Conserving Biodiversity: A Qualitative Method for Analyzing Federal Environmental Policies in the Greater Yellowstone Ecosystem

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TABLE OF CONTENTS

CHAPTER **PAGE**

1. INTRODUCTION

Biological diversity includes the variance in genes, organisms, and relationships found in nature. Also called biodiversity, it provides countless economic, social, and personal benefits to people in the United States and all over the world. In the U.S., this is recognized by the federal government most explicitly in the Endangered Species Act's protections for those flora and fauna whose survival is least likely and most endangered by human action. Unfortunately, there are many anthropogenic threats to biological diversity. In order to protect this incredible natural resource, responsible management must be implemented across all levels of government. Given the amount of funding, large spatial scales, and public interest at stake, the federal government is the best suited to this task. The federal government must play a key role in the protection of biological diversity.

The purpose of this paper is to provide a qualitative analysis of the federal government's management of biological diversity in the Greater Yellowstone Ecosystem. Examining management at these scales is uncommon, yet extremely valuable. By examining management on scales that coincide with the scale of natural processes, we can better see the broad implications and interactions of our management policies. We can also determine how to sharpen management in order to more accurately address these important scales. In order to achieve this, a basic overview of modern conservation science and terms to be utilized will be provided. Building upon this overview, four categories will be describe, which, according to the science, are vital to the preservation of biological diversity. These categories are cores, connectivity, restoration, and monitoring. There will be three standards used to assess the quality of policy. Scientific foundations, the human-nature nexus, and adaptability are these three measures. The

Greater Yellowstone ecosystem will then be described. Finally, in each of the four categories, examples of policy or management action will be described and analyzed via the three measures of successful policy. This analysis shall provide examples of policies with varying degrees of success. By extrapolating management from these representative case studies, an aggregate picture of management across the ecosystem will be gained. It is hoped that such analysis will uncover areas where management may be improved and facilitate the spread of successful policies and management ideas. It is also intended as a suitable framework for examining and creating biodiversity management policies in other ecosystems, regions, and countries.

2. CONSERVATION SCIENCE

In 1985, Michael Soulé introduced the emerging field of conservation biology. His classic piece "What is Conservation Biology" (Soulé 1985) described an entirely new, interdisciplinary field aimed at providing "principles and tools for preserving biological diversity" (Soulé 1985). For over 20 years, this article has defined a growing scientific field at the forefront of protecting our biological resources. However, a great deal has changed in the world, and especially in conservation, since 1985. In order to find success in the pursuit of the preservation of biological diversity, an understanding of the most up to date conservation science is required.

In this section, I outline a modern understanding of conservation science. Starting with a description of the central focus and the values behind the field, I then posit several key tenets of conservation science which may be used as benchmarks, or qualitative measures of effective biological conservation.

Although much has changed since Soulé's groundbreaking piece, one thing remains constant: the goal of conservation science. At its heart, the purpose remains the preservation of biological diversity. Which begs the question, what exactly is biological diversity? Originally, this term was used synonymously with species diversity, but has since become more inclusive and multidimensional (Olson 2006). According to the Society for Conservation Biology, biodiversity includes three distinct components: (1) *All forms of life,* from bacteria and fungi to vertebrates (2) *All levels of organization of life,* ranging from genetic material, to species, to ecosystems (3) *All the interactions among the forms of life and their levels of organization*, including competition, predation, symbiosis and more (Society for Biological Conservation, 2013). These principals are summarized more concisely by the Global Biodiversity Assessment as taxonomy, genetics, and ecology (Heywood 1995).

Also central to the field of conservation biology are several "normative postulates" (Soulé 1985). Essentially, these are a set of values which are inseparable from conservation science; they provide the mandate for action and a guide for research for those in the field. There are four such postulates: biological diversity is good, ecological complexity is good, evolution is good, and biotic diversity has intrinsic value, irrespective of its instrumental or utilitarian value (Soulé 1985). While the final of these postulates is a philosophical understanding of humanity's place amongst existence, the remaining three postulates have scientific foundation. Many of the ecosystems services and aesthetic qualities which humans depend upon are themselves reliant upon biological diversity and ecological complexity: both of which derive from evolutionary processes.

But why conserve biological diversity? There exist at least two powerful reasons to pursue this mission: ethics, and socio-economic incentives. From an ethical perspective there are several arguments for the protection of the world's biodiversity.

In nearly all cases, it has been anthropogenic alterations to the environment which have caused environmental degradation. While it is true that natural disturbances may temporarily impoverish an area of its biodiversity, these disturbances are part of a region's *ecological memory* (Bengtsson et al. 2003). This means that ecosystems have evolved "the capacity to reorganize and recover from perturbations" (Bengtsson et al. 2003). In certain cases this capacity exists for human-caused disturbances, such as the human-dependent, "cultural landscapes" of Europe, Africa, and Asia (Vos & Meekes 1999). However, this is not the norm. The vast majority of cases of human disturbance degrade the landscape. This clearly leads to the ethical concern of human responsibility, and, for many, necessitates "benign human intervention" (Soulé & Noss 1998).

In addition to this responsibility, there exists an imperative for our individual and social health. Some scholars implore society to restore the emotional and subjective essence of "wild" to our landscapes. Without large unimpeded expanses of nature, complete with a full range of wildlife (especially large carnivores), "human opportunities to attain humility are reduced" (Soulé & Noss 1998).

Beyond the ethical imperatives, which for many are less convincing, are a whole host of economic and social benefits that coincide with the preservation of ecosystems and biodiversity. These benefits include purification of air and water, mitigation of floods and drought, generation and renewal of soil and soil fertility, pollination of crops and natural vegetation, nutrient cycling, partial stabilization of climate, UV protection, generation of compounds and features which are key to agricultural, medicinal, and industrial advances, support of diverse human cultures, and the aesthetic beauty and intellectual stimulation which provide for the enrichment of human life (Daily 1997). Globally, these services are valued at between $2.9 and $33 Trillion every year (Heywood 1995, Daily 1997). While these services are mostly maintained by ecosystems themselves, the preservation of biodiversity is viewed as essential insurance for the long term sustainability of ecosystems, as well as the services they generate (Folke et al. 1996, Naeem 1998). It has been shown that stability, functioning, and sustainability of ecosystems depend upon biological diversity: with increased species and relationships in an ecosystem come increased functional roles (Tilman 1997). The widespread acceptance of this fact is demonstrated by the spectrum of parties to the Convention on Biological Diversity, which now consists of 193 nations (Convention on Biological Diversity 2013)[1].

In order to fulfill its purpose, the field of conservation science has become academically broad and ever-expanding. From its introduction it included fields ranging from Genetics to Biogeography to Physiology to Ecophilosophy to Natural Resource Management (Soulé 1985). With recent descriptions it has become even more inclusive, with the fields of Economics, Agriculture, Anthropology, Sociology, Public Health, and Climate Science, all contributing (Kareiva & Marvier 2012). Essentially, conservation science has come to recognize that "nature can prosper so long as people see conservation as something that sustains and enriches their own lives" (Kareiva & Marvier 2012) and therefore has integrated human *and* natural needs into its area of consideration.

This point, however, is not universally recognized. According to Michael Soulé and Reed Noss, "a conservation plan cannot give equal weight to bio-centric and socioeconomic goals, or the former will never be realized. Biology has to be the bottom line." (Soulé & Noss, 1998)[2]. It is this intellectual divide which continues to place conservationists at odds with each other and the broader populace. A truly balanced vision for the future of people and wildlife may not be quite as bio-centric as some would hope, but at least it is plausible.

Given the basic mission and attributes of conservation science, it is now necessary to outline certain tenets of the field which may be used as categories for examining current conservation policy and implementation by the federal government. As there is currently no broadly accepted framework for requisite conditions for the preservation of biological diversity,

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[1] The United States has yet to ratify this treaty. However, this is due to political pressure surrounding technology transfers and intellectual property rights provisions (Tinker 1995), not a lack of acceptance of the scientific foundations.

[2] While this view is understandable, especially in light of many political compromises in regards to balancing conservation and humans, this author strongly disagrees.

it is necessary here to devise a novel collection of such tenets. This collection must represent the various current understandings of conservation science and provide qualities which, when fully enacted, help to secure the preservation of biodiversity.

The categories I have selected as necessary for the conservation of biological diversity are: Cores, Connectivity, Monitoring, and Restoration. These four categories are vital to the protection of biodiversity, especially in lieu of a specific and targeted governmental focus on biodiversity conservation. Federal environmental policies which address these four categories in the Greater Yellowstone Ecosystem shall later be analyzed. But first, the ideas, utility, and current science behind each must be demonstrated.

2.1. CORES

The idea of cores or wildland areas is not a recent development in the history of conservation. Beginning with the creation of Yellowstone National Park, the idea of the core area was that it maintain “the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (“Organic Act” 1916).

We can see clearly, in one of the very first clarifications of a core area, an example of one of the current scientific mandates for such reserves: *persistence*. Persistence is the idea that once established, reserves should “promote the long-term survival of species and other elements of biodiversity they contain by maintaining natural processes and viable populations and by excluding threats” (Margules & Pressey 2000). The second primary biological objective of reserves is *representativeness.* This refers to the need for cores to protect the full range of biodiversity of an area (Austin & Margules 1986).

When both of these goals are met, core areas may fulfill their role as a central element of conservation regimes, as areas that “are of the highest conservation value and are often irreplaceable” (Noss et al. 1996). Cores often act as source populations which maintain and rejuvenate species populations in surrounding, less intact habitats, or sink populations. This source dynamic of a core area has been clearly documented with Grizzly bears in the Greater Yellowstone Ecosystem (Schwartz et al. 2012), where populations from the national parks and forests in the ecosystem act as sources for more fragmented areas. There is fairly unanimous agreement on core, reserve, or wildland areas as being a central component of any conservation strategy (e.g. Noss et al. 1996, Soulé & Noss, 1998, Groves et al. 2002). This does not mean that all cores are currently meeting these goals, however, and much work is being done on expanding current notions of cores in order to fulfill their potential (see Bengtsson et al. 2003).

At the heart of this work is the recognition that cores alone are not enough to protect the biodiversity they contain. Whether due to reserve size, population dynamics, edge effects, or disturbance size relative to reserve size, there are numerous reasons why core areas alone are not sufficient (Bengtsson et al. 2012). A concrete example would be the loss of native mammal species that has occurred in many U.S. National Parks in recent years, even amongst the largest of these reserves (Newmark 1995). So what exactly is missing? As Noss et al. posit, “the landscape context is at least as important as internal habitat quality to the viability and defensibility of core areas” (Noss et al. 1996). A central property of landscape context is connectivity.

2.2. CONNECTIVITY

Connectivity is the next category I will use for evaluating federal biodiversity management. The idea of connectivity came as the logical outgrowth from the realization that cores alone are not enough to maintain biodiversity. According to Soulé and Terborgh, "the elements of the solution to this problem are known: bigness and connectivity" (Soulé & Terborgh 1999). While these appear to be two distinct elements, they are in fact one. If many cores are protected and connectivity between them is strong, the landscape as a whole retains the qualities of large spatial scale. Connectivity in the landscape creates the element of bigness.

There are two aspects of connectivity, structural and functional. Structural connectivity refers to the physical qualities of the land, or the "spatial arrangement of different types of habitat" (Crooks & Sanjayan 2006). Functional, or behavioral, connectivity refers to the responses of individuals, species, or processes to the physical structure of the landscape (Crooks & Sanjayan 2006).

Supporting connectivity is the idea that "promoting the movement of individuals between fragmented habitats can increase the persistence of populations and local survival of species" (Soulé & Terborgh 1999). This movement of individuals, also known as dispersal, is seen as a critical ecological process (Ims & Yuccoz 1997, Calabrese & Fagan 2004). Dispersal is an ecological process and thus may have negative outcomes as well. It is possible that, if core habitats are not large enough, connectivity will allow for dispersal rates which exceed reproduction rates. This would entail the dispersal of a previously concentrated species to the point where the population faces rapid declines. However, as long as a core is large enough that migration out of a core does not affect the population viability of species within it, then connectivity can only play a positive role. Landscape connectivity in these cases maintains rates of dispersal for species and organism which does not threaten their viability and is vital to protecting ecological processes.

Another prominent feature of connectivity research is the role that connectivity plays for large predators. The scale of ranges for large predators such as the grizzly bear, is well above that of any reserve in the continental United States. Grizzly ranges are approximately 20,000 km squared, whereas Yellowstone National Park, for example, is approximately 8,800 km squared (Craighead, 1976). This, in combination with low population densities, gives some idea as to the mismatch between large predators and cores, and highlights the urgent need for connectivity.

While there is a wide variety of connectivity metrics, there is also a lack of consensus over which metrics to use in what cases (Tischendorf & Fahrig 2000). However, there is agreement that instruments of connectivity, both political and actual, must be designed for specific species (i.e. Tischendorf & Fahrig 2000, Belisle 2005, Crooks & Sanjayan 2006). Due to behavioral characteristics and elements of spatial scale such as genetic distribution requirements, individual species have varying requirements for connectivity. Thus, in designing connectivity policies and instruments, explicit acknowledgement of goal species or processes is mandatory.

While there is still disagreement about the specifics of the term connectivity (Crooks & Sanjayan 2006), the need for connected landscapes is clear. As habitat destruction and fragmentation are the most pressing threats to biodiversity (Wilcove et al. 1998), improved connectivity should be an immediate goal for any management regime hoping to preserve biological diversity. The work of establishing and facilitating connectivity on the ground is far from easy. Jurisdictional boundaries, issues of scale, and the complexity and species by species basis are all major obstacles to its implementation.

2.3. RESTORATION

The next category in which I will examine federal policy in the GYE is restoration. Generally, the term restoration refers to actions which aid in the reconstitution of functioning large-scale ecosystems with natural disturbance regimes that allow for as full a spectrum of biological diversity as is practical, including the presence of apex predators. This understanding of restoration coincides with Soulé and Terborgh's (1999) mandate for restoration of keystone species and disturbance regimes as the only way to ensure the return of top-down regulatory processes. This is in contrast to local restoration projects which are "modest in scale and ambition and are oriented toward plants and bottom-up processes" (Soulé & Terborgh 1999).

While it is central to most management schemes, the concept of the restoration of ecosystems is disputed. There exist both terminological issues, focused on what activities constitute restoration (Hobbs & Norton 1996), and theoretical ones, focused on the term restoration (Higgs 1997) and the possibility of restoration at all (Elliot 2000). Perhaps most centrally, is the inherent promise of the word's etymology: that of bringing back a place to some previous state. This notion is a common misunderstanding of restoration, and represents an "increasingly untenable notion that an ecosystem can be returned to some previous state and raises the subsidiary question of the date of the original condition" (Hobbs et al. 2011).

Large scale restoration of these top-down ecological regulatory processes is a daunting task, one whose scope and complexity almost assuredly require federal action. Thus, policies containing such restoration will be looked for and examined. According to conservation biologists, this large-scale restoration requires that three distinct factors be addressed: control of invasive species, reintroduction and support of threatened native species, and the reestablishment of natural disturbance regimes (Soulé & Terborgh 1999). While a full and immediate restoration of pre-western ecological conditions is not likely, the federal government is in the best position to pursue this work and has a responsibility to do so if it wishes to protect the invaluable natural resources it possesses.

2.4. MONITORING

The final category to be used in examining federal policy in the GYE is monitoring. Monitoring is essentially the continued collection of data regarding environmental factors and health of the ecosystem. As stated by Lovett et al. (2007), "monitoring should be considered a fundamental component of environmental science and policy." In the arena of law and policy, monitoring "can provide essential information to regulators, legislators, industry, and the public about... the conditions of the ecosystems human life depends upon" (Biber 2007). Monitoring provides information on the effectiveness of regulation, safety for public health, and a benchmark for future policy. On a managerial level, effective monitoring is the foundation of adaptive management. An "accurate assessment of the extent of the problem" is a prerequisite of both formulating a plan and maintaining its effectiveness through adaptation to changing conditions (Logan et al. 2009).

On the scientific side, Carpenter (1998) suggests that monitoring is an essential component of ecosystem science. Such long-term study of conditions provide a principal record of change (especially of slowly changing variables, such as those relating to climate change), a context for short-term experiments and observations, a benchmark for extreme or unusual conditions, and parameters for environmental models (Lovett et al. 2007).

While many agree with the ideas behind monitoring, it is seen by some as unscientific, expensive, and wasteful (Lovett et al. 2007). These ideas persist because of ill-conceived monitoring plans which collect unimportant data, are inconsistent, or whose findings are not easily shared. While there are many cases where these characteristics ring true, this does not negate efficient and effective monitoring as an urgent need of sound, adaptive management and the conservation of biological diversity.

Sound monitoring is an absolutely vital part of any management scheme. Given the complexity and unknown in regards to biological diversity and ecosystems interactions, monitoring programs must be utilized, funded, and synthesized by the federal government. These programs are vital to understanding current conditions, processes, and relationships, and provide the necessary platform for adaptive management of our natural resources. The occurrence and quality of federal monitoring programs will be examined.

3. POLICY METRICS

Thus, we have cores, connectivity, restoration, and monitoring as the major areas of focus. Now that these categories, and their necessity in the conservation of biodiversity, have been established, it is time to discuss the metrics. These metrics will allow for a qualitative analysis of the suitability and probable success of specific policies which are relevant to biodiversity management in the Greater Yellowstone Ecosystem. These metrics are: (1) Scientific Foundations, (2) Socio-economic Considerations, and (3) Adaptability.

The necessity of strong scientific foundations in any policy or management for the preservation of biodiversity should be clear. The interactions and relationships amongst biotic and abiotic factors in an ecosystem are immensely complex. Due to the ever evolving nature of scientific understandings of this complexity, and their general trajectory toward accuracy, the inclusion of the most up-to-date scientific knowledge possible allows for the best possible management and policy action. Scientific foundations for the various polices shall be examined in terms of the agreement amongst those in the field on the principles included. The presence and inclusion of generally accepted scientific principles and foundations shall be evaluated.

The importance of the human-nature nexus in the public management of natural resources is one which is often overlooked by those in the hard sciences (For example, Soulé (1985), as noted earlier). This second metric denotes the two-way relationship between humans and the natural world. It also acknowledges that many management decisions have effects beyond just the natural systems they aim to control: they also affect people. In practice, it can be thought of as the attention given to socio-economic considerations. The connection between management and economic and social factors is one which must be addressed by management. Given the democratic, politicized nature of federal action, the needs of the people must be accounted for in any management plan. This can be in the form of sustainable use to maintain jobs, recreational use plans for constituents, efficient and effective use of publicly accrued funds and more. Without clearly stated positive outcomes for the people, no management plan will be politically sustainable, regardless of the environmental good it does. Enacting powerful, stable management is a necessity to natural resource management.

Another way this standard may be understood is as a balance of values or needs: between the needs of humans and those of nature. Biocentric understandings such as those put forth by Michael Soulé are indicative of arguments which are centered over the "nature" end of the spectrum. In the arguments of extractive companies, one can find viewpoints centered firmly over the human end. What I am advocating for are policies which, at the very least, have given thoughtful consideration to that balance and find themselves at a carefully considered intermediate point on the spectrum.[3] Ultimately, this standard is about recognizing the needs of both humans and nature and, when possible, working toward their mutual benefit.

The final standard I am using in order to evaluate policies is adaptability. Adaptability is the ability to understand circumstances and alter behavior to more effectively meet goals within those circumstances. It allows us to constantly sharpen our understanding of ecological cause and effect, especially in relation to natural resource management, and implement more effective management. Adaptive management confronts the evolving nature of scientific understanding, the element of uncertainty in regards to ecosystem functioning and the recognition that our knowledge of the repercussions of our management action is fallible and these actions may have unexpected consequences. By doing so, it allows managers to more effectively fulfill agency,

[3] It is worth noting that my personal values inevitably enter my analysis. And in general I lean toward the "nature" end of the spectrum.

community, and program goals. Adaptive management is both a learning tool and the ability to confront changes. In light of the coming perturbations of global climate change, adaptability in management is more important than ever.

4. STUDY AREA[4]

The Greater Yellowstone Ecosystem (GYE) covers approximately 20 million acres of land and includes Yellowstone and Grand Teton National Parks at its core. The area includes the National Parks, the surrounding Complex of National Forests and Wildlife Refuges, BLM lands and more, in the states of Montana, Idaho, and Wyoming. As the home of the very first National Park, established in 1872, the Yellowstone area holds an important place in the American psyche. With its diverse wildlife, complete with megafauna predators such as the grizzly bear and grey wolf, the GYE is well known and loved as a reasonably healthy bioregion.

One of the first academic references to the Greater Yellowstone Ecosystem occurred in a 1979 study of Grizzly Bears (Craighead 1979). Here, the geographical area of the Greater Yellowstone Ecosystem was determined by the home range of the (then much smaller) grizzly population. In 1987, Clark and Zaunbrecher found that "the GYE is recognized as a unified natural system", but that "a precise boundary of the GYE has not been delineated for policy, administrative, or management purposes" (Clark & Zaunbrecher 1987). Even today, the GYE is a widely recognized ecological area that lacks agreed upon boundaries. In part this is due to the difficulties in mapping something as qualitative as a greater ecosystem. Thus, some differences in estimates of size still exist[5], but the consensus is generally around 19 million acres (Keiter & Boyce 1994).

At the heart of the GYE are Yellowstone and Grand Teton National Parks. Together, these parks compose an area of approximately 2.9 million acres. Surrounding the parks is a

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[4] Much of the information of this section was synthesized from the author's previous work (Williams 2013)

[5] For example, the NPS suggests a minimum size of 12 Million acres (Yellowstone National Park 2013), while conservationist group the Greater Yellowstone Coalition sites a size of 20 Million acres (Greater Yellowstone Coalition 2013)

complex of 6 National Forests and 3 Wildlife Refuges that contain approximately 4 million additional acres of federally designated wilderness. This center, some of which is itself currently open to resource extraction, is surrounded by private, state, local, and tribal lands, all of which have the ability to threaten the biodiversity of the GYE. In general, protected lands in the GYE are at higher elevation, following the classic "rock and ice" conservation paradigm of scenic areas (Noss 1994) over those with greater biological value.

In terms of its ecological health and biodiversity, the GYE is the "southernmost area in North America that still contains a full suite of native carnivores, along with other wilderness qualities" (Reed F. Noss et al. 2002). These positive wilderness qualities support free-ranging populations of large ungulates and ecosystem dynamics which in some cases remain somewhat similar to their pre-industrial states. And yet, this overall biological health belies some of the shortcomings of the representativeness of federal holdings in the GYE. As noted earlier, the 68% of the GYE that is publicly owned (Gude et al. 2007) is generally higher elevation land. This means that protected land has less fertile soil, a shorter growing season, and lower primary productivity than mainly private, lower elevation valley floors (Wessels et al. 2004). This also means that most of the biodiversity hotspots are concentrated on these private lands and are thus more open to threats. Therefore protected lands, especially those with lower elevation ecosystems, must provide the best possible protections.

There are numerous threats to the biodiversity of the region. One of the most pressing of these is the ecological impact of anthropogenic climate change. The current impacts of climate change are relatively small in the region. However, the future of the GYE will most certainly be shaped by the changing conditions it presents. There remains "a tremendous uncertainty about the direction and magnitude of future environmental changes," (Romme & Turner 1991), yet biodiversity management must be able to prepare for, and adapt to, these outcomes. According to a 1999 review of the literature, the largest outcomes of climate change on biodiversity relate to (1) the shifting of vegetation zones upward across altitudes and latitudes, (2) shifts in ranges of individual species and composition of species assemblages, (3) interactions between the effects of climate change and habitat fragmentation, and (4) alterations in ecosystems functioning (Kappelle et al. 1999). Protecting biodiversity amongst all of these, and possibly other, changes will be no easy task.

A second urgent threat to biodiversity is the burgeoning human population in the GYE and with it increased exurban development (Gude et al. 2007). The region is currently undergoing a land-use and demographic shift, with the population increasing by 55% since 1970 (Hansen et al. 2002). As human population increases, so too does housing and land development, especially in areas with natural and aesthetic values such as healthy, wild ecosystems. A review by Hansen et al. (2005) found that exurban development can have harmful impacts upon reproduction and survival of native species due to factors such as increased harmful human-wildlife interactions, fragmentation, and the favoring of exotics. This continued development also appears to be increasing the potential for species depletion in National Parks (Hansen & Rotella 2002).

The social and political environment of the Greater Yellowstone is also of interest. With over 200 environmental non-profits working in the region, there is intense competition among NGO's (non-governmental organizations) for funds, projects, and attention. While this may make life for an NGO hard, it is a boon to the scientific community working to protect the greater ecosystem. There are many benefits to such a robust environmental non-profit culture. Several key roles are played by environmental non-profits. One is representing environmental interest through litigation, lobbying or other means. Acting as environmental "watchdogs" not only decreases environmental mismanagement through litigation, but also provides preemptive pressure for agencies to act within existing federal law. These organizations also contribute to the funding and implementation of scientific research and the dissemination of scientific knowledge in general (Breckenridge 1998). Finally, non-profits have increasingly collaborated with government agencies, pooling resources and knowledge in order to better preserve and manage habitats and ecosystems (Tober 1989). The social and political landscape in the region is a boon to managing its biological diversity.

The Greater Yellowstone Ecosystem was chosen as the area of study for a variety of reasons. The general health of this ecosystem, the fact that there remains much biodiversity to be saved, is a leading one. Also, due to the popularity of the area, with Yellowstone National Park alone receiving over 3 million visitors a year (National Park Service 2012), federal agencies in the GYE receive high levels of funding. These funding levels, along with the robust non-profit environment, have led to many innovative federal management policies and the potential for many more. These innovative and effectual policies will be explored. As with any governmental management, there are also areas of waste, inefficiencies and ineffectual policies. These shortcomings will also be demonstrated and assessed. The Greater Yellowstone Ecosystem is also the best studied greater ecosystem in the United States[6]. While this doesn't mean we know everything about the ecosystem, this wealth of research does create a strong scientific foundation which may be utilized in creating powerful and effective management policy.

The GYE provides an example of a well-funded, beloved, and fairly well understood ecosystem. These three factors should create one of the best resource management regimes in the

[6] A Recent (12.4.2013) search of "Greater Yellowstone Ecosystem" on Google Scholar produced 5,700 results. A number which similar ecosystems do not match (for example, "Greater Everglades Ecosystem" returned only 699 results).

United States. Thus, the GYE, and the federal resource management policies therein, shall make an excellent area of study.

5. CASE STUDIES: CORES

5.1. THE WILDERNESS ACT

As the Wilderness Act of 1964 approaches its fiftieth anniversary, it is as good a time as any to examine the consequences of the implementation of this act on the biodiversity of the Greater Yellowstone Ecosystem. Wilderness, as defined by the act, is "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain" (Section 2.(a)). While some dispute the underlying assumptions of this wording[7], the act is often lauded as one of the most important protections the United States can offer its wild places. This section shall introduce the 1964 Wilderness Act, then outline a brief history of wilderness in the Greater Yellowstone Ecosystem. Then an evaluation of the effects of the Wilderness Act on biodiversity will be undertaken, assessing the science, adaptability, and attention to the nexus of human and natural needs.

The Wilderness Act provides staunch protections for designated lands. For instance, the act mandates that lands categorized as "designated," be managed so as not to diminish the wilderness qualities and resources they possess and applies the concepts of "minimum requirements" to management decisions. These minimum requirements restrict certain uses such as motorized vehicles or mechanized equipment unless their use is necessary for the continued management of the wilderness (Section 3.(c) and Section3. (d)).

The wilderness qualities the act protects are as follows: An area that "(1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size

[7] See Core section discussion

as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value" (Section 2. (c)). In these qualities, the values of the act are made clear. It is an Act to preserve the natural qualities of an area in order to facilitate human recreation: any ecological, geological, or scientific features are secondary.

Given the history, natural qualities, and public value of the Greater Yellowstone Ecosystem, it should come as no surprise that protected Wildernesses are abundant in the area. There are 11 distinct wilderness units in the Greater Yellowstone[8]. Any designated wilderness unit becomes a part of the National Wilderness Preservation System, or NWPS. In the GYE, the majority of NWPS units are managed by the United States Forest Service, except for small sections of the Lee Metcalf Wilderness which is managed by the BLM, and Red Rock Lakes National Wildlife Refuge, managed by the US Fish and Wildlife Service. The distribution of these wilderness units forms a curious shape in the GYE. *Figure 1* illustrates Wilderness in the GYE, compared with the GYE as delineated by the non-profit group the Greater Yellowstone Coalition. In the Northern, Eastern, and Southern areas of the ecosystem, these wilderness areas form an outline of Yellowstone National Park, and provide a smaller version of the general shape of the GYE as a whole. The protections on the west of the Park are less stalwart and consist of Idaho's Harriman State Park, Red Rock Lakes National Wildlife Refuge, and some National Forest land.

[8] These are the Bridger, Teton, Gros Venture, Winegar Hole, Jedediah Smith, Lee Metcalf, Absaroka-Beartooth, North Absaroka, Washakie, Fitzpatrick, and Popo Agie Wildernesses (Greater Yellowstone Coordinating Committee 2009)

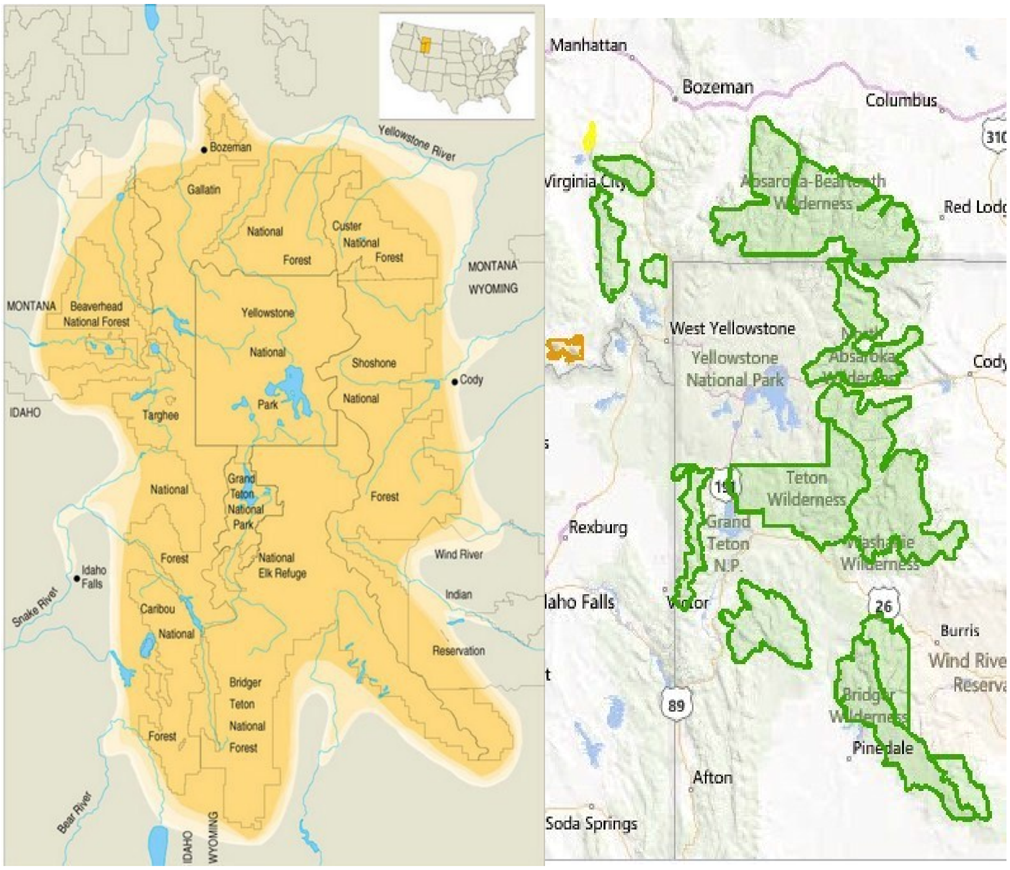

Figure 1. Left: The whole GYE, according to environmental non-profit Greater Yellowstone Coalition (Greater Yellowstone Coalition 2007). *Right:* The Wilderness areas of the GYE (Wilderness Institute 2013)

The Wilderness Act specifically includes the National Park System in its drafting and directs the Park Service to assess the suitability of all of its roadless lands as wilderness. This directive is aimed at protecting the wilderness resources of the National Parks. In 1972, 90% of Yellowstone National Park was recommended for federal wilderness designation. It is clear in the figure above that the very core of the GYE, Yellowstone National Park, is not provided with wilderness protections. This is because congress has yet to act on the proposal. This has meant that the proposed lands of Yellowstone National Park are afforded no congressional protections under the Wilderness Act.

Fortunately, management of the wilderness areas of Yellowstone Park was altered in 1999, when Robert Stanton, then Director of the NPS, issued Director's Order #41. This order states that recommended wilderness must be administered to protect wilderness values and resources. Further, it mandates that lands categorized as "recommended," "proposed," "suitable," or "study area" be managed as though they were wilderness. Lands categorized as such meet the prerequisite conditions for wilderness lands but have yet to receive that designation from congress. In May of 2013, Jonathan Jarvis, current Director of the National Park Service, updated and reissued Order #41, leaving the wild lands of Yellowstone and Grand Teton National Parks to be managed as wilderness until that order is updated or rescinded.

With the reissue of Order #41, 90% of both parks will remain identical in all but congressional law to a wilderness unit. This means that despite the heavy traffic they receive, it may still be reasonable to assume that the wilderness qualities of the parks provide suitable habitat for the megafauna, and biodiversity in general, of the GYE.

The effects of the Wilderness Act shall now be evaluated. These effects include the designated wilderness areas of the GYE and the innovative inclusion of Yellowstone National Park in the pursuit of wilderness management. Though the act was intended to provide recreational resources, it shall be evaluated for the preservation of biodiversity.

Science

"Untrammeled" is a term which means not hindered in action or expression. In the Wilderness Act, this term is used to refer to areas which are free from the influence of man. But the view of wilderness as an "untrammeled" area is an outdated and increasingly inaccurate one.

In 1984, Paul Martin and Richard Klein edited a nearly thousand page anthology of 38 scientific papers all of which point to anthropocentric extinctions dating back approximately 40,000 years (Martin & Klein 1984). Historically, man has changed all lands in North America through his presence. In addition to the historic role of man, the pervasive nature of man's ecological impact also negates any notions of areas existing which are "untrammeled" by man. There are over one hundred papers written about the ecological effects of global climate change on the GYE alone. Clearly no wilderness area is beyond the influence of man: an influence which can hinder or restrict the natural expression of ecosystems.

Thus we have in the foundations of the Wilderness Act an inaccurate understanding of the interconnectedness of the world. An understanding which, at the very least, casts doubt on the logic behind the act. The central question of this section, however, relates to the protection of biological diversity afforded by the Wilderness Act. How well do the existing areas which are managed as wilderness in the GYE incorporate sound science in their application as valuable habitat cores?

There is general agreement that the protections provided by Congress for designated Wilderness areas are effective measures not just for our recreation purposes, but for existing wildlife as well. This includes the lack of anthropogenic disturbances such as timber harvest or motorized vehicle use, the lack of roads which can weaken connectivity, and the protection of natural processes such as fire within their bounds. All of these protections prove valuable not just for the human experience, but for the biological diversity (see Mittermeier et al. 2003)

If wilderness areas are to hold up to deeper scientific scrutiny as core areas or habitats, they must meet two criteria: persistence and representation. The ideas of persistence and representation are most commonly seen in research on conservation planning, where new areas are to be delineated and protected (see Margules & Pressy 2000). As these criteria are valuable to biodiversity conservation, they should be applied even to those units which were not established with them in mind.

Representation is the idea that core areas should provide a representative sample of the biodiversity of an area. This idea has been well established (Austin & Margules 1986). In the Greater Yellowstone, there is a large occurrence of high elevation wilderness areas. This is pertinent because it is the lower elevation valley floors which tend to have more biological diversity. Thus, in terms of representativeness, the wilderness areas of the GYE are lacking wide-ranging samples of lower elevation ecological communities. This lack of representativeness is a general trend in protected federal lands in the U.S (see Scott et al. 2001, Crumpacker et al. 1988). In large part this is due to the fact that such areas are determined by congressional vote. Thus, we follow the pattern of “Rock and Ice” conservation of those areas with less competing user groups and greater scenic values (Noss 1984).

Persistence, the ability to protect biodiversity in perpetuity, is another key concern for conservation biologists. As discussed in the Connectivity section, more than just these protected areas are required for the longevity of biodiversity. The spaces covered by wilderness simply are not large enough on their own. Linkages between these ecosystems are also mandatory. So do these wilderness areas provide persistence? Individually, they do not, but as a whole, in the Greater Yellowstone Ecosystem there is a qualifiable core. The ecological qualities of Yellowstone National Park and the surrounding complex of wildernesses, as secured by the Wilderness Act and Directors order #41, are remarkable. The close proximity of wild areas to one another, the vast stretches of protected lands, and the centrally organized layout provide many important qualities of a core that, with continued proper management, will be able sustain many species into the foreseeable future.

Human-Nature Nexus

In the case of wilderness areas, the nexus of the values of man and nature is felt most strongly in the balance between the biological and ecological needs of an area with its recreational values. Although these values often coincide, for instance in regards to the need for large undeveloped space, and limited human presence and effect, there are times where the two are opposing. Yellowstone National Park lists "accommodating established amount of visitor use" as the primary concern for the maintenance of Park wilderness values (Yellowstone National Park 2013). Recreation is perhaps the most well-known threat to wilderness values, with recreation use increasing 10 fold in the last forty years (Cole & Landres 1996). Due to the high elevation nature of these wildernesses, the ecosystems they contain are naturally stressed and are not resilient to human disturbance (Cole & Landres 1996). Thus, recreation in these areas poses a significant threat to Biodiversity.

The wording of the act itself contributes to the problem. Recreational values were seen, or at least presented, as the largest goals of the Wilderness Act. The ecological values of a designated area are not recognized for their intrinsic value. Instead, their value is secondary: they matter for what they can provide the recreator, not for their own sake. In this way, the balance of values in the Wilderness is weighted toward the human end of the human-nature nexus.

Adaptability

Adaptability is definitely not a word that could or should be applied to the 1964 Wilderness Act. Neither the structure nor implementation of the act lends itself to alterations to suit changing conditions. The static nature of the Act is due to its reliance upon measures of Congress for designation or alterations to management. A congressional vote is required for determining which areas are wilderness. Given the stringent protections and cessation of almost every economic activity within wilderness areas, this makes sense. To block such economic activity without democratic measures would go poorly in the conservative west.

Such legislative dependence also means that something as simple as minor management alterations which go against the letter of the act, even if they are more productive in achieving its spirit, are illegal. Say, for example, it was found that mountain bikers produced less harmful environmental consequences in wilderness type settings than horses. Even if this was proven conclusively, it would take an act from congress to alter management to accept mountain bikers and reject the previous user group of horse packers. Such an act is subject to the political winds felt by all congressional matters. Thus, a simple management decision becomes reliant on a slow and stagnant political core to produce change. This is in direct contrast to the ideals of adaptability.

In part, the above issue is illustrative of a "top-down" management approach. Such a management style, while easier to implement[9], lacks the ability to respond to the individual characteristics and variables of differing situations. A main concern of adaptive management is that management practices align more closely with growing knowledge in order to more

[9] This is especially important because the Wilderness Act allocates no additional funding to coincide with designation as wilderness.

effectively pursue stated goals. Clearly, in a top-down approach such adaptation is all but impossible.

Discussion

The 1964 Wilderness Act was an innovative law that provided superior protections to areas with specific wild qualities. However, this law is not without its flaws. First off, the logical and scientific foundations of the law have some inadequacies. The drafting of the law aims to maintain conditions that do not currently exist. There is no longer any natural area which is separate from the machinations of humans, whether from chemical flows, pollution, or global climate change. Additionally, the wording of the Act creates a duality between man and nature and, in the eyes of many scholars, is a misleading and inappropriate delineation (see Cronon 1996)[10].

From the perspective of protecting biological diversity, there are weaknesses in the implementation of the Wilderness Act. Representation of all ecosystems and biodiversity in the region is lacking. In general, more diverse and productive low elevation areas are private. That being said, the protected lands at the heart of the GYE are massive, relatively well connected, and, in part due to the Wilderness Act and Director's Order #41, are ecologically healthy and protected. This core will most likely be able to provide for the persistence of many species over time. For example, with a 500 year horizon, the grizzly bear has an estimated risk of extinction below 5% (Noss et al. 1996).

In terms of the balance of human and ecological needs, the Wilderness Act again has some shortcomings. The anthropocentric wording of the Act as creating recreational

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[10] The discussion on the dichotomizing qualities of the act, and their repercussions, is lively and extensive, but will not be examined further in this work.

opportunities for man is seemingly at odds with the conservation of biological diversity. It values human recreational wants over the ecological needs of biota. But at the same time, it offers many powerful environmental protections. While understanding the democratic nature of the Act, this author sees in it the possibility for a more balanced valuation of man and nature.

It is conceivable that recreational and biological values could be viewed equally with respect to wilderness areas, where management of wilderness would focus equally on fulfilling both needs. This equalizing, however, would probably require additional resources to make it a reality, and thus the lack of extra funding to designated areas in the Wilderness Act would be problematic in implementation. While this is intellectually easy to imagine, politically it is less so.

Finally, while the non-adaptability of wilderness in the GYE has been thoroughly noted, it may not necessarily be a short-coming. Powerful economic and use restrictions, which aid, almost universally, in the health of the ecosystems are carried out under the Wilderness Act. Were the restrictions adaptable, they would almost surely be manipulated in local cases by those with the most to gain, such as extractive industries. So, the unyielding nature of these protections is actually one of the most valuable assets of the Wilderness Act. While this does create bitter opposition when new wilderness is proposed or considered for designation, the payoffs (nearly pristine habitats) are worth it. Multiple use land, such as that of the Forest Service or BLM provides an arena for such adaptability in uses. The maintenance of wilderness through use restrictions as provided by the Wilderness Act should not be adaptable.

There are two notable areas where the Wilderness Act could sensibly be improved upon. The first is the logical framework and value system behind its drafting. In balancing the value given to man and nature, more protections could be afforded the ecological systems found in wilderness areas, without necessarily reducing the recreational values found therein. Following such an ideological shift, it is easy to imagine that areas to be designated as wilderness could also be considered based upon their representativeness and suitability for persistence. While persistence is achieved to some extent in the Greater Yellowstone, this is not necessarily true of wilderness units in general. Therefore, an eye towards these to factors in the proposal and designation of wilderness could provide an enormous benefit to the longevity of the biodiversity they contain.

5.2. SHOSHONE NATIONAL FOREST AS A CORE

Introduction

Yellowstone and Grand Teton National Parks have long been considered some of the most impressive in America. But these parks alone do not contain the Greater Yellowstone Ecosystem. In examining *figure 2*, it is clear that these two central parks protect the heart of the ecosystem, but much of the rest is under the protection of the United States Forest Service. Clearly then, the management practices on Forest Service land matters to the health of the ecosystem.

The Forest Service was initially an arm of the Department of the Interior, but, since the Transfer Act of 1905, has been housed within the Department of Agriculture. As such, its traditional focus has been on the harvest of timber resources. Recently, the focus of Forest Service management has shifted to *multiple-use*, or “harmonious and coordinated management of the various resources, each with the other, without impairment of the productivity of the land.” (Multiple-Use, Sustained Yield Act 1960). These various uses include timber harvest, recreational use, mineral, oil, and gas extraction, downstream water users and more. The focus on protecting and managing all of these varying uses and users creates a substantially different set of considerations for forest management than, for example, National Park management.

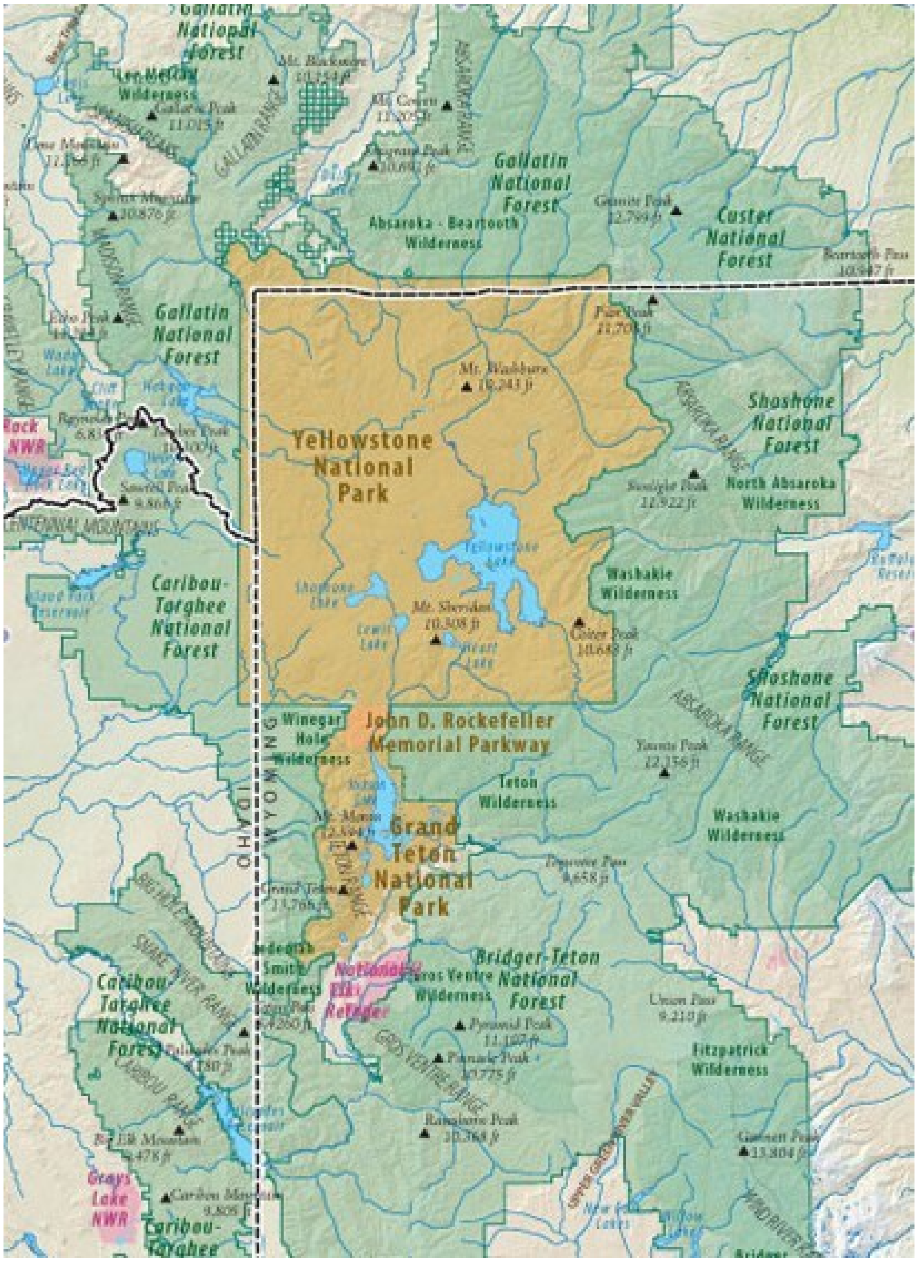

*Figure 2: "The Greater Yellowstone Ecosystem: Forest, Wilderness, and Parks (*Greater Yellowstone Coalition)

In total, there are six National Forests, spread across 3 distinct Forest Regions, in the Yellowstone Area, totaling approximately 10 million acres (Mumma & Grigsby 1994). In *figure 2* above, it is clear that Forest Service land almost totally encapsulates the smaller, more stringently protected National Parks found at the center of the ecosystem. They compose the majority of Federal land in the ecosystem and thus, the role they play as core habitats is vital to the health and biodiversity of the GYE. Does the management of the non-wilderness back and front-country areas of Forest Service land do justice to the idea of Cores? Does it protect the resources that are required for the sustenance of the biodiversity it contains?

In order to gain a picture of Forest Service management, the Forest Plan of one unit will be examined. With hundreds of pages of planning documents for each holding, investigating all six National Forest in the GYE is simply implausible. Therefore, in order to provide a general picture of management policies, a representative example shall be evaluated.

Forest Plans are the quintessential guiding documents for all national forest activities. They are each written to guide the management of one Forest. Each plan is intended to establish the multiple-use goals, management directives, and operation of activities. However, "Forest plans estimate future management activities, but the actual amount of activities accomplished is determined by annual budgets and site- specific project decisions." (USDA Forest Service 2014) Therefore, one cannot expect all actions described in Forest Plans to necessarily be implemented as specified. With budget constraints further limiting its capabilities, each plan is intended to ensure that management is "adjusted to match available funds and *congressional intent of appropriations*." (USDA Forest Service 2014, emphasis added). That such intent is upheld is a key assumption of this section.

By examining the Forest Plan of one specific National Forest, specific, small-scale procedures may not be uncovered, but the guiding principles, thought, and skeleton of management will be visible. It is these which will be examined in order to distill how forest management affects biodiversity in the GYE.

Shoshone National Forest

The National Forest Plan that will be evaluated is the newly Revised Shoshone National Forest Plan, which was released in draft form on January 21, 2014. As of this writing, the draft is in a 90-day objection phase. Pending strong objections, minor changes may occur. If any changes in response to these objections are approved, they would be implemented following the close of this period. For the purposes of this thesis, the plan will be evaluated as is.

While the Yellowstone area is best known for containing the world's first national park, it is also home to America's first National Forest. In 1891, in response to growing concern over the quantity and quality of natural resources, Congress established the Yellowstone Timber Land Reserve. The majority of this protected land would later become Shoshone National Forest (USFS & NPS 1987). With 2.4 million acres, 1.4 million of which are designated Wilderness, the Shoshone plays a large role in the functioning of the Greater Yellowstone Ecosystem.

At more than 180 miles long, the Shoshone extends nearly the whole north-south length of the GYE, on its eastern flank. It contains elevations ranging from 4,600 feet in Clark's Fork Canyon to the 13,804 foot tall Gannett Peak (USDA Forest Service 2014). These vast and varied landscapes provide many of the habitats necessary for wide-ranging wildlife such as bear and wolf. This is further evidenced by the 335 native species of wildlife residing there, including the largest population of bighorn sheep found in any National Forest (USDA Forest Service 2014).

Beyond the important spatial, habitat, and biological values it contains, the Shoshone is also the most recent National Forest in the GYE to release a revised Forest Plan. The revisions process spanned 8 years and included over 75 public meetings (USDA Forest Service 2014). Every 10 to 15 years, Forest plans are to be thoroughly examined for components which require updating, and many GYE forests are past due. Therefore, the Revised Shoshone Forest Plan represents the probable direction of other forthcoming GYE forest plan revisions.

The 2014 revised version of the Shoshone National Forest Plan shall now be evaluated for its ability to ensure that non-Wilderness designated Forest Service land has the protections it requires to act as a core for biological diversity.

Science

In order to most efficiently evaluate the Forest Plan according to the three metrics of science, adaptability, and socioeconomic considerations, the three most controversial issues shall be examined. These issues are oil and gas development, mechanized off-road travel, and status of more stringent designations, i.e. as Wilderness or Wild and Scenic Rivers.

In the Revised Forest plan, opportunities for oil and natural gas development are greatly diminished. In total, there was a nearly 300,000 acre reduction in the areas available to such development from the draft proposal to the final plan (Storrow, 2014). This is a great sign. Even better is that many more areas, especially those containing critical habitat such as Line Creek Plateau Research Area or Swamp Lake Botanical Area, are protected from all surface occupancy. This means that any materials within those areas must be extracted from outside their bounds, utilizing directional drilling technologies. This does an excellent job of protecting habitat in crucial areas, as no surface perturbations are present.

An area of considerably less protection is that of mechanized use allowance. Snowmobile use alone was increased to a total of 592,000 acres. This acreage includes valuable habitat areas. While snowmobiles on snow covered areas have relatively little impact on plant communities, travel on uncovered vegetation is destructive (Geller et al. 1974). Neuman and Merriam (1972) found that 78% of saplings were injured after just one pass of a snowmobile, with 27% of those saplings predicted to have a high probability of mortality. Additionally, the high running volume and artificial lighting of such machines creates disturbances for many animals in the harshest time of the year. For example, increased vigilance and effects upon group size of social ungulates (for example elk, moose) were correlated with increased human disturbances of this type (Manor and Saltz 2003). Carnivores can also suffer increased stress from snowmobiles (Creel *et al*. 2002), and have a higher risk of being illegally shot or run over (Claar *et al*. 1999). Therefore, the increase in snowmobile accessible areas is a negative aspect of the plan, which weakens the ability of Forest Service land to act as a core.

While no new Wilderness designations were recommended for congress, the 34 eligible areas retain many protections in order to maintain their eligibility. While this decision upsets many area environmentalists, the protections that eligible areas receive appear stringent enough to protect the natural values which they are meant to. Part of the stated goal of such protections is that “the ecological integrity... including processes, composition, and structure, is [to be] maintained” (USDA Forest Service 2014). The focus on process is important and scientifically sound.

In general, the scientific foundations of the revised plan appear to be solid. However, the plan is majorly deficient in the overall attention it calls to scientific knowledge. There are no specific goals, standards, or guidelines (all official FS planning categories) that call for active scientific guidance of management. More than cursory mentions of ecosystem sustainability are absent as well. The lack of reference to, or use of, scientific directives is somewhat unsettling. In fact, in some cases, goals are even contradictory to habitat maintenance. For example Management Area 3.3B goal is to "provide quality... winter motorized recreation opportunities" (USDA Forest Service 2014, pp. 155), without so much as the inclusion of the word sustainable.

Adaptability

The very fact that a revised plan is being evaluated is a good sign of adaptability. When it is deemed that single amendments are insufficient adjustments to Forest Service management, the revision process begins. The ability to make drastic changes, such as those included in this plan, is vital; they are at the heart of what it means to be adaptable.

However, there is an uglier side to adaptability as well: the side that allows decision makers to bypass the intent of planning documents to fulfill other motives. The goals, standards, and guidelines are official terms to describe differing strata of planning directives. The way they are structured in the Shoshone National Forest Revised Plan is that they are relatively open-ended, single statements such as "Recreation trails should be located to avoid impacting the ecological conditions and processes ... of the natural area" (USDA Forest Service 2014, pp. 147). Statements such as this allow for differing interpretations. For example, the words, "*should*" and "*impacting*" allow quite a lot of wiggle room for management [See example in *Discussion*]. They are not binding and do not include specific definitions to narrow their meaning.

It could be argued that the fact that standards and guidelines are this open to interpretation is a negative feature of the plan. It allows management to not only adapt to possible environmental factors, but also to adapt the degree to which it follows the intent of the Forest Plan.

Human-Nature Nexus

As noted by Schembra (2013), the forest service is “faced with a nearly impossible task of serving many different interests”. In light of this circumstance, many of the decisions made by forest planners are more understandable. For example, the move to leave areas open to oil and gas extraction is a good balance of needs. In spite of the fact that all 34 previous wells were either not producing or shut down due to low production, the plan keeps the most promising areas open to development (USDA Forest Service 2014). This move allows for possible drilling and thereby recognizes the importance of job creation and domestic energy for the US. At the same time, it does not pose much of an environmental threat, as many critical habitat areas were closed off to extraction.

As a multiple-use institution, the Forest Service must acknowledge and provide for the interests of all of those multiple uses. This necessarily means that its non-wilderness holdings will not retain the same core qualities as a wildlife refuge, for example. However, considering the numerous user groups, this plan strikes a fine balance for both people and the environment.

Discussion

So, are non-wilderness Forest Service lands acting as strong cores, as evinced by the revised Shoshone National Forest Plan? Like many of these analyses, the answer is a qualified “yes”. Yes, Shoshone National Forest is acting as a core, but, it could be stronger. The protections from oil and gas development in many areas, the continued limiting of development in roadless and wilderness eligible areas, and the overall protections for the land allow it to act as core habitat. However, in the areas of mechanized off road travel, the lack of tighter restrictions of the plan is limiting its ability to protect natural processes in vital areas.

As of 2006, there were 13 million Americans utilizing snowmobiles for winter travel and recreation (Davenport & Switalski 2006). This form of recreation is exceedingly popular in the Greater Yellowstone Area, where, in the year 2000, 60% of wintertime visitors to Yellowstone National Park utilized snowmobiles (Davenport & Switalski 2006). As illustrated in the *science* section, the allowance of snowmobile travel has definitive negative impacts on the wildlife of the area. These negative impacts do not seem to be properly accounted for in the revised plan. The widespread availability of land to motorized winter use, even when motorized summer use is not allowed, appears to be a compromise that landed far too squarely on the human end of the human-nature spectrum.

In addition to rampant motorized wintertime use, there is a general vagueness and non-inclusion of scientific baselines, monitoring, or reference in the directives of the plan. There are often positive intentions, as evidenced by the drafting, but without any clear cut ways to analyze policy effects scientifically to ensure that they are meeting those intentions. In order to make sure that Forest Service lands can indeed act as strong core habitats, such scientific measures and standards are absolutely mandatory. For example, in the standard mentioned earlier ("Recreation trails should be located to avoid impacting the ecological conditions and processes ... of the natural area" (USDA Forest Service, 147), some alterations should be made. The switching of "should" with the word "will", the inclusion of an actionable definition of "impact", and the processes by which it will be scientifically verifiable that no impacts are made, would all greatly aid in the protection of these natural resources. Therefore, you would have something more along the lines of, "Recreation trails will be located to avoid negatively affecting the health of the ecological conditions and processes, as verified by the monthly monitoring reports of trained scientists, in the natural area" .

The plan is fraught with vague and undefined terms and directives such as the above. A thorough reexamination of the plan and substantive changes in order to remedy this situation are in order for these lands to more fully fulfill their role as natural core habitats.

Taking into account the necessity for the Forest Service to juggle a variety of uses and user-groups, this plan is remarkably balanced. While it may not provide optimal protections for nature, given the goals of its agency, it cannot really be expected to. The fact that such important compromises were made (i.e allowing popular winterized vehicular use, withdrawing oil and gas development from key areas, and more) is indicative of a fine line being walked. The forest service has managed to toe the line between human and natural needs in order to provide the best possible outcome for each. In doing so, the agency has maintained cores that overall should maintain persistence for the biodiversity they contain and has balanced the needs of nature and humans, providing mutual benefit where possible. While cores are just the first piece of the puzzle, the Shoshone appears to be fulfilling this role as effectively as could be hoped for. And with the continued attention of environmental non-profits in the area, this is unlikely to change.

A final note about the Shoshone National Forest Plan is that it is optimistic to assume that this is the standard level which all other GYE forest plans are currently meeting. Because this is the most recently revised, it is unlikely that natural needs were balanced with human needs as delicately in the plans of other GYE National Forests. However, given the high intensity of regional environmental groups, and the pressures they create as a user-group (and thus as an influencer on forest service policy), it is not unreasonable to assume that in the not-too-distant future, other forest plans in the area will catch up. Thus we have hope that, in the coming years, Forest Service lands will fulfill their potential; that given their political restrictions, they will provide the best possible core habitats for the biodiversity of the Greater Yellowstone Ecosystem.

5.3. CORE DISCUSSION

Federally created and managed cores are abundant in the Greater Yellowstone Ecosystem. From Wilderness holdings to Forest Service land, federally owned core habitats are the dominant land ownership pattern. These existing cores are widespread, covering vast amounts of the GYE, as is visible in *figure 2*. Overall, these areas fulfill their role as core habitats. As a whole, they provide representativeness of this ecosystem. While lower elevation land is generally where human settlement and development occur, the percentage of land area that is off limits to such development is quite high. They also help to fulfill the need for persistence among core habitats. However, this last component does depend on management actions outside of federal holdings, especially for large carnivores and endangered species. However, these core areas are not without their flaws.

In order to better conserve the biological diversity of the Greater Yellowstone Ecosystem, more weight must be placed toward the nature end of the human-nature spectrum. Federal Agencies with multiple use missions, such as the Forest Service and BLM must recognize the dependance that all of those multiple uses have on the health of ecological communities. From recreational values, to harvest yields, to water resources; perhaps everything except for mineral extraction either depends upon, or can be improved with, a healthy the ecosystem. By recognizing and promoting this fact, these multiple use institutions may act as even stronger core habitats, in many cases without significant reductions in certain of their multiple uses. By including guiding language reinforcing this view, and ensuring its inclusion in multiple-use institution planning, cores in the Greater Yellowstone could be even better protected.

Multiple use institutions are charged with managing for outdoor recreation, range, timber, watershed, wildlife and fish, mineral extraction, and more. However, the relative weight that managers must give to each purpose is not specified by congress (Kannan 2009). If the relative weights were specified, or even if guidelines were enacted, managers would have less wiggle room: room which allowed for a Forest Supervisor to "allocate 100% of forage to livestock and none to wildlife" in 2003 (Kannan 2009). Such guidelines could be based on scientific research illustrating the importance of ecosystem health for the other of the multiple uses of the land, for example range quality and recreational values. One can imagine a system in which the uses with the largest negative impacts upon the health of the ecosystem would receive the least weight. A hierarchical system such as this would certainly help to protect the ability of federal multiple use lands to act as core areas.

Another piece that is lacking is the general inclusion of scientific guidance in management documents, and Forest service planning regulations especially. In the 1982 Planning Rule, which many current Forest Plans were developed under, there is a mandate to use the "best available data" in the creation and implementation of monitoring and inventory programs. There is next to nothing requiring the sound use of science in guiding management decisions after that point.

The most recently developed rule, the 2012 Planning Rule is the new guiding document for the creation of Forest Plans. All future plans in the GYE will follow these guiding rules. While this plan does a better job of including sound science in the planning process, it almost completely ignores any further use of science in making management decisions. It states that it "[requires] the responsible official to take science into account in the planning process and would require documentation as to how science was considered" (USDA Forest Service 2014). The only further relevant discussion is the inclusion of a requirement to "maintain viable populations of species of conservation concern" (USDA Forest Service 2014). While this is legally binding, and certainly helpful to the protection of biological diversity, its wording could be much more proactive. Any other discussion of the inclusion of science is absent.

This is unacceptable for two main reasons. First of all, to assume that the scientific information guiding the creation of forest planning will remain unimproved for the coming decades is naive, and has the potential to be disastrous. Ecosystems and the interrelationships of their components are exceedingly complex. As our understandings change, so too must our management. Secondly, not requiring scientifically founded management lessens a manager's ability to adapt to changing environmental conditions such as those relating to the perturbations of global climate change. Without the continued reliance upon scientific information, effective adaptive management is impossible. While the intense environmental non-profit community makes sure to steer GYE managers toward scientific management, this presence does not exist in the same way across the United States. These groups have the political clout to ensure management in this ecosystem utilizes science by going to open meetings, writing letters, utilizing public comment mechanisms in planning processes, and more. This is not true to the same extent at National Forests around the United States. Thus, it is recommended that stronger language be included in the Forest Planning Rule, language which requires the continued use of sound science in making and carrying out management decisions.

The final issue of cores in the ecosystem relates to the variation among the missions of their managing agencies. From the NPS to the FS to the BLM, these agency missions differ drastically. With varying missions, the separate management schemes and their implementation can also differ drastically. In doing so, they reduce the ability of these coterminous federal lands to act as one unified core, to some extent. Utilizing the social capital and interagency communication of the Greater Yellowstone Coordinating Committee (GYCC) can help alleviate these jurisdictional issues which fracture these core habitats. The GYCC and its role in interagency communication and management are further discussed in the monitoring section.

In general, core areas of the Greater Yellowstone Ecosystem are strong, but there is some room for improvement. If the valuation of management goals was adapted to encourage ecosystem health, the use of scientific data for planning *and* implementation purposes was included, and the social capital of the GYCC was leveraged, these cores could become a standard towards which other areas could progress. These core areas are already some of the strongest in America. With a little more work they could be even better.

6. CASE STUDY: CONNECTIVITY

6.1. BRIDGER-TETON NATIONAL FOREST PRONGHORN AMENDMENT

Introduction

Connectivity generally refers to connections between island-like source habitats. Such connections can be measured in different ways and for different purposes. From the necessity for specific habitats, such as riparian linkages, to simple movement corridors, connectivity refers to a wide variety of circumstances.

The most simple form of connectivity (as movement corridors) can be understood by examining animal migration. Migrations generally occur when a population has habitat requirements that cannot be met by one location across all four seasons. Thus, these animals develop “seasonal ranges” in order to meet their energetic and nutritional needs (Hall, Lindzey, & McWhirter 2005). Clearly, the pathways taken by animals to reach one seasonal range from the other must not inhibit their passage or it will threaten their survival. Maintaining these pathways is the goal of this most basic type of connectivity.

Ungulates, or large mammalian herbivores (Owen-Smith & Novellie 1982), often engage in these migrations. From the African Wildebeest, to the Arctic Reindeer, these seasonal migrations occur all over the globe and can cover distances as long as several hundred miles (Harris et al. 2009). Unfortunately, “knowledge of mammal migrations is low, and human impacts on migrations high” (Harris et al. 2009). Increasing development and human disturbance have threatened the future of long-distance migrations around the world (Berger 2004). In the Greater Yellowstone region alone, about 75% of elk, bison, and pronghorn migrations have been extirpated from the landscape (Berger 2004).

The maintenance of these migrations is important for a couple of reasons. Ecologically speaking, these animals form an important part of the trophic structure of an ecosystem, and their extirpation could throw that structure out of balance, hurting the health of the ecosystem in both their summer and winter ranges. Additionally, as these migrations become less and less abundant worldwide, it is important to maintain the occurrences of this phenomena whenever possible (Berger 2003).

One participant in such migrations is the American Pronghorn, or *Antilocapra americana*: a deer-like animal that evolved on America's grassland-savanna during the tertiary period. Historically intense predation by numerous predators, such as the North American cheetah or Saber-Toothed tiger, led to impressive running speeds of up to 100 kilometers per hour for pronghorn (Byers 1997). Of 8 historical pronghorn migrations in the GYE, 6 are no longer occurring (Berger 2004). The focus of this section will be on federal action relative to one of these remaining Pronghorn migrations.

Every year, approximately 200 individuals make the trek from summer range in Grand Teton National Park to the winter range in the Green River Valley. This journey, which spans 116 - 258 kilometers (Sawyer et al. 2005), has been occurring for at least 6,000 years, according to the archeological evidence (Miller & Sanders 2000). This population of pronghorn is the only one to spend its summers in the Grand Teton National Park and Jackson Hole area, meaning that without this group, park visitors would not have an opportunity to see pronghorn.

In response to the threat of losing yet another pronghorn migration and the last remaining population in Grand Teton National Park, local non-profit and governmental organizations began to take action by raising awareness, educating constituents, and beginning the search for solutions. What was needed was federal action in the Pronghorn's migration path that would ensure its survival. In 2008, Bridger Teton National Forest Supervisor Kniffy Hamilton signed the Decision Notice and Finding of No Significant Impact: the document implementing an amendment to the 1990 Forest Plan.

This vital step secured a “significant portion” of the pronghorn’s migration path, totaling approximately 47,000 acres of Forest Service land (Forest Service 2008). The core of the amendment is essentially the designation of the wildlife corridor and the legal standard, “[all] projects, activities, and infrastructure authorized in the designated Pronghorn Migration Corridor will be designed, timed and/or located to allow continued successful migration of the pronghorn that summer in Jackson Hole and winter in the Green River basin” (Forest Service 2008). The designated area can be seen in *figure 3*. Created under the 1982 forest planning regulations, the standards of this amendment are legally binding (Ament 2009), meaning that conservation groups have extra leverage should the Forest Service fail to meet its mandates.

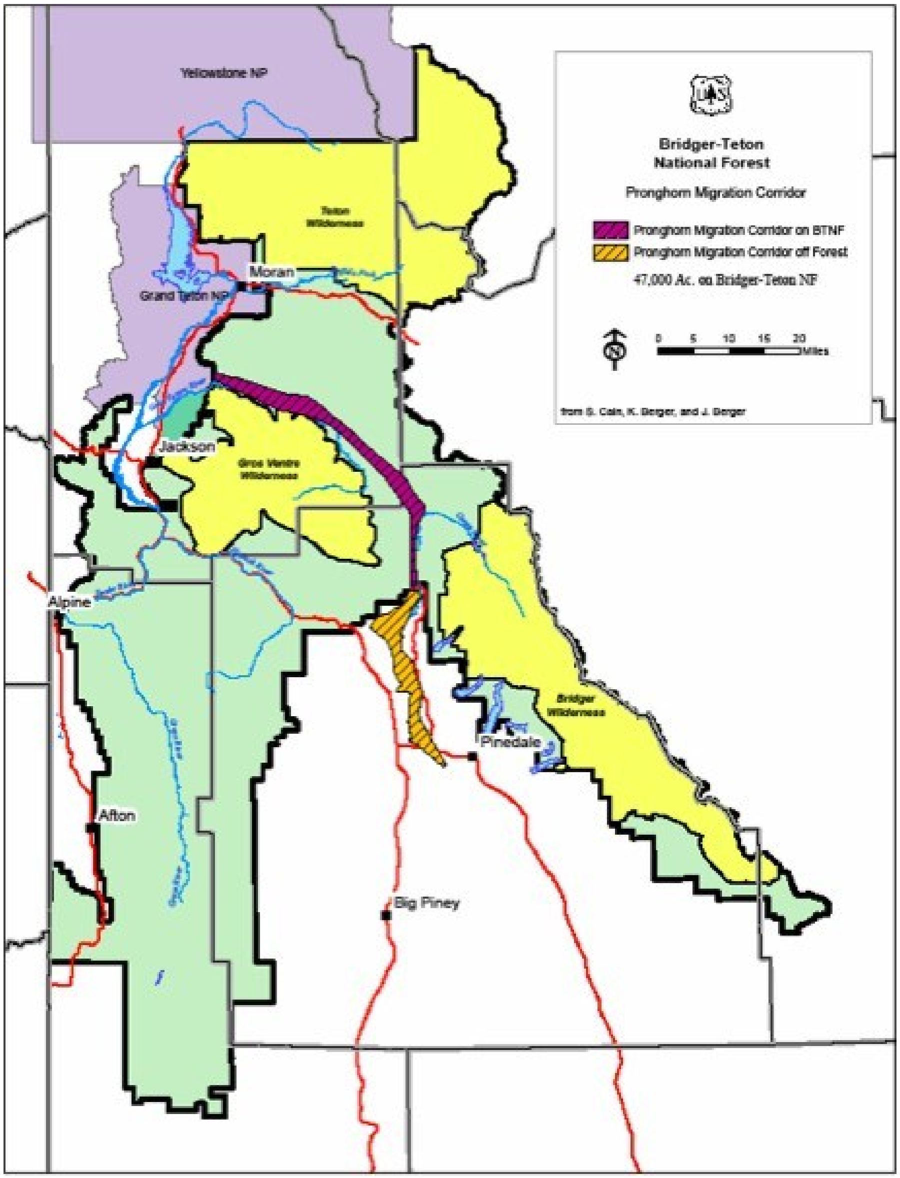

Figure 3. The pronghorn migration corridor between GTNP and the upper Green River Valley (USDA Forest Service).

It is clear in the figure above that the protected area does not encapsulate the totality of the pronghorn migration path. The orange area represents that portion of the migration path which lies on BLM, state, and privately-owned land. The forest service amendment offers no protections outside of the forests boundaries.

Fortunately, the state of Wyoming has funded several wildlife overpasses and other projects to aid in the pronghorn's survival. Various non-profit groups have continued work to bring attention to this issue and facilitate whatever protections possible.

The Bridger-Teton Forest Plan amendment shall now be evaluated according to the three standards of science, adaptability, and the consideration of human and natural needs.

Science

Determining the area which it was to protect, the Forest service turned to several radio-tracking studies (Sawyer et al. 2009, Sawyer, Lindzey, & McWhirter 2005). These studies helped to clearly define the precise area used by this herd of pronghorn on their yearly migrations. Due to the herd size, consistency of movement, and surrounding geographic and land distribution characteristics, the pathway was able to be precisely delineated. This allowed the Forest Service to be sure that they were protecting the correct area within Bridger Teton National Forest. The accuracy and correctness of the location of protected lands has been further verified by subsequent tracking of animal movements through the corridor.

Another scientific issue at the heart of pronghorn migration protection was the allowance of grazing within the geographic corridor. In 2008, there were several fencing structures that were utilized by cattle grazers within the corridor. These structures were given the green light in part because they were intended to be temporary, and yet remained for years (Dorsey 2009). These structures were viewed by conservationists as contrary to the goals of the amendment; in some cases they were poorly designed for pronghorn passage, pushing the animals to walk for miles around them.

After public outcry, a settlement agreement was reached and these corrals were removed in 2012, along with the promise not to allow further corrals and impediments to pronghorn in the corridor, even in cases where they were to be "temporary" (Ertz 2012). This was a positive outcome for the pronghorn. Pronghorn do not jump as many other ungulate species do, and instead travel under fencing barriers when possible. In order to allow their passage, a fence's lowest barrier must be at least 18" off the ground and not be barbed in any way (North Dakota Game and Fish Department 2012). The corrals did not meet these requirements and had to be removed or altered in order to protect the pronghorn migration.

Finally, although a large component of the migration corridor was located on National Forest land, this tract did not entirely encapsulate the area. Thus, even with the passage of this amendment, the maintenance of this herd is not guaranteed. Actions on BLM, State, and privately-owned land still matter tremendously to the future of this herd.

Adaptability

Again, with this policy we see a clear example of adaptability within the larger institutional structures of the USDA Forest Service. This amendment was introduced because it was deemed a necessary, and fairly non-controversial, action that needed to occur before the reexamination of the Forest Plan. The mechanisms that allowed for this amendment are clearly very adaptable and allow for evolving and powerful management.

The language of the amendment itself is not all that adaptable. However, given the historic nature of the migration and the surrounding geography and human development, this seems completely suitable. If conditions were to somehow change, the system used to create this amendment could again be applied to alter or retire it.

Human-Nature Nexus

In her Notice of Decision, Forest Supervisor Kniffy Hamilton states that "Activities currently authorized by the Forest Service within this migration corridor, including livestock grazing operations, coexist with the currently successful pronghorn migrations, so changes to current activities and infrastructure are not required by this amendment" (Forest Service 2008). In other words, this amendment appears to be in little conflict with local interests. In fact, during the scoping process, 19,400 emails were received in support of the amendment, and only a few livestock interests opposed (Forest Service 2008). This lack of controversy cleared the way for the speedy passage of the amendment. In part, the lack of dissent was due to the limited geographical scope of the amendment and the dearth of current conflicting uses in that area as well as local non-profits mobilizing their constituencies.

As discussed previously, however, it turns out that Hamilton and the Service's assumption about current uses being acceptable was incorrect. With the recent settlement, it would appear that cattle grazers received the bad end of the bargain. At approximately $12,000 to $16,000 per mile (Cherney 2011) to alter the existing corral fences, corral removal was the only option open to grazers, halting their operations in those areas.

However, it wasn't that the presence of grazers in general was contradictory to the goals of the amendment. Instead, it was that their corrals were incompatible with pronghorn movement *and* that the processes that lead to their placement were legally inadequate. The largest issue with the corrals was that the Forest Service did not comply with NEPA and NFMA stipulations. In the settlement, it was agreed that future cattle use in the migration corridor would be allowed as long as these laws were followed. Assuming that such future actions will meet the letter of those laws and the intent of this amendment (by having pronghorn permeable fencing), it is quite plausible that the Service will be able to balance the needs of grazers and pronghorn well into the future.

Discussion

In the limited arena of protecting the pronghorn migration corridor on Forest Service land, this Forest Plan amendment is succeeding. It is scientifically viable, as adaptable as it must be, and puts very little restriction on popular human activities in the region. This case appears to be an example of how federal managers can begin the process of implementing connectivity measures into land management. However, upon close examination, the path of the pronghorn illuminates the biggest issue for federal connectivity work: jurisdictional boundaries.

The remainder of this migration corridor faces a land owner distribution of federal and state government agencies down to private owners. With winter range in this second ownership patchwork, it is clear that there is still much to do in order to ensure that this pronghorn herd may continue to survive. While private and state land preclude the option of federal agency decision-making having an impact, there is a considerable amount of BLM land in the upper Green River valley.

Unfortunately, the BLM has not given the path of the pronghorn the same attention as the Forest Service. Instead of agreeing to protect this great migration, the BLM continues to allow the development of natural gas in areas of heavy pronghorn use. The agency does so in the face of strong evidence that the disturbance of gas field have negative effects on pronghorn behavior (Beckmann 2012).

The majority of the disruptive extraction has occurred in an area known as the Jonah Natural Gas Field. This 30,000 acre area is believed to contain 14 trillion cubic feet of natural gas, and its development is expected to continue its trajectory: 3,100 additional gas wells are expected to be drilled at a rate of 250 wells per year (Burnett 2010). These activities threaten the good work done by the Forest Service, State government, and private organizations in their mission to protect the path of the pronghorn.

This example shows us that with connectivity work, it is almost always about working together to lessen the impact of jurisdictional boundaries. The BLM has thus far failed to truly engage with other federal agencies and conservationists in their work to protect the pronghorn. It is impossible to tell at this point, but the continued development of areas such as the Jonah Natural Gas Field could threaten this herd. Has the Forest Service done a good job to help the pronghorn? The answer is an emphatic yes. In looking at the federal government as a whole, the answer is not so clear. The lack of attention the BLM gives to this issue is unacceptable and threatens the work of federal, state, and private groups. In order for connectivity work to succeed, all players must, at the very least, take the time to listen to each other.

6.2. CONNECTIVITY DISCUSSION

Connectivity policy in the Greater Yellowstone Ecosystem is not as pervasive as one might hope. There is a dearth of management documents which produce tangible, on the ground projects or impacts for connectivity. In this research, only one example was even detailed and concrete enough to perform an evaluation of: the path of the Pronghorn amendment to Bridger-Teton National Forest. While this is not the only mention of connectivity among federal agencies in the GYE, it was the most action oriented and tangible.

Besides this forest plan amendment, examples of connectivity in the ecosystem are limited to notes about the importance of connectivity, vague guidelines stating missions of protecting connections between habitats, and other even less actionable material (Ament & Meiklejohn 2009). For example, in the Gallatin National Forest Travel Plan FEIS, managers are to “provide for wildlife movement and genetic interaction (particularly grizzly bear and lynx) between mountain ranges” at various locations (Forest Service 2006). There are no details about what this means, or how to achieve it. Empty statements about connectivity such as this are found all over the GYE (see Ament & Meiklejohn 2009).

Fortunately, there has been an increase in awareness and public support for connectivity measures. In part this can be seen in President Obama’s numerous recent actions in support of connectivity. These actions include “policy initiatives, memoranda, orders, plans, strategies and other administrative avenues” that promote the conservation and facilitation of both structural and functional connectivity (Ament 2012). One example is the inclusion of multiple mentions of connectivity in Obama’s America’s Great Outdoors program. Hopefully this increase in concern for connectivity will continue to help support increasing federal connectivity measures: measures with actionable, verifiable mandates which can truly aid in the connectivity in the GYE.

There are several reasons for the current paucity of connectivity work in the GYE. The first is the role of jurisdictional boundaries. Jurisdictional boundaries are political boundaries, usually with little to no ecological correlates, where management differs by agency from one side to the other. Different agencies have different goals, areas of concern, and management styles. Also, communication across, and sometimes within, agency boundaries can be drastically slowed by the bureaucratic nature of federal agencies. While groups such as the GYCC work to diminish the impact of these boundaries, they can still have negative effects upon the biological diversity of the ecosystem.

The next reason for the limited number of actionable connectivity policies is the complicated nature of connectivity itself. Functional connectivity, or the degree to which organisms can travel between habitats, is based on the behavioral patterns, energetic and nutritional requirements, disturbance tolerance, and more, of individual species. Connectivity must be assessed based upon which species is being managed. Cases such as the pronghorn allow this to occur relatively easily: the herd follows the same exact route every year and individuals are large and observable. It did not take too much research to figure out what exactly had to be done to protect this migration. However, the case of the pronghorn is singular. Everything from large predators to amphibians require connectivity, and creating connectivity for these species is almost never as simple as it was for pronghorn. These creatures must be studied extensively in order to determine how to best implement meaningful connectivity for their conservation. Therefore current knowledge is often not precise enough. The complexity of functional connectivity is a large barrier to its political implementation.

Currently, connectivity between the habitats of the Greater Yellowstone Ecosystem is good, but not great. The reason it is good is because the ecosystem retains “the elements of ...bigness and connectivity” (Soulé & Terborgh 1999). Due to the preponderance of federally owned land in the ecosystem, it has avoided much of the increased development and increases in human populations which have perturbed other landscapes. The enormous tracts of National Park and National Forest lands maintain that element of bigness, and the general lack of development maintains much of the ecosystem’s connectivity. However, there is room for its improvement.

With more direct, concrete policies related to connectivity, the natural values of the GYE could be even more secure.

There are several specific policies or changes which could be implemented to improve connectivity in the Greater Yellowstone. First of all, the social capital of the GYCC could be leveraged to a greater extent. The goals, structure, and projects carried out by the Greater Yellowstone Coordinating Committee all succeed in moving toward managing the parts of an ecosystem so as to manage the whole. Connectivity work especially can benefit from the increased awareness and interagency communication and cooperation that the GYCC facilitates. The ill effects of jurisdictional boundaries in connecting habitats could be ameliorated through such collaborative focus.

Another way connectivity could be improved in the GYE is the continued focus on large predators such as bear and lynx. In this way connectivity can also be improved for many other species, as large predators are often considered “umbrella” species. In making sure they have the connectivity they need, other species may also benefit. These types of projects also make sense because of the high public interest and support that usually coincides with large predator conservation.

A further step that could be taken is increasing the inclusion of connectivity in individual management plans. As was noted earlier, these plans often allude to connectivity, or describe its importance, without any concrete actions to be taken. Now that the ideas and science behind connectivity work are improving, more explicit management is necessary. The next step for GYE managers is to include detailed, physical work that can aid in connectivity. There has been enough awareness raised, it is time to implement more action!

Finally, the federal government, through any number of grants or agencies could allocate funding to connectivity projects such as wildlife overpasses and underpasses. The overpasses built along the path of the pronghorn were powerful, successful tools in their conservation. These expensive structures were paid for the Wyoming Department of Transportation. In many cases with less public support for such structures, cost can be a limiting factor. If the federal government were to set up a specific grant system or some similar mechanism to pay these costs, connectivity could be greatly improved. Sums of money which may be prohibitive to state governments are often just a drop in the well for federal level budgets. Imagine a time where the documentation of all animal-vehicular collisions was collected, and hot spots were found (programs which are currently pursued by several state agencies), and then federal funding would provide for the construction of wildlife over or underpass structures, structures that would not otherwise exist. We would not only be improving ecological connectivity, but saving human lives.

One simple way that funds could be collected to fund these structures would be an optional fee coinciding with park entrance. National Park visitors could be asked to donate $5 additional dollars along with their entry fee. Even if only one in five chose to participate, given Yellowstone National Park's annual visitation rates, the Federal Government would collect $3 Million to be put towards these structures. Due to the high rewards on minimal investments, and the creation of additional funds that need not be allocated from other uses, such a plan would make this suggestion much more plausible.

By leveraging the mechanisms and social capital of the GYCC, increasing the focus on large carnivore connectivity, delineating specific connectivity actions in federal agency planning documents, and providing funding for wildlife road crossing structures, the federal government could greatly improve connectivity in the GYE. In this ecosystem their are relatively few barriers to connectivity work, fewer perhaps than any other in the continental United States. Given the high percentage of often coterminous federal land, there are much less significant connectivity barriers due to large human populations and their coinciding habitat destruction and development. With smaller hurdles, and greater funding and consideration, for connectivity, Yellowstone could become one of the most well connected ecosystems in the western world. All that is required is an increase in federal focus on this issue.

7. CASE STUDIES: MONITORING

7.1. GYCC WEED COMMITTEE

Introduction

Human beings are changing, and in most cases impoverishing, natural environments and ecosystems all over the world. Besides our penchant toward pollution and habitat destruction, another less-discussed, but no less significant, way that our species does this is the spread of exotic invasive organisms.

What exactly is an exotic invasive species? According to one of the fathers of conservation science, Reed Noss, "the terms "exotic" and "native" ... are ... about as ambiguous as any in our conservation lexicon" (Noss 1990). A precise definition of exotic is necessary for academia, education, and management of exotic species. How could one manage exotic invasives without knowing what they are? Perhaps the most useful definition is that "a species is exotic to the extent that it has not significantly adapted with the local ecological assemblage" (Hettinger 2001). Thus, exotic species are those which have not yet become a balanced member of an ecological community. Oftentimes, this unbalance negatively affects more than just the species in question.

There are many reasons to be wary of exotic invasive species. Such species may have negative effects on natural systems and human health and economies. Impacts of invasive species upon local ecologies is a widely studied field (Parker et al. 2001), and invasives are now viewed as a significant component of anthropogenic global change (Vitousek et al. 1996). First of all, exotic invasives can alter ecosystems processes. Primary productivity, nutrient cycling, natural disturbance regimes such as fire, and more may all be disturbed by ecological invaders (Vitousek et al. 1996, Brooks et al. 2004). These alterations on existing natural systems often have adverse consequences for local species. Such changes may lead to species extinctions and impoverishment of local biodiversity (Vitousek et al. 1996).

In the United States alone, invading alien species “cause major environmental damages and losses adding up to almost $120 billion per year” (Pimentel et al. 2005). Additionally, about 42% of all organisms on the Endangered Species list are threatened primarily by exotic invasive species and their effects on ecosystems (Pimentel et al. 2005).

The Greater Yellowstone Ecosystem has not escaped the impact of invasive organisms, and especially that of invasive plants. In the national parks of the GYE, there are currently more than 200 known species of exotic plants, with 75 of these being invasive in certain habitat types (Crowe 2005). These invasive plants have the capability to reduce native plant species, and therefore biodiversity, both “directly (through competitive exclusion) or indirectly [through] changes in vegetative structure, vegetation succession, fire cycles, and nutrient cycles” (Crowe 2005). Invasive plants are already to blame for some of the species and habitats most at risk in the GYE (Hansen 2009). Such risk to the biodiversity of the Greater Yellowstone is unacceptable.

This section shall examine an interagency monitoring program for terrestrial weeds in the GYE. The reason that effective monitoring programs for weeds are essential is that they “increase the efficiency and effectiveness of weed control programs and provide needed information for weed management staff” (Crowe 2005). Such effective and efficient management is absolutely vital in diminishing the threats to biological diversity posed by invasive plants. Without information about where weeds are located, how they spread, and the impacts they can have, the fight against them in the GYE would be futile.

The specific program which will be evaluated is the work of the Greater Yellowstone Coordinating Committee's (GYCC) Terrestrial Invasive Species Committee. The Greater Yellowstone Coordinating Committee was first developed in 1964 with a Memorandum of understanding between the National Park Service and the Forest Service. Since this time, the United States Fish and Wildlife Service and most recently, the Bureau of Land Management have joined this organization. The purpose of the GYCC is to "pursue opportunities of mutual cooperation and coordination in the management of core federal lands in the Greater Yellowstone area" (Greater Yellowstone Coordinating Committee). Essentially, the group facilitates communication and cooperation between these federal agencies in order to more effectively address landscape scale issues in the greater ecosystem. By pursuing collaboration, redundant efforts are reduced, resources are aggregated, and some of the hindrances of jurisdictional boundaries are sidestepped.

The GYCC does not have any employees of its own. It is simply an organization which facilitates cooperation amongst many governmental agencies across various levels of government. Thus, a member of a committee is sharing their time and expertise, representing their specific agency, and utilizing the shared knowledge, tools, and funds that the GYCC has to offer. In this way, the GYCC offers a platform for sharing resources, both intellectual and monetary, between the many agencies at play in the area.

Formed in 1991, the Terrestrial Invasive Species Committee, more commonly called the Weed Committee, is one of eleven subcommittees which compose the GYCC. This committee focuses on creating shared inventories, establishing cooperative weed management areas, developing best management practices, and funding and disseminating education materials in order to prevent the spread of exotic invasive weeds. Perhaps the most important element of their work is the collection and aggregation of information regarding infestations. In other words, the role they play in monitoring weeds in the Greater Yellowstone. The committee has developed extensive mapping of infestations for over 60 species of weeds in the GYE. For each invasive species, it provides a map of known infestations in the greater yellowstone, pictures of individuals, descriptions, and links with more information. The committee is also in the process of fleshing out these profiles with information about pertinent biological controls and current projects involving the species.

So far, the Weeds Committee has been most effective at collecting, aggregating and sharing information regarding weed infestations which can be used by managers across federal, state and county government agencies. Cooperating organizations include the Forest Service, Park Service, and BLM, non-profits such as the Nature Conservancy and the Hold the Line Project, and approximately thirty counties or county-based institutions.

In the last five years, the committee has received $102,500 in funding for its projects (Greater Yellowstone Coordinating Committee 2014). While this may sound minimal, it is important to remember that the GYCC has no employees. Therefore, this money is invested directly into projects. Additionally, in most cases it is the specific agencies which provide the funding for the implementation of monitoring and implementation projects.

The data collection and aggregation of the Weed Committee shall now be analyzed according to the three criteria of science, adaptability, and the human nature nexus.

Science

In 2005, 95% of habitat in the GYE was brought under jurisdiction of cooperative weed management associations, or CWMA's (Greater Yellowstone Coordinating Committee 2014). CWMA's are groups which connect government agencies, private non-profits, and landowners in the selected area in order to develop more effective weed management strategies. Most of the mapping of noxious weeds in the GYE is performed by the CWMA's at a much smaller, more feasible spatial scale. The work by these organizations is detailed, precise, and accurate. However, it is limited in scope and does not necessarily fit in with the mapping tools of organizations focused on larger geographic areas. Because weeds can spread incredibly quickly, CWMA's and other agencies needed more information: information about what weeds are infesting lands beyond their jurisdiction.

The Weed Committee was to fulfill this need. As each CWMA and agency is responsible for its own data collection and mapping, the information was often in different, incompatible formats. Soon after its creation, the committee began to fund the aggregation of this data, making it presentable to land managers and the public, and formatting it to fit into broader governmental mapping projects. Managers from the various concerned agencies may now look at precise, ecosystem-wide mapping for infestations of 62 weed species (Fremont County Weed and Pest Department 2014).

This powerful tool gives managers exactly the kind of scientific information they need to address the problem of invasive weeds. Since these maps were developed on much smaller scales, they are much more accurate as to the numbers and locations of infestations. The aggregated information they provide is invaluable to stopping the spread of harmful invasive weeds in the GYE.

Adaptability

Every year, a large portion of the funds received by the Weeds committee go directly to mapping projects. The reason for this continued funding is that the committee is updating its maps as often as possible. Invasive weeds, by definition, spread. If the map was a one-time deal it would very quickly lose any impact it may have had as certain weeds claimed new territory and managers won battles against invasives in other areas. These updates allow managers to depend on the given maps as accurate and up-to-date representations of current infestations and are the very definition of adaptive. The maps are altered to better meet changing environmental circumstances. *Figure 4* below is an example of such an updated map and illustrates the severity and pervasiveness of weed infestations in the GYE.

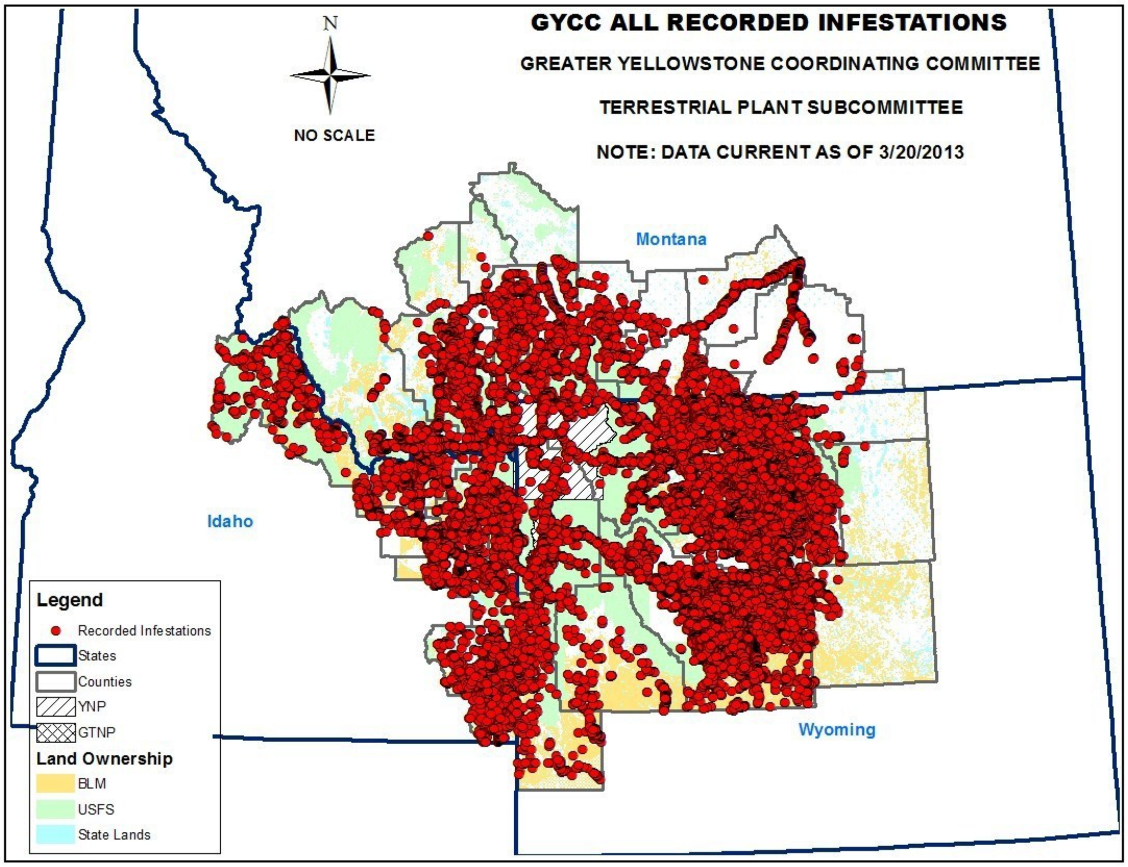

Figure 4: all current weed infestations in the Greater Yellowstone Ecosystem (Fremont County Weed and Pest Department 2014).

In addition to the evolving nature of the mapping work, the Weed Committee is adaptive in its structure. With biannual spring and fall meetings, committee members have the opportunity to share information and ideas which may be incorporated into the future work of the committee. In fact, the distribution of membership is specifically designed to facilitate this sharing and adaptation among the committee. With members from every type of organization, best management practices, new science, and integrated and adaptive management are pursued.

Finally, the mapping work of the Weed committee lays the foundation for adaptive management by any organization concerned with the spread of noxious weeds. These openly available resources give managers the information they need in clear formatting and with annual updates. This allows managers to more effectively and positively influence the ecosystems under their jurisdiction.

Human-Nature Nexus

It was stated earlier that over the last five years, the committee has received just over $100,000 dollars to pursue its goals. Anyone familiar with federal agency budgets will surely realize just how small this amount is in the face of the multiple billions spent by federal agencies in Greater Yellowstone each year. Similar to the Amphibian monitoring project, the Weeds Committee is able to add tremendous value to managers at extremely minimal costs to taxpayers. Such efficiency is uncommon in the federal government and should be appreciated when it arises.

The issue of noxious weeds is one which garners support from many parties and receives opposition from almost none. Ranchers, farmers, environmentalists all have vested interest in slowing the spread of these infestations, whether for the health of the cattle, productivity of their land, or the health of the ecosystem. While certain industries and user-groups may be indifferent to weed control, for example extractive industries, none are actively opposed to it. The control of weeds does not threaten the interests of any group. Therefore the program has strong support and has gained a ton of traction since its development 13 years ago.

Discussion

The Weed Committee of the GYCC pursues many important projects in its attempts to slow weed infestations and the deleterious environmental effects they entail. The monitoring and mapping of noxious weeds is a powerful resource for land managers across the ecosystem and one of the most useful initiatives of the committee. It gives managers accurate and important information regarding the location of exotic invasive plants, can adapt to changing environmental conditions and institutional needs, and efficiently tackles a non-controversial issue. This mapping project is another clear example of a powerful monitoring project in the GYE. By funding similar regional projects around the country, the federal government could make great strides in reducing the negative impacts of weeds in natural places all across our country.

7.2. GRYN AMPHIBIAN MONITORING PROGRAM

Introduction

The current human-driven extinction event is showing extinction rates which are up to 1000 times the background rate shown in the fossil record (Baillie et al. 2004). One group which is facing the harshest consequences is the taxonomic class Amphibia. Amphibians as a class appear to be quite vulnerable (Baillie et al. 2004) and have the highest proportion of species threatened by extinction (Stuart et al. 2004). Decline in amphibian populations has even been a problem in robustly protected National Parks (Adams et al. 2013). In fact, this is the first time an entire class of animals has been globally affected by the cumulative anthropogenic impacts on this planet's natural systems (Gascon et al. 2007). In part this is due to the limited habitat ranges amphibians can survive in. Such limited habitat means that amphibian populations correlate strongly with the amount of usable habitat accessible to them.

In 2003, amphibians were selected by the Greater Yellowstone Network (GRYN) as a "vital sign" for monitoring (Jean et al. 2005). The Greater Yellowstone Network (GRYN) is a collaboration of the three National Park System units in the GYE: Grand Teton and Yellowstone National Parks and John D. Rockefeller Memorial Parkway. It also includes Bighorn Canyon National Recreation Area, which is just outside of the Greater Yellowstone Ecosystem. According to a 2013 GRYN report, the main reasons for selecting amphibians were: "to track and estimate changes in the distribution and occurrence of breeding amphibians within [Grand Teton National Park] and [Yellowstone National Park's] wetlands... [and] to evaluate if this important and obligate wetland indicator group or vital sign could be used to assess the status and condition of wetland ecosystems and their associated biodiversity over time" (Bennets et al. 2013a). Due to their vulnerability and dependence on wetlands, and the relative ease with which they can be monitored, amphibians are the natural choice for monitoring these key ecosystems. Widespread acknowledgement of this fact can be seen by the congressional directive for Department of Interior agencies to initiate a national program of amphibian monitoring and research, called the Amphibian Research and Monitoring Initiative (AMRI).

Wetlands are among the most productive ecosystems in the world and are vital for the maintenance of biodiversity (Halls 1997). The biological diversity in wetland systems is due to both the high productivity of such systems and the strong selection pressures they contain (Gibbs 2000). Migratory species and waterfowl depend highly on these ecosystems. Wetlands also provide countless socio-economic and ecological benefits to humankind (Woodyard & Wui 2001). Thankfully, the National Parks in the GYE afford wetlands in their borders many protections which these ecosystems do not receive elsewhere (i.e. from development, pollution, and destruction). Even with these protections, however, the amphibian populations in National

Parks have been rapidly declining and are of great concern (Bury 1999). There are numerous direct threats to amphibians worldwide, but specific threats to amphibians in the GYE are "disease, fish stocking, and habitat modification associated with road and housing developments" (Bennetts et al. 2013a).

Clearly, the conservation of wetlands and amphibians is a critical component in maintaining the biodiversity and existing natural resources of the GYE. A prerequisite of effective conservation is knowledge. Hence, an inventory of wetland status, as achieved through amphibian monitoring, is necessary in the Greater Yellowstone Ecosystem.

The program to be evaluated is the Amphibian Monitoring Program of the Greater Yellowstone Network, U.S Gelogical Survey (USGS), and Idaho State University. The monitoring program itself was created, and is implemented, by scientists from each of these entities. Previous research by the Herpetology Laboratory of ISU determined that there are three native amphibian species that are regularly observed in Grand Teton and Yellowstone National Parks. These are the Columbia spotted frog (Rana luteiventris), the boreal chorus frog (Pseudacris maculata), and the barred tiger salamander (Ambystoma mavortium). The borealis toad (Anaxyrus boreas boreas), also occurs in the GYE, but sightings are scant. This research provided the "natural history, occurrence, and methodological information for the current monitoring program" (Amphibian Monitoring Working Group 2008, 3).

The methods of the current program were first developed in 2003, and by 2004 a pilot study was carried out to evaluate the approaches, definitions, and methods of the sampling design and monitoring procedure. By 2007, such preliminary testing was complete and the major strategies of the program were finalized and implemented.

The sampling design of this program is a stratified cluster design, with a stratified random selection of catchments (a smaller unit than sub-basin, but still containing individual wetland sites) from major sub-basins. The term stratified means that they were categorized hierarchically so that "more easily accessible than remote catchments are included in our sample targets, and more catchments in the high and medium habitat quality classes are prioritized for annual sampling" (Bennetts et al. 2013a, x). This was done in order to minimize costs and maximize efficiency of the program.

Once catchments are selected, all specific wetland sites within are surveyed. There are four main tasks for the field crews at each survey site. They survey for amphibians, collect important habitat and amphibian data, record this data, and document the site visually with a picture or sketch. Once it is collected, data is uploaded to a central server. There, it can be accessed through a front end file with greater ease of use. Finally, occupancy estimations are calculated and utilized in order to determine whether occupancy differs across the selected variables, like time or habitat quality.

With the annual collection of data over an extended period of time, this program is intended to "characterize changes in wetland condition and estimate occupancy rates for breeding native amphibian species" (Greater Yellowstone Network 2013, 1). It is also aimed at contributing to regional and national monitoring efforts to better understand and assess trends in amphibian populations. With the background information established, the Amphibian Monitoring Program of the GRYN, USGS, and Idaho State University shall now be assessed for its scientific and policy merits.

Science

A main goal of the Amphibian Monitoring Program was to create protocols that were "robust and scientifically defensible for long-term monitoring" (Bennetts et al. 2013a, ix). The collaboration between NPS, USGS, and ISU scientists has produced a document which does just that.

Beginning with the process of creating this act it is clear that scientific defensibility was not only a catch phrase, but a guiding principle. The evolution of amphibian monitoring in the GYE occurred as more interested parties began to emerge, concerns crystalized, and recognition of the problem became widespread. From the individual works of the ISU Herpetology Laboratory, to the current collaborative nature of the monitoring, there has been a sharpening of the methods and tools used in the GYE. This is especially true in the three year period of pilot studies, the purpose of which was to find study methods which were viable, effective, and efficient. The attention to creating such a sound document is wonderful in its own right, but the process produced more than just good intentions.

The AMP utilizes occupancy modeling (see MacKenzie et al. 2002 for full definition). Occupancy modeling has become the standard in amphibian monitoring (Bailey & Nichols 2009) and adjusts estimations based upon detectability: a variable gained through repeated observation. This method is a well-accepted way of assessing occupancy which in turn can be used to determine the multi-year breeding presence of amphibians across the NPS units of the GYE (Gould et al. 2012). Its creators see this method as an invaluable way to achieve "long-term, unbiased, baseline data" (Gould et al. 2012, 386) and there are no indicators to the contrary.

A large component of the Amphibian Monitoring Program is the inclusion of analysis at two spatial scales: individual sites, and catchment level. Petranka et al. (2004) have suggested that monitoring a set of single sites is inadequate in understanding the status of amphibians over large spatial scales. However, catchment- scale studies alone leave finer-scale dynamics totally unaccounted for. Thus we have in the AMP the inclusion of both. By implementing this stratified design across catchments and sites, the planners are able to include monitoring at both of these scales without straining limited resources. The power of the two scales is that the data may become more precise and a deeper understanding of differing variables and the dynamics at play at each scale may be gained.

Both the attention to the scientific foundations and the actual scientific research behind this program are phenomenal. This program exemplifies the ideals of the science metric used in this paper.

Human-Nature Nexus

With such a robust scientific foundation, one might expect exorbitant costs. However this program has successfully made decisions for the sake of efficiency and reduced cost without sacrificing quality. As this program is carried out exclusively on the NPS units, it does not restrict any sort of economic activity. It is also not disruptive to wildlife. With so little to fight over, there is relatively little concern regarding finding an appropriate balance between the needs of humans and biota. The only area where this balance could come into play has to do with fiscal side of the program.

If the program were run inefficiently, it could be seen as wasting tax payer dollars on an unnecessary cause. However, the Amphibian Monitoring Program carefully controls its expenditure so as to run efficiently and effectively. There are numerous examples of this found throughout the GRYN reports. One example is the use of occupancy estimation as the assessment method. Count Indices or abundance estimates are both viable options scientifically, but are prohibitively expensive or impossible to implement across the large spatial scales at play in the study area (Gould et al. 2012).

The whole idea behind amphibians as an indicator species is cost effective in its own right. Due to the relative ease with which amphibians may be monitored, and the correlation they have with healthy wetland ecosystems, this whole program could be viewed as a cost saving measure. Instead of monitoring hundreds of distinct characteristic, this collective is monitoring amphibians in order to extrapolate the other environmental qualities. This whole program is an efficient and sound use of federal resources to monitor and protect biodiversity. In the Standard Operating Procedures there is even a directive to use sedans as opposed to SUV's, due to the fact that most areas are accessible via paved roads and the sedans have "better fuel efficiency and lower operation costs" (Bennetts et al. 2013b). You have to love it!

Adaptability

As stated in the introduction section on monitoring, a vital component of successful, useful programs is consistency. The goal of consistency runs somewhat counter to the goal of adaptability. In order to provide useful long-term data, a consistent, unwavering approach must be taken. Otherwise, any attempts at data comparison or monitoring of trends are futile. It is hard to imagine that a new procedure, even if it produced more accurate data, could outweigh the value of such consistence. This is an instance where the category doesn't fit. And it doesn't need to. Given the time and energy spent creating such a sound, efficient monitoring program, adaptability is not necessary.

Discussion

The Amphibian Monitoring Program, run by a collaborative effort between the GRYN, USGS, and Idaho State University, is an example of an extremely well designed monitoring instrument. The robust scientific foundations, supported by smart and efficient policies come together to create a grand example of a powerful landscape scale tool for monitoring amphibians. The inclusion of other federal agencies and an educational entity is another well-designed aspect. This collaboration distributes costs, pools knowledge, and creates mutually beneficial outcomes. Federal or state agencies looking to perform similar work are advised to examine the methods and work of the GRYN, USGS, and ISU. Here is a beautiful example of monitoring which will greatly aid in the conservation of biological diversity.

7.3. MONITORING DISCUSSION

In the two monitoring programs evaluated, we see two effective and efficient examples of how monitoring can be implemented by federal land management agencies. These cases provide examples where the programs used tax dollars cost-effectively, had little to no competing user-groups or management goals, are consistent in their measurements, and are based on strong scientific research. With these two programs as indicators, it is logical to believe that monitoring programs throughout the GYE are well-managed. With programs like this, the category of monitoring is certainly a stand out in the ecosystem.

One thing of interest to note with many monitoring regimes is that they appear only to be implemented with broader federal programs, or with management regimes in specific areas. They are almost never stand alone instruments. This gives them specific goals, purposes, and, usually, the necessary funding. These characteristics, in addition to their consistent nature, mean they tend to be very well executed programs.

The only suggestion I have for federal monitoring in the Greater Yellowstone Ecosystem is even more efficient data sharing between federal agencies and the public. The work of the GYCC in connecting agencies and the general transparency of federal work is good, but not great. By improving public access and interagency communication the value of these monitoring programs could be expanded. They provide scientifically sound information that is pertinent to many interests. By more fully sharing this information, the value of these programs is increased.

This could happen several ways. The first are agency mandates, whether through a Memorandum of Understanding (MOU), the order of a Supervisor or Director, or other means. Increased public interest and outcry for improved transparency could also play a role in achieving this. Finally, by leveraging the work done by the GYCC, either by increased focus or funding, these projects could be more successfully shared between federal agencies and the general public. Such work would strengthen an already fantastic monitoring regime in the Greater Yellowstone Ecosystem.

8. CASE STUDIES: RESTORATION

8.1. ENDANGERED SPECIES ACT and GRIZZLY BEAR

Introduction

When the expedition of Meriwether Lewis and William Clark first ventured through the unexplored interior of today's Rocky Mountains in 1804, there were an estimated 50,000 Grizzly bears (Hall 1999). Since then, the grizzly bear has been extirpated from more than 99% of their historic range in the United States (Miller & Waits 2003), with the population reaching a nadir of only several hundred individuals (Erickson 2012). This extirpation has been due almost exclusively to human caused mortality and habitat usurpation (Mattson & Craighead 1994, 102).

In 1975, in recognition of the fragility of the remaining grizzly bear populations, the U.S Fish and Wildlife Service (FWS) listed *Ursus arctos horribilis* as a threatened species in the coterminous United States under the Endangered Species Act (ESA). The listing process mandates the creation of a species recovery plan, and thus the Grizzly Bear Recovery Plan was devised.

Since the implementation of the Grizzly Bear Recovery Plan there have been several amendments to ESA and changes in the management grizzly bears in the GYE. These are summarized concisely by Erickson (2012). This management regime has produced a healthy population of ~ 610 individuals in the GYE (with a range of 549- 672 with 95% confidence), as recorded in 2012 (Haroldson et al. 2012). There have also been several attempts by the FWS to delist the GYE subset, or distinct population segment (DPS), of the Greater Yellowstone grizzlies. These attempts have thus far been unsuccessful (see Greater Yellowstone Coalition v. Servheen).

I will now outline the protections that were put in place by the listing of the grizzly as an endangered species and the creation of the Grizzly Bear Recovery Plan. I will then analyze this policy according to the three criteria of sound science, well-rounded socio-economic considerations, and adaptability.

The Endangered Species Act defines the term “endangered species” as “any species which is in danger of extinction throughout all or a significant portion of its range” (ESA). There are five means by which a species can become endangered: threats to its habitat or range, over-utilization by man, disease or predation, the inadequacy of regulatory mechanisms, and other natural or manmade factors affecting its continued existence. If a species is threatened by extinction from any one of those factors, it can be listed as endangered. This also includes the inverse; once a species’ long-term survival is not threatened by any one of these, it may be “delisted”. Once a species is listed as endangered, it receives full ESA protections.

Section 4(f) of the Endangered Species Act mandates the creation and implementation of a recovery plan for any listed species. In order to create this plan, the interagency Grizzly Bear Steering Committee was instituted at the time of listing. In 1983, this committee was replaced by the Interagency Grizzly Bear Committee (IGBC). The mission of the IGBC is “to ensure recovery of viable grizzly bear populations and restoration of their habitats...through an interagency coordination of policy, planning, management, and research” (USFS 2011). The group’s specific responsibilities involve the implementation of the Grizzly Bear Recovery Plan, directing research and monitoring, and supervising the subcommittees of the IGBC.

This recovery plan, along with the Interagency Grizzly Bear Management Guidelines, are two pieces of documentation which have been the largest drivers of grizzly bear management in relation to the ESA (Silliman 2002). Thus it is these documents which will be evaluated.

The 1993 Grizzly Bear Recovery Plan

The Grizzly Bear Recovery Plan was first published in 1982 and later revised by the FWS and re-published in 1993. This plan is one of two administrative documents that were instrumental for realizing the goals of the ESA (Silliman 2002). This plan does not mandate specific programs, actions, or resource allocations. Instead, it outlines steps which will facilitate grizzly bear recovery and, "in practice, sets only broad conservation targets and provides technical information to public land managers" (Silliman 2002). For the purposes of this analysis, the revised addition shall be examined.

Science

Of the two documents, the 1993 GBRP has a more effective discussion and inclusion of scientific research related to the grizzly bear in regards to its management. For example, there are well-supported sections discussing population viability, the effect of isolated "island" habitats, effective bear habitat, genetic diversity and the effect of these considerations upon management. In fact the only section found to be truly lacking was the assessment and discussion of linkage zones.

In the GBRP, "linkage assessment" is seen as a needed component for bear recovery. This is accurate; for bears to thrive in the long run, there must be mobility between habitats. Such mobility facilitates genetic flow between populations and allows source/sink dynamics to play out, ensuring the presence of grizzly in their traditional range even when conditions are less than ideal. However, the plan does not provide any specific management advice for maintaining, creating, or facilitating these linkage zones. Instead, the plan calls for an evaluation of these linkages to be given in five years' time in the GBRP 5 Year Reviews. Looking to the most recent of these, the 2011 Review has only this to say: "we will continue interagency efforts to complete the linkage zone task in the Recovery Plan (FWS 1993) to provide and maintain movement opportunities for grizzly bears, and reestablish natural connectivity and gene flow among all grizzly bear populations in the lower 48 States" (USFWS 2011). While this sounds reasonable enough, no more specifics are given. The lack of detail about any specific action being taken casts doubt on the actual implementation of linkage monitoring and evaluation. It is also stated in the 1993 Recovery Plan that such linkages "are desirable for recovery, but not essential for delisting" (USFWS 1993, 25). The view that connectivity between cores is not essential for the long-term survival of grizzly bears is one with which many conservation biologist would disagree (see Noss 1983, 1987, Craighead and Vyse 1996, Paetkau et. al. 1998).

While all of the science contained within the revised Grizzly Bear Recovery Plan dates back to at least 1993, it is still well-supported in many areas. Some areas where large advances have been made, such as genetic considerations, may be lacking, but a complete evaluation of these is beyond the scope of this paper. There were, however, noticeable shortcomings in regards to connectivity in both the Grizzly Bear Recovery Plan, and its most recent 2011 assessment. From the standpoint of biodiversity conservation, such short-comings are not acceptable.

Human-Nature Nexus

In any public policy matter, the nexus of people and nature is of great concern. In the case of the grizzly, it is even greater. In the GBRP, the grizzly is listed as a 6C species, meaning one with a high level of threat but also a high recovery potential that is, or may be, in conflict with some form of economic activity. This is delineated early on in the GBRP (pp. ii).

The GBRP does a nice job of balancing concerns for the recovery of the grizzly and the health of the economy and society. There is a whole section within the revised GBRP (pp. 28-30) discussing the social, cultural, and economic factors pertaining to bear management, and the impact of these factors on successful conservation. The ideas of values, differing positions and interests, institutional/regulatory structures, and social structures are briefly discussed.

This discussion does a good job of raising awareness of these issues to management agencies. It presents many of the various and competing interests in an understanding light. It does not, however, offer suggestions for the inclusion of these concerns in actual management. Thus, it only raises the issue, and does not aid in dealing with it. This means that managers must learn from the literature, each other, and their communities about how best to incorporate a proper balancing of the human-nature nexus in their policy. This could be a blessing or a curse, leading to a powerfully specific solution, or no solution at all.

Another concern of the human-nature nexus is that of efficiency; how much good is being done for the environment and at what cost? A positive example of efficient management is the improved grizzly bear population monitoring techniques. Monitoring of bear individuals is a pertinent need for their management and listing under the ESA. As stated in the GBRP, "the development of a population monitoring system requires balance between precision and cost" (pp. 19). This is achieved via monitoring of females with cubs, occupancy, and mortality indicators. A detailed rationale is given for each of these that is very satisfactory. It lends credence to the idea that these are efficient and effective means of population monitoring that balance precision and costs.

Adaptability

In terms of its adaptability, the ESA includes a mandate for a status report of listed species to occur every 5 years (section 4(c)(2) ESA). Thus the effects of the GBRP are reviewed, and may be accounted for, every five years. It is flatly stated that “this plan is intended to be dynamic and will be revised as future research indicates that changes are needed” (pp. 31). In this way, room is left open for the plan to be altered to fit with changing science and environmental, social, or political conditions.

Additionally, the revised version I evaluated is proof of adaptability. It was released ten years after the original plan and included revised population monitoring methods, delineation of recovery zones, population targets, post-delisting conservation strategies, and a long-term strategy for the Yellowstone grizzly population. These revisions were based on newer science and understandings of the effects of previous management.

Interagency Grizzly Bear Management Guidelines

The second document which has been crucial in managing grizzly bears is the Interagency Grizzly Bear Management Guidelines. These guidelines were first developed in the GYE in order to create a set of procedural means to grizzly recovery, and adopted by the IGBC in 1986. At the heart of the Guidelines are the stratification of 5 different management scenarios relating to habitat suitability and presence of grizzlies. These five management situations are used to classify areas and provide guidelines for the management of each. For example, in Management Situation 1, the area is a key grizzly bear population center (i.e. a source population) with pristine or high-quality habitat. In such a situation, recommendations for management include maintenance and improvement of habitat and reduction in human-bear conflict as the highest priority directives. In such areas, disruptive land uses shall also be disallowed. Management Situation 1 is an example of an area with the highest protection, on the other end of the spectrum are areas which are not suitable for bears, and any problematic occurrences will be removed.

Science

The delineation of the different management situations in the IGBMG is a scientifically sound management suggestion. This demarcation protects the core or wildlands areas which are so important in the eyes of conservation biologist such as Michael Soulé or Reed Noss. These cores are protected by prioritizing bears over economic activity, disallowing disruptive land uses, and limiting the "controlling" of problem bears[11]. It also aids in the minimization of human-bear conflict, which is a major threat to the survival of individual bears, and if poorly managed, can threaten populations as well.

The IGBMG also includes a "biological opinion" of its suggestions. This biological review found that the "implementation of the Guidelines for Management Involving Grizzly Bears in the Greater Yellowstone Area will promote the conservation of the grizzly bear" (pp. 92). This biological review was submitted in accordance with the Interagency Cooperation Regulations of the ESA, meaning it utilizes the "best scientific and commercial data available" (ESA section 7(c)(1)). It does not, however, cite any specific biologist or other scientists who evaluated and approved its efficacy.

[11] Such that killing only occurs in cases where individuals can have negative effects on the population as a whole or have been habituated to behaviors which are a direct threat to human safety.

Human-Nature Nexus

The different management situations created in the IGBMG, offer a valuable compromise between the needs of humans and bears. By creating a sliding scale of the biological needs of bears, and the economic and safety needs of humans, a balanced policy can be implemented. Where the needs of bears outweigh those of humans, they receive priority, where humans are well established and bears are merely transitory, it is the needs of humans which are weighed more heavily. This system of weighted interests avoids the all-or-nothing management of the past.

In addition to the inclusion of these different management situations, there are also guidelines for the determination of nuisance status and the controlling of nuisance bears. These guidelines offer a sound way to assess bear interactions and determine the threat an individual poses to humans and then balance that threat against the well-being of the bear. It also provides measures for the "control" or killing of bears which are a threat to humans and cannot be dealt with in any other way. These guidelines effectively denote and deal with nuisance bears in ways which appropriately balance the needs of humans and the needs of the animals.

Adaptability

The IGBMG includes adaptability rhetoric in its drafting. For example, on the fifth page of the document one sees an entirely capitalized paragraph with the words "Guidelines are subject to change as research provides additional data and/or management directives change" (pp. 5). Clearly, this is a section which the drafters wanted to highlight. Whether or not these guidelines have actually been adapted to account for such change in data or directives is less clear.

Another inclusion of adaptability comes from the management situations. The specific management situation classification of an area is determined by the Forest Supervisor, Park Superintendent, or BLM Area Manager in their respective areas of responsibility. Although it is not explicit, the ability of respective mangers to delineate management situations allows for the possibility of change in demarcations. As new conditions appear or are understood, it seems as though the relevant manager could acknowledge said change by reclassifying an area as a different Management Situation.

Discussion

In the Greater Yellowstone Ecosystem, being listed under the Endangered Species Act affords the grizzly bear many stout protections. Two of the most utilized documents which clarify and carry out these protections are the revised Grizzly Bear Recovery Plan and the Interagency Grizzly Bear Management Guidelines (Silliman 2002). An important note on these two documents is that neither of them is binding, allocate resources, or mandate specific actions or programs. Thus, the policies, suggestions, and guidelines they contain do not necessarily reflect the action of all agencies. This could definitely be considered a weakness of these policies. However, they are often followed very closely and discussed point by point when working on management plans (Fletcher 2013). The recent delisting and subsequent re-listing of the grizzly bear has created some discrepancies between Forest Plans and these two documents, as they were altered during delisting and may not have been restored since re-listing occurred (Fletcher 2013).

Overall, these two documents have relatively sound science, good observance of the needs of humans and wildlife, and are adaptable. They are well written documents which aid heavily in the restoration and conservation of the Grizzly bear. The applicability and success of these documents, and the ESA as a whole in relation to grizzly bears, may be seen in the healthy sub-populations which now exist in multiple ecosystems. It is helpful to note however, that in part, these successes are due to the public support of the cause of the grizzly. With such intense support, greater levels of federal funding and higher priority were given to the effort to conserve these iconic creatures.

Despite these factors, there are certainly areas where these documents could be improved. First of all, creating binding management guidelines along the lines of the GBRP or IGBMG would increase their capacity for grizzly restoration. The non-binding nature of these documents leaves too much wiggle room for federal action. The next, and largest of these improvements is in relation to the science of connectivity. In both plans there is a lack of actionable material in regards to connectivity, corridors, linkages, or any other habitat bridging system. In light of the findings of conservation biology, this is unacceptable. The U.S. subpopulations of bears must be linked to each other and to the larger Canadian populations if they are to survive in perpetuity. Without such connections, the introduction of breeding bears will remain a necessity and natural gene flows will not occur.

The issues of linkages could be addressed by utilizing the knowledge, resources, and tools of the private sector. Non-governmental organizations pursuing education, conservation easements, wildlife bridges, and more, could be instrumental in the protection and creation of such habitat linkages. By actively pursuing relationships with these organizations and including findings regarding linkages in the federal management of bears, great strides could be made in fully restoring grizzly bear populations to their position as a natural top-down ecosystem regulator.

8.2. WHITEBARK PINE RESTORATION

Introduction

On windswept ridges, in the harsh conditions on the leading edge of tree line, one can often find beautifully twisted trees. With many gnarled limbs stripped of life and several with triumphant shoots of green, these grizzled ancients carry on. They are a well-loved sight to high mountain travelers. Called krummholz, a german word for bent wood, these contorted trees are an example of life in some of the world's most brutal conditions. One species that commonly forms krummholz is the Whitebark pine, or *Pinus albicaulis*.

Whitebark pine is found at tree line, where it is often a dominant species, or in sub-alpine forest communities (Arno & Hoff 1990). As a species, they can be incredibly long-lived, commonly surviving over 700 years, with the oldest recorded individual reaching the age of 1270 (Arno & Hoff 1990). Named for their outward appearance, these trees are an important feature of the mountains of the Rockies West for aesthetic and, more importantly, ecological purposes.

The whitebark pine is often described as both a keystone and foundation species; where the former has an ecological role that is disproportionately large in comparison to its abundance, and the latter is one that plays a defining role in ecosystem structure, function, and process (Smith & Smith 2001). They are ecologically important for a number of reasons. The most obvious is the nutritional value of their seeds. Lipids compose 50% of their seed matter, an extremely high percentage which makes them "one of the most energy-rich vegetative food sources available to many wildlife species" (Bockino 2008). At least 110 species utilize these energy rich seeds as a food source during the year (Tomback 1986). Clark's nutcracker, red squirrel, and grizzly bear are some of the most dependent species. In fact, in late August, grizzly bear will seek out squirrel middens for their buried stashes of whitebark pine seeds, and eat almost nothing else (Mattson & Reinhart 1994). In regards to bear, researchers also found that "management trappings of bears were 6.2 times higher, mortality of adult females 2.3 times higher, and mortality of sub-adult males 3.3 times higher during years of small seed crops" (Mattson et al. 1992). Clearly, the health of grizzly bear in the region are correlated with the health of whitebark pine.

In addition to providing nutritional sustenance to many important species, whitebark pine fill other important ecological roles. These trees positively affect local hydrologic conditions by "trapping snow, increasing accumulation, and regulating the retention of snowdrifts that generate late-season stream flow" (Bockino 2008) which can have benefits to entire watersheds, including downstream human users. This species is also important for forest succession, often being an early colonizer and a key facilitator of regeneration on recently disturbed land (Tomback 2005). Finally, whitebark pine can act as important soil stabilizers that reduce erosion and avalanches (Bockino 2008).

With all of these important ecological roles, whitebark pine plays a huge role in "[promoting] regional biodiversity" (Keane et al. 2012). It is clear that any threat to the species will have broader, "cascading effects with diverse impacts ranging from watershed protection to threatened and endangered species" (Logan & Powell 2001). Unfortunately, such threats already exists, and have brought about pervasive, large-scale reductions in the abundance of whitebark pine.

In recent decades, the populations of whitebark pine across the west have been in rapid decline. For example, in Glacier National Park, the species is down to a mere 5% of its historical range, and outside of Missoula, MT, 60-80% of these trees have died (Keane 2001). Across the northern Rocky Mountains as a whole, whitebark mortality is as high as 90% (Gibson et al. 2008). There are three main factors which are commonly cited as the reasons for these population declines: white pine blister rust (*Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosae*), and fire suppression regimes (Keane et al. 2012).

White pine blister rust is an exotic fungal pathogen which was introduced to the western United States in 1910 (Keane et al. 2012) This pathogen kills branches and trees by girdling, or completely encircling, trunks and branches (Hoff 1992). Besides simply killing the pines, this disease also results in a diminished rate of seed cone production (Keane et al. 2012) Whitebark pine is very susceptible to blister rust, with only about "26% of the GYA population showing genetic resistance to the rust" (Hoff et al. 2001)

Mountain pine beetle are native to the Rocky Mountains, and historically cause some mortality among whitebark pines. Although mountain pine beetles co-evolved with whitebark pine, in recent years their effects on the trees have been much greater in magnitude. The most recent mountain pine beetle outbreak has achieved "unprecedented intensity and geographic extent, driven by rising temperatures that many associate with anthropogenic climate warming" (Keane et al. 2012).

Finally, whitebark pine is a fire adapted species that relies on varying intensity fires for successful reproduction. Recently burned areas create "good caching habitat for Clark's nutcracker" (Keane et al. 2012). These sites, with relatively little competition, provide beneficial growing conditions for whitebark pine and allow them to flourish. Whitebark pine are also shade intolerant, meaning that once more shade tolerant plants enter a stand, the whitebark tend to slowly die out. A long history of fire suppression has caused this succession to happen in many areas which would have seen fires that allowed whitebark regeneration.

In order to address the risk to whitebark pine in the Greater Yellowstone Ecosystem, the Greater Yellowstone Coordinating Committee created the Whitebark Pine Subcommittee in 2000. The mission of this subcommittee is to "work together to help ensure the long-term viability and function of whitebark pine in the Greater Yellowstone Area" (GYCCWPS 2011). In 2011, the committee released their official strategy for whitebark pine management, called the Whitebark Pine Strategy for the Greater Yellowstone Area. This central strategies of this document are monitoring, restoration, and protection of whitebark pine. This section shall focus on management actions within the restoration section, as well as some from the protection section, which this author deems restoratory in nature.

Within these areas of focus, are four main categories of action. There is (1)protecting existing stands, (2) creating a seed orchard, (3) tree planting, and (4) facilitation of stand regeneration. Each of these categories shall be considered in the evaluation of this policy document.

Science

Throughout the document, there is a rigorous attention to the science behind each management action. There is even a strategic objective to "ensure that the most recent research is incorporated into whitebark pine management actions" (GYCCWPS 2011). Each of the four categories of action shall be analyzed.

In order to protect existing stands, the Whitebark Pine Strategy document recommends several actions. The two most significant are the application of carbaryl and verbenone, an anti-aggression pheromone. Carbaryl is a preventative insecticide spray which provides protection for 1-2 years from mountain pine beetle (GYCCWPS 2011). Unfortunately, this pesticide can be harmful to animals, especially amphibians (see Relyea & Mills 2001). While whitebark pine sites are generally located at higher altitudes and poorer soils than those which support amphibian populations, there may be a risk of chemical runoff. This risk, or lack thereof, is never addressed in the plan. Verbenone is a pheromone which can reduce attacks by pine beetle as well. In fact, it was found by Kegley and Gibson that protection could be up to 80%. However, it was also determined that if more than 15% of trees are already attacked by beetles, this treatment will be less effective (Kegley & Gibson 2009). This important piece of information is not noted in the plan. Additionally, it was found that, "unquestionably, treatments are more focused when verbenone is applied at a rate of 2 pouches per tree, compared to 20-40 pouches per acre in an area treatment" (Kegley & Gibson 2009). Unfortunately both of these practices are suggested in the Whitebark Pine Strategy document, instead of just the more efficacious one. The protection of existing stands lacks scientific grounding in these areas.

In order to retain important genetic material which could later be used for tree plantings, a whitebark pine seed orchard was created. In order to obtain valuable genetic material, seeds were collected from trees which appeared to be genetically resistant to white pine blister rust. In order to find such trees, teams are sent to areas with high rates of blister rust infection and search for individuals which exhibit no sign of infection. While this is a logical step, it does not necessarily mean that these trees samples are resistant. In order to be certain that any trees to be planted in the GYE were rust resistant, a breeding procedure and performance test were conducted. This breeding test allowed researchers to determine which individuals had the best genetics, isolate those with poorer resistance, and breed trees for reintroduction (GYCCWPS 2011). This seed bank appears to do a great job of ensuring rust-resistant individuals.

The next category of restoration work in the Whitebark Pine Strategy document is the replanting of individual trees back into the ecosystem. The planting regulations were developed based on a surprisingly deep foundation of academic work (McCaughey et al. 2009). In general they include growing a seedling for two years in a controlled environment before planting, and then characteristics about planting steps and necessary conditions. These regulations appear to be academically sound and each guideline is supported by scientific research (see McCaughey et al. 2009).

The final aspect of restoration in the Whitebark Pine Strategy is the facilitation of stand regeneration. There are two distinct ways the plan pursues this goal: prescribed burns and the creation of nutcracker openings. In order to return ecosystem processes to whitebark pine landscapes, fire must once again plays its part (Keane 2001). Prescribed low-intensity fires would be used to kill primarily sub-alpine fir in the understory (as well as some in the overstory), without threatening mature whitebark pines (GYCCWPS 2011). Doing so would help whitebark pine in these mixed population forests to continue to flourish by removing their competition and successional followers. The science behind this section is limited, and the mandates appear to be more common sense based. As the outcomes of these actions will be monitored, that is not necessarily a bad thing as it provides an opportunity for learning and adaptive management.

The second aspect of stand regeneration being pursued by the Whitebark Pine Subcommittee is the creation of nutcracker openings. These openings are intended to increase the natural regeneration of whitebark pine through increased caching by Clark's nutcracker

(GYCCWPS 2011). It is also hoped that doing so will increase genetic diversity of whitebark pine (Krakowski et al. 2003). Guidelines for the size and location of these openings are based on multiple studies of Clark's nutcracker behavior and past whitebark pine regeneration (See Lorenz et al. 2008; Moody 2006; Klutsch et al. 2008). They are sound, scientifically-based management suggestions.

While there is some question about individual suggestions in this plan, such as an inattentiveness to the possible outcomes of introduced pesticides, as a whole it appears quite sound. With solid, scientifically-backed attention to each of these four categories, the future of the whitebark pine looks more and more hopeful.

Adaptability

The adaptability of this program can be seen in two main ways. The first is the ongoing seed orchard work and the second is the pervasive inclusion of climate change related discussion and actions.

In order to maintain viable seed populations for replanting objectives, the seed orchard undergoes constant performance testing. This testing looks into characteristics such as performance, cold hardiness, blister rust resistance, growth, and genetic diversity (GYCCWPS 2011). This allows managers to be constantly tuning their seed crop to make sure it can survive in changing environmental conditions. Additionally, the collection of new genetic material is ongoing, giving managers the opportunity to seek out preferable traits for their breeding program: allowing adaptation as the program continues its course.

Throughout the Whitebark Pine Strategy document there are numerous mentions of climate change, one of the most pressing issues which land managers will have to adapt to in the coming years. There are a whole set of guidelines for selecting sites in the program which are based off of adaptable management to deal with coming perturbations of climate change. For whitebark pine, the relevant environmental changes are temperature and precipitation changes: changes which could strengthen the onslaughts of both blister rust and mountain pine beetles (Keane et al. 2012). In order to deal with these possible changes, the document has management guidelines for increasing ecosystem resistance and resiliency to the possible outcomes of those changes. These instructions include promoting genetic diversity, a mosaic of age and stand types, and considering future climactic conditions when selecting planting sites (GYCCWPS 2011).

The above promote adaptive management of whitebark pine to help ensure its survival, even in the face of worsening climactic conditions.

Human-Nature Nexus

The entirety of the area which will see the whitebark pine restoration work of the GYCC carried out is federally owned land. Not only is it all under federal jurisdiction, but due to the high-altitude habitat of the whitebark pine, their are general very little land use conflicts. Due to their location, whitebark pine stands are generally only accessible via intense hikes. Thus they do not usually coincide with rangeland, wood extraction, or other, possibly conflicting, uses.

As it usually does when conflicting uses are minimal, much of the balance of human and natural needs comes down to the amount, and efficiency, of resources spent on the program. There are two main ways the GYCC Whitebark Pine Strategy reduces costs: pooling resources and aiding in natural whitebark pine regeneration.

By its nature as an interagency cooperative organization, fundamental to the GYCC's purpose is the pooling of resources, the reduction of redundancy, and the coordinated management of an issue. By participating in the GYCC's Whitebark Pine Subcommittee, these organizations know what other agencies are doing, and therefore the extent to which they should pursue certain elements of management. For example, because the seed bank is under the management of a solitary agency, no other agency has to allot funds to create seeds. Having segmented management in this way also allows operations to run much more quickly. By relying on only one agency to operate specific segments of the Whitebark Pine Strategy, bureaucratic hurdles are not created unnecessarily. Thus, the benefits of cooperation can be achieved without the monumentally slow pace it can sometimes entail.

The strategy document also promotes natural regeneration of whitebark pine in the GYE. The first way this is incorporated into the plan is in the site selection process for replanting. When choosing sites to replant, areas where conditions are beneficial and promising for natural regeneration of whitebark pine, such projects shall be avoided. Also, by creating open areas for Clark's nutcracker, natural regeneration can be promoted, reducing costs and saving seed stock, and other resources for projects in areas where natural regeneration is unlikely to occur. Both of these directives increase the efficiency of the program, saving taxpayer dollars and whitebark pine.

Discussion

As it is written, the Whitebark Pine Strategy for the Greater Yellowstone Area is a well-written document. It creates a powerful, well-supported restoration regime for the declining whitebark pine population of the entire ecosystem. This regime responds to the major threats to the species, handles them scientifically and thoroughly, and creates a multi-faceted approach to return the health and abundance of the whitebark pine to its historic levels. It is a fairly non-controversial program that is run efficiently at minimal costs. It is also an adaptive program, which should be able to protect and restore the whitebark pine for years to come.

8.3. RESTORATION DISCUSSION

Restoration projects are some of the federal government's most notable accomplishments in the Greater Yellowstone Ecosystem. The reintroduction of wolf and bison populations, and the restoration of the health of grizzly bear are the perhaps the most obvious and appreciated of these projects. However, works such as those being carried out with whitebark pine, and, to a limited extent, fire are also worthy of praise. All of these projects are helping to restore the functioning of these ecosystems to their pre western degradation conditions. By restoring ecosystem components such as apex predators and by allowing fire to burn (until it threatens people or structures) in Yellowstone National Park, top-down ecological processes are being restored. These top-down ecosystem regulators are exactly the type of projects that conservation biologists hope to see. By returning these top-down ecological processes and components, the broader health of many diverse components of the ecosystem is helped.

The many restoration projects occurring in the Greater Yellowstone are significant. They represent powerful management to aid in the return of these important ecological members and processes. However, more could be done. Notes have already been taken on possible improvements for management of whitebark pine and grizzly bear restoration. On a larger scale I have one major suggestion.

With so much of the current focus of restoration projects on individual species, it feels as though significant, rare, or endangered assemblages of species are not being given the consideration they deserve. With the Endangered Species Act, individual species across the animal and plant kingdoms are being given an intrinsic value, a value seen as worthy of protection. While this is not disputed, this author also sees such intrinsic value in the broader ecosystems and assemblages existing in nature. It may not be that the sum is greater than its parts, but at the very least it is equal. So far the federal government has almost always valued the parts more than the whole. The ESA clearly gives value to the individual, then offers protection to the whole only if it is necessary for that individual. This is the way that critical habitats are protected under this act.

Imagine a legislative effort that instead primarily valued the whole and secondarily valued the parts that compose it. By valuing the whole and enacting protections and restoration projects which are specifically suited to protecting the overall health and function of the ecosystem, this style of management could be more effective *and* efficient. By managing for the health of the parts, the greater picture can be missed, funds can be used redundantly, and the work is probably considerably less efficient. Valuing and managing for the health of the whole would not only provide managerial improvements, but could also help to promote the societal value placed upon not just individuals, but natural systems. The idea of an Endangered Ecosystems Act should, at the very least, be researched further to provide insights into the benefits, implementation, and barriers to such legislation.

An additional government product that could aid in restoration is the funding of continuing research and education into the economic and human benefits of individual species and ecosystems health. By illuminating our dependence upon these natural systems and their health, and educating constituencies about their importance, perhaps further support, and thus more funding, could be funneled into these projects.

The future of restoration projects in the Greater Yellowstone looks healthy. Built upon a strong foundation of existing projects, the health of the ecosystem appears to be continually improving. And this shows no signs of changing. For one thing, the protections offered by the Endangered Species Act are powerful, and so far, successful. Management is unlikely to vary too much across species and so one can foresee strong protections into the future. With a sharp, informed, and connected nonprofit presence in the region, political pressure for these projects will remain a strong presence for federal managers in the area. This pressure should maintain strong levels of federal focus on effective restoration projects in the ecosystem for years to come.

9. GREATER YELLOWSTONE ECOSYSTEM DISCUSSION

In the Greater Yellowstone Ecosystem, the federal government is successfully implementing at least 7 policies within the four most important parts of any biodiversity conservation management scheme: cores, connectivity, monitoring, and restoration. While there is room for improvement, as noted in each of the subsections, the current state of management in each of these examples is impressive with regards to its basis in strong science, its adaptability, and its attention to the human nature nexus.

In order to draw an aggregate picture of the federal conservation of biological diversity in the Greater Yellowstone Ecosystem the question must be asked: how representative are these policies of all others in their category of management. For example, how accurate a picture do we paint of core management in the entire ecosystem when we examine wilderness and Shoshone National Forest policies? If the policies selected paint an inaccurate picture of management in each of those four realms, our overall picture shall be very skewed. This question of representativeness shall be examined for each of these four categories for successful biodiversity management.

The protections offered by the Wilderness Act and the Forest Plan of the Shoshone National Forest do not necessarily represent the majority of federal holdings in the Greater Yellowstone Ecosystem. However, in the years to come, as National Forests must redraft their Forest Plans to adapt to changing circumstances and fulfill their legal charges, one would expect that more and more plans will begin to resemble that of the Shoshone. It has been noted that there are major shortcomings with the planning rule for these documents, especially in relation to the inclusion of science and the balancing of the multiple uses of an area. However, with strong public interest and high non-profit presence, similarly balanced plans will be forthcoming. If all National Forests are managed like the Shoshone, and both the Wilderness holdings and the non-designated but similarly managed wildlands of Yellowstone National Park, are considered, then the majority of federally owned cores in the ecosystem will be protected under the two policies which were evaluated. Thus, it is reasonable to assume that these policies generally represent the level of federal protection for cores in the Greater Yellowstone Ecosystem.

Connectivity is the category for which the evaluated policy, the pronghorn amendment to the Bridger-Teton National Forest Plan, is the least representative. This policy is the only one of its kind in the ecosystem. This is in part due to the simplicity of the pronghorn requirements. However, as was noted earlier, all other notes on connectivity management and facilitation are vague, non-committal, or devoid of actionable directives. The only reason that the ecosystem can be taken to have generally good connectivity is the incredibly high percentage of coterminous protected lands, and the minimal amount of development in between. While development is expected to continue increasing in the GYE, these increases are limited to acres outside of these protected areas. The fact that so many lands are federally owned has been a saving grace for the biologically diversity of the greater ecosystem and, with increasing federal focus, should continue to be long into the future. This is, however, the category where the least amount of work has been done, and perhaps where the greatest potential for future projects exist.

The two programs which were selected for evaluation in the monitoring category were both strong programs which would provide invaluable data for the conservation of biological diversity. Both were structured and implemented to some degree by collaborative federal groups. One could imagine that given this collaborative nature these programs would be more effective than programs designed and implemented by only one agency, however this is unlikely. There is a consistent need for credible environmental information, which often does not diminish across agencies. This need means that, using the same tools, federal agencies will probably develop similarly powerful monitoring programs. There is no reason to assume that other monitoring programs in the ecosystem are substantially less effective than the GYCC weed program or the GRYN amphibian program. And as long as other programs remain in the same ballpark, monitoring across the ecosystem looks very good.

Finally, the restoration of grizzly bear and whitebark pine in the Greater Yellowstone Ecosystem should be very representative as well. The grizzly bear receives the majority of its protections, and thus its management is driven in large part by, the Endangered Species Act. Therefore it is reasonable to assume that other organisms, especially large predators such as wolf and lynx, which receive listing under the act will receive similar protection. It is even reasonable to assume that *any* species listed as endangered would receive similarly scientific and adaptive policies aiding in its restoration and protection. The whitebark pine provides an example of the restoration of a highly valued plant species. Its mandates also fulfill each of the three metrics of sound policy. These two species are both of particular interest to conservationists, managers, and other stakeholders in the ecosystem. Therefore, one might again assume that level of restoration they receive is greater than that of other organisms. However, even if these examples are slightly above average in the ecosystem, then the average is still quite good.

Many readers may question these selections and wish that other choices had been made, such as an analysis of wolf or bison management. In this expansive and well-managed ecosystem, there were simple too many choices to examine them all. These policy case-studies are but a small sampling, even among the “big” issues in the ecosystem.

10. CONCLUSION

In each of the four required categories of the sound management of biological diversity there were strong, representative policy examples. Nearly all of these examples were great policies, as measured by the three metrics: the inclusion of, and basis upon, credible science, the adaptability of management, and the attention to the confluence of the needs of humans and biological diversity. In assessing the federal government and its management of biological diversity in the Greater Yellowstone ecosystem, this is incredibly important. The federal government is creating and implementing sound policies in each of the required areas.

There will always be room for more improvement. As was noted in each of the section discussions, multiple actions could be taken to improve how well the government meets the four categorical requirements of cores, connectivity, monitoring and restoration. This is true in connectivity especially, where the current lack of policies is somewhat surprising and where such policies working on both intra and inter-ecosystem connectivity could benefit wildlife and ecosystem processes even more. But these areas for improvement do not mean that federal management is seriously lacking in any way, they just mean it could be improved.

With nearly every category strongly fulfilled, either through good policies or existing land ownership patterns (i.e. in connectivity), the federal government is doing good work in managing and conserving the biological diversity it stewards in the Greater Yellowstone Ecosystem. Although it is tied to management in many ways, the conservation of biological diversity in the GYE is not a specific legislative goal. There has also been no overarching legislation to pursue the categories of cores, connectivity, monitoring, and restoration, specifically for the protection of biological diversity. With these points considered, the quality of work in the GYE relative to these four categories is quite strong. In terms of the policies it implements, the federal government is conserving biological diversity in a very sound manner in this ecosystem. While global climate change will provide unprecedented challenges for federal natural resource management, with the powerful protection of cores, innovative and efficient monitoring and restoration programs, and the sub-landscape scale connectivity presently available the future does not appear as questionable for the ecosystem as some would believe.

The biggest threat is the lack of broader, landscape scale connectivity between this ecosystem and others. As environmental changes related to climate change occur and organisms travel across altitudinal and latitudinal gradients, their progress must not be impeded. Non-profit initiatives such as the Spine of the Continent and Yellowstone to Yukon (Y2Y) seek to protect these large swaths of land, and connectivity between them, in the Rocky Mountains. By focusing on this least developed, yet latitudinally representative swath of land, important landscape connectivity is sought. Due to the scale, multiple jurisdictions, and political framing of this type of large landscape connectivity, Federal programs for these regions appear to remain a proposal for the future. However, with an ever-increasing recognition of the need for this broader connectivity and the continued growth of non-profit initiatives focusing on connecting the Greater Yellowstone Ecosystem to others, there is hope for a healthier, more interconnected future for North American wildlife.

With such a positive overall picture of federal management, the next logical question becomes, “why?” What factors have helped establish a management regime that designs powerful policies to conserve biological diversity? In this analysis there have been several components which have stood out the most as positively shaping federal management.

The first of these components has been the existing land ownership pattern. The high percentage of land that is federally protected within the Greater Yellowstone Ecosystem is incredible. Not only is the percentage high, but the distribution of these lands is often advantageous as well. Because many of these holdings are coterminous, there is relatively little land which has been available to become developed and to fragment this great ecosystem. This has left large intact areas that are often connected together. These land ownership patterns are unique in the United States and have definitely facilitated the conservation of the biodiversity of the ecosystem.

These patterns also helped influence the creation of the GYCC and its ability to pursue meaningful work in the region. Only with so many interdependent federal interests working in the same ecosystem would such a system of federal collaboration flourish. The potential for future projects facilitated and organized through this organization is nearly endless. By more fully leveraging the communication, resource sharing, and funding of the GYCC, the conservation of biodiversity may become even stronger.

The second factor is the level of attention this ecosystem receives. The public attention to, and affection for, this ecosystem has allowed for two important outcomes: an increase in the amount of federal funding and a highly active environmental non-profit sector. The work of the non-profit sector has been referenced throughout this analysis. From maintaining Endangered Species Act protections, to participating in public opinion components of federal management development processes, the non-profit sector has shaped federal management in this ecosystem in a profoundly positive way. It is impossible to know what management in regards to biodiversity would look like in the GYE today without an intelligent, focused, and concerned sector of organizations honing its implementation. And this sector does not appear to be in danger of abating anytime soon.

11. AREAS FOR FURTHER RESEARCH

The intention behind this analysis is to gain a broader picture of federal management across an entire ecosystem. By taking a step back and analyzing the current quality of management, not just in limited or small-scale instances, but across entire regions, many productive insights can be gained. Ecosystems have no clear edge, no delineation where organisms inside their bounds stop, and no lines that ecological interactions no longer occur across. These systems are incredibly vast and yet, incredibly interdependent. Evaluating management on a park by park or forest by forest basis can provide many insights, but it does not show how the management therein is affecting the broader area. In evaluating management across this expanse of land, the policies of many different institutions were evaluated: from the Forest Service to the National Parks, to the GYCC. By doing so, an aggregate picture of management on a broader scale is attained: a scale of management which more closely aligns with the scales and interdependence found in nature. By examining our management at these more fitting scales, we can begin to more accurately assess the impacts of our work. Doing so is an increasingly important step in conserving the ever endangered, ever diminishing biodiversity that our lands harbor.

There is currently an astounding lack of scholarship attempting to analyze our management practices and impacts at these greater scales. The methods utilized herein are perhaps one way to look at the problem, but there are assuredly many more. One way this could be done is by producing a more thorough evaluation of not just how policies are written, but to what extent and quality they are implemented across their applicable agencies. This type of analysis would ensure that the policies I evaluated were being implemented as written, and thus aid in the applicability of this investigation. Another type of study which could be performed is meta-analysis of scientific studies on the on-the-ground presence of biodiversity in the Greater Yellowstone Ecosystem over as many years as possible. Data analysis across multiple biodiversity indices could provide a much more scientific picture. This type of method could give quantitative data to the question I investigated qualitatively, and would perhaps provide results which could stir others to investigate questions of biodiversity and ecosystem health on these larger scales.

Another important area of research related to this study is comparative analyses of greater ecosystems. Whether using my methods or some of the other suggestions above, such comparative study could be invaluable for seeing how management and conservation of biological diversity differs across the United States. This could highlight areas which are limited in effectiveness, disseminate management ideas and solutions, and increase the overall effectiveness of federal management. Such comparative study could also be utilized to help determine what factors play the largest role in how well we are conserving biodiversity. One could discern the effects of a strong non-profit presence, healthy tourism industries, and other factors on management in greater ecosystems.

Finally, any studies which can ensure that management actions and processes are meeting their intended biodiversity goals should be pursued. By determining the efficacy of certain actions, manager will gain insights into how to better protect the biological diversity they protect. Such work will allow for the constant adjustment of policies and strategies. This sharpening of management is vital if we are going to protect what biodiversity remains in an ever changing, and shrinking, world.

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