understand the complexity involved in the iconic JHV. The JHV can be classified as a SES, as there are multiple interactions between the natural and human systems. A literature review and interviews with multiple agencies provided insights into the interactions between entities within the Robustness framework (links 1-6). The Robustness framework has helped systematically identify the various capacities, vulnerabilities, and shocks (links 7 & 8) that the JHV is prone to. We hope that this research is of use to various entities within the JHV as a tool to help convey the complexity of the situation and build social capacity. We further hope that the research will continue and evolve over time with our collaborators in Jackson, WY.

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