SAGUARO NATIONAL PARK

Saguaro Wilderness

The aerial application of herbicides used to combat non-native invasive buffelgrass in the Sonoran Desert

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Case Study of Ecological Restoration in Wilderness

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NATIONAL PARK SERVICE

TABLE OF CONTENTS

SUPPORTING GRAPHICS 2
INTRODUCTION 4
FRAMING THE ECOLOGICAL PROBLEM 5
RESTORATION PROPOSAL & IMPLEMENTATION 7
RESTORATION OUTCOMES 15
CONCLUSIONS 16
DOCUMENTS CONSULTED 18
AGENCY STAFF CONSULTED 21

This case study is part of a collaborative partnership between the Aldo Leopold Wilderness Research Institute and The Wilderness Society to describe ecological restoration actions that have been implemented within the National Wilderness Preservation System. The specific case studies were selected to represent a mix of wilderness agencies, geographic regions, restoration issues and complexities. The case studies were written by staff at the Leopold Institute, in consultation with wilderness managers.

ALDO LEOPOLD WILDERNESS RESEARCH INSTITUTE

THE WILDERNESS SOCIETY

SUPPORTING GRAPHICS

Background Timeline

- 2008 started Environmental Assessment compliance process for aerial application of herbicides for buffelgrass control
- 2009 Aerial Herbicide Application Workshop (USFS Region 3)
- 2010 Interagency Aerial Herbicide Application Demonstration Project – Pima County Tucson Mountain Park
- 2012 Restoration Plan and Environmental Assessment (EA) re-initiated
- 2012 Aerial mapping of buffelgrass
- 2013 SNP received three year grant for aerial application of herbicide for buffelgrass control
- 2014 EA completed & project initiated

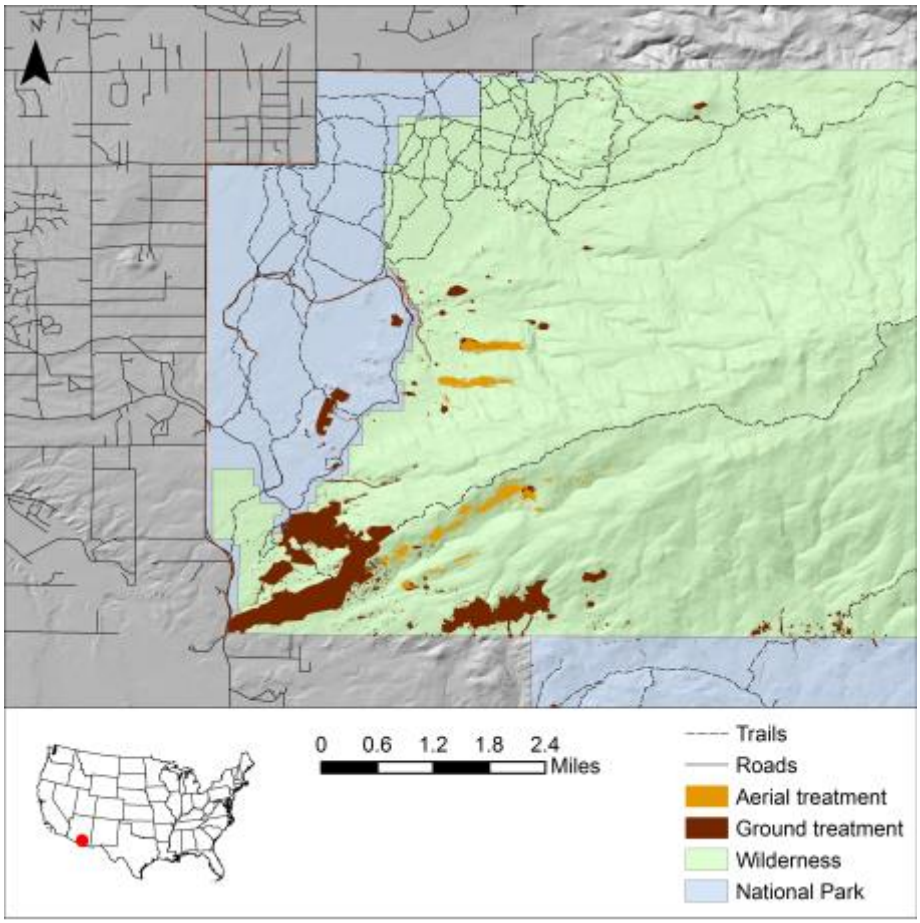

Figure 1 Area treated with herbicide to combat invasive buffelgrass in Saguaro Wilderness and Saguaro National Park.

Acronyms Used
EA: Environmental Assessment
MRA: Minimum Requirements Analysis
NPS: National Park Service

Helicopter with spray boom (USFS)Aerial application with spray ball (USFS during demo)

2015 aerial application of herbicide in Saguaro Wilderness

INTRODUCTION

The passage of the Wilderness Act by Congress in 1964, followed by President Lyndon Johnson signing the Act into law, marked a new era in protected area designation and public land management for the United States. Under the newly established National Wilderness Preservation System (NWPS), wilderness was, "recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions…" (PL 88-577).

Fifty years after the passage of the Wilderness Act, a combination of major ecological stressors-including invasive species and climate change-are creating new and unprecedented challenges for wilderness managers. Today, ecological restoration has become one of the most important, ethically complex, and potentially litigious wilderness stewardship issues in the history of the Wilderness Act. More specifically, the legal mandate to preserve the natural quality of wilderness character is leading managers to consider increasingly intrusive management interventions in place of historically minimal management. The dynamics and uncertainties of this management shift call into question traditional planning approaches, such as the use of historic conditions to define management targets; and require the incorporation of diverse legal, scientific and ethical considerations into management planning.

The four agencies that manage wilderness—the Department of the Interior Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), and the Department of Agriculture U.S. Forest Service (USFS)—receive hundreds of proposals to implement ecological restoration and other types of intervention actions within the NWPS every year now, including an increasing number of proposals generated by climate adaptation objectives. Ecological interventions that are currently proposed and implemented within wilderness include:

1. Actions that sustain, restore, or manage vegetation (e.g., chemical and mechanical removal of invasive plants, planting trees, spreading seed and fertilizer);
2. Actions that sustain or restore fish and wildlife, or manage insects and disease (e.g., biological control agents, fish stocking, animal removal, fish barriers, water guzzlers, introducing animals);
3. Actions that manage soil and water issues (e.g., diverting water for irrigation, mine site reclamation, spreading lime to buffer acid deposition); and,
4. Actions that manage fire (e.g., suppressing naturally-caused fire, mechanical fuels reduction treatments, prescribed fire).

Current laws and policies do not provide an explicit, decision-making framework for wilderness stewardship in the face of these new threats, but require wilderness managers to evaluate the effects of proposed restoration actions while simultaneously preserving wilderness character. Based on the legal definition of wilderness, National Wilderness Preservation Managers agree on five fundamental qualities of wilderness character: (1) Untrammeled; (2) Undeveloped; (3) Natural; (4) Solitude or primitive and unconfined recreation, and, (5) Other features of value. As defined by the Wilderness Act, wilderness lands were intended to be protected in their "natural condition" (i.e. species, patterns, and processes that evolved in the area) and "untrammeled by man" (i.e. free from intentional modern human control and manipulation). Balancing the natural and untrammeled qualities of wilderness character is a persistent wilderness stewardship challenge that may force a decision tradeoff. In addition, the accumulation of seemingly small-scale decisions and management actions has the potential to change wilderness character over time.

In this document, we present a case study of an ecological restoration action that has been implemented within a designated wilderness area in an attempt to preserve its wilderness character. The intent of these case studies is to provide detailed information about the tradeoffs involved in making decisions that simultaneously affect the natural and untrammeled qualities of wilderness, characterize similarities in management activities across projects, learn more about the basis for proposed ecological restoration, and quantify the extent to which climate adaptation is cited as the motivation for taking action.

FRAMING THE ECOLOGICAL PROBLEM

History of the Saguaro Wilderness

President Hoover first designated what is now Saguaro National Park as a National Monument in 1933, with the main purpose of protecting a superb example of a Sonoran Desert ecosystem. In 1976, Congress designated 71,400 acres of the Saguaro National Monument as the Saguaro Wilderness, in accordance with the Wilderness Act of 1964 (P.L. 94-567). Several boundary changes ensued throughout the late 1900s, and in 1994, the Monument was officially changed to Saguaro National Park (Presidential Proclamation 3439) to afford more permanent protection to the unique desert landscape. Saguaro National Park encompasses 91,450 acres which are divided into two districts, Rincon Mountain District and Tucson Mountain District (with wilderness areas in both districts), which are separated by the urban metropolis of Tucson. Today, 78% of Saguaro National Park is federally designated wilderness, part of the National Wilderness Preservation System (NPS 2014).

The wilderness boundary includes areas ranging from 2,180 feet to 8,666 feet (664 meters to 2641 meters) above sea level. This elevation gradient, along with mild winters and bimodal precipitation, provides for a high level of biodiversity, including over 500 native plant species in the Tucson Mountain District (TMD) and almost 1,200 native plant species in the Rincon Mountain District (RMD) of the park. The unique location of the Saguaro Wilderness, situated between the Chihuahuan Desert of Mexico and the Rocky Mountains to the north, provide habitat to species found in both of those geographic regions. In addition, some species from the nearby Mojave and Great Basin Deserts are present (NPS 2014).

Within the Saguaro Wilderness resides a wide variety of desert and mountain species such as the iconic saguaro cactus-the tallest cactus in the United States-as well as several varieties of other cacti, cholla, palo verde, ocotillo, and prickly pear. Saguaro National Park also protects several significant cultural resources such as petroglyphs, etched into the rock by the prehistoric Hohokam people. Some species, such as the black bear and mountain lion, were extirpated in the early 1900s and are now re-establishing themselves in the park. Other federally listed threatened, endangered and candidate species such as the Mexican spotted owl, lesser long-nosed bat, yellow-billed cuckoo, and desert tortoise are becoming rarer (NPS 2014).

> Insert SNP Photo of Sonoran Desert. Caption would read, "In the Rincon Mountain District, Sonoran desert-scrub occurs at the lowest elevations, transitioning into desert grassland with increasing elevation and precipitation. At higher elevations, woody plants become larger and more dominant, and plant communities change to pine-oak woodland, pine-oak forest, and pine forest. Mixed conifer forests occur on north-facing slopes at the highest elevations of the Rincon Mountains. The changes in species composition are gradual, leading to many shared species

between adjacent plant communities. Riparian forest and riparian woodland occur locally in canyon bottoms, and wet and dry meadows are found in scattered clearings at high elevations. The Tucson Mountain District contains only desert plant communities – specifically desert-scrub and desert grassland" (NPS 2014, p. 62).

Historically, fire was a rare phenomenon in the Sonoran Desert, although more common in the higher elevations. Despite Saguaro National Park being one of the first places in the country where fires were allowed to play a more natural role in the ecosystem, recently most natural fires in the park have been suppressed, thereby causing a significant build-up of fuels. Saguaros and other desert plants did not evolve in an environment where fire was active and are therefore very sensitive to fire; in fact they evolved to store water, not resist fire (NPS 2014). Other historical activities that have shifted the Saguaro Wilderness out of its natural state include increased development on the periphery of the wilderness area, cattle grazing, hunting and trapping of predators and other wildlife, diverting water, and the introduction of non-native plant species (NPS 2014).

Ecological Restoration Issue

Buffelgrass, *Cenchrus ciliaris* syn., *Pennisetum ciliare* is a non-native invasive perennial grass that was introduced to the southwest United States from Africa in the early 1940s for use as cattle forage and erosion control. The life history characteristics underscore the aggressively invasive quality of buffelgrass. It grows rapidly, produces an inflorescence in less than two weeks, can grow during any season (with as little as half an inch (6.3mm) of precipitation), has long-distance dispersal activities and produces as many as thirty thousand seeds per plant (Ward 2006). Buffelgrass also has the ability to colonize disturbed and undisturbed sites up to 5,000 feet (1,524 meters) in elevation where it out-competes native Sonoran Desert plant communities (NPS 2014).

A significant characteristic of buffelgrass is its favorable response to fire; studies have demonstrated that buffelgrass has the ability to increase the size, frequency and intensity of wildfire in an ecosystem like the Sonoran that is not adapted to fire (Esque 2004). Since buffelgrass occupies the space between plants that was historically a micro fuel break, it now acts as a bridge and helps carry fire across the landscape. Studies have demonstrated that buffelgrass fuel loads are capable of being 4,000 times higher than normal fuel loads and buffelgrass-fueled fires can reach temperatures of 1,300-1,600 degrees Fahrenheit (McDonald and McPherson 2011). These increased fuel loads and temperatures cause more severe burns as well as soil erosion and debris flows, therefore increasing saguaro and saguaro-dependent species mortality. Buffelgrass provides a path to increased wildfire in a fire-intolerant system, leading to the potential for extirpation of the park's iconic species and habitat (McLaughlin and Bowers 1982, Rogers 1985, Esque et al. 2004, NPS 2012a). Not only does buffelgrass pose a serious fire hazard, buffelgrass competes with native plants for resources, alters wildlife habitat, and impedes native plant recruitment and establishment (Olsson 2012, Gray 2012, Sommers and Chesson 2015). Due to these numerous threats, including a fire threat to home and property, buffelgrass was listed as an Arizona Noxious Weed in 2005.

Several factors have led to the increasing spread of buffelgrass into the Saguaro Wilderness, including massive plantings in Sonora, Mexico (less than 100 miles (161 kilometers) away), planting in southern Arizona for mine stabilization and cattle forage, favorable climatic conditions, and increased disturbance

from nearby developments. If left untreated, monitoring demonstrates that buffelgrass is doubling every two to seven years in the Tucson Basin (Olsson 2012). The Implementation Plan for this restoration action states, "Buffelgrass is unquestionably the greatest natural resource threat that the park has ever faced because of the direct threats to the survival of the saguaro cactus" (NPS 2012a, p. 4). Manual removal of the buffelgrass from the Saguaro Wilderness began in 1995 and ground-based herbicide treatment began in 2005; however, multiple treatments are needed to effectively control buffelgrass due to the fact that buffelgrass seeds remain viable for at least three years. Despite these efforts, by 2012 aerial mapping documented approximately 2,000 acres of buffelgrass-infested park land, with only about 500 acres accessible for ground-based treatments. The remaining acres are in remote, rugged and inaccessible areas where ground crews cannot work in a safe manner.

Studies indicate that the remote buffelgrass infestations have the potential to spread through most of the park and wilderness below 5,000 feet (1,524 meters), displacing native Sonoran Desert plant communities and the wildlife that are dependent on them (Chambers 2002). Although there have been many successful treatments with the use of ground crews, there are insufficient resources to respond to the rapid spread of buffelgrass (NPS 2014). Studies indicated that a dramatic spread of buffelgrass could cause an ecosystem type conversion from an arid desert to a non-native savanna-grassland ecosystem, thereby degrading the natural quality of wilderness character (D'Antonio, C.M. and P.M. Vitousek 2002, Martin et al 1999).

Climate Change

The restoration project in Saguaro Wilderness would improve the natural quality of wilderness character by manipulating an ecosystem that is currently experiencing measurable impacts from climate change such as decreased precipitation, warming and fewer frost-free days. Both native desert species and buffelgrass are frost-intolerant, so fewer frost-free days could cause buffelgrass to spread north and to higher elevations. Buffelgrass is also thriving with the decrease in precipitation and is outcompeting native grasses and forbs (Fairfax 2000). Although the decision to restore the Saguaro Wilderness was not motivated by climate change, the foreseeable effects of climate change will undoubtedly exacerbate the detrimental effects of buffelgrass on the native Sonoran ecosystem.

RESTORATION PROPOSAL & IMPLEMENTATION

In this section we review the legal and political framework guiding the restoration action in Saguaro Wilderness, along with the restoration objectives, ecological criteria for restoration, monitoring plans, management alternatives, values and ethics, and the effects analysis.

Legal and Policy

The Saguaro Wilderness is managed in accordance with the provisions of the following laws and policies.

Laws

The Wilderness Act of 1964[1] (P.L. 88-577)

[1] http://www.wilderness.net/NWPS/documents//publiclaws/PDF/16_USC_1131-1136.pdf

Section 4(b) of the Wilderness Act says that "each agency administering any area designated as wilderness shall be responsible for preserving the wilderness character of the area and shall so administer such area for such other purposes for which it may have been established as also to preserve its wilderness character." Section 2(c) defines wilderness and states that "An area of wilderness...which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable" (PL 88-577).

The National Park Service Organic Act of 1916[2] *(16 U.S.C. 1-4)*

The Act that established the National Park Service states, "The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations… by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve 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." The Act was reaffirmed by Congress in 1970, in 16 USC 1a-1, the *General Authorities Act* added more specific guidance, particularly regarding leaving park resources unimpaired.

Enabling Legislation[3] *(34 Stat. 225 and P.L. 103-364)*

President Hoover gave a Presidential Proclamation on March 1, 1933 creating Saguaro National Monument under the Antiquities Act to protect for the "public interest" its "outstanding scientific interest because of the exceptional growth thereon of various species of cacti, including the so-called giant (saguaro) cactus." In 1994, President Clinton signed Public Law 103-364 establishing Saguaro National Park to further protect the integrity of the natural resources from continued threats due to the expansion of the greater Tucson area.

National Park Service Wilderness Designation[4] *(P.L. 94-567)*

In 1976, Congress added several new wilderness areas to the National Wilderness Preservation System including 71,400 acres within Saguaro National Park (National Monument at the time of designation) known as the Saguaro Wilderness. One special provision was amended by inserting the phrase "without impairment of its natural values, in a manner which provides for such recreational, educational, historic preservation, interpretation, and scientific research opportunities as are consistent with, based upon, and supportive of the maximum protection, restoration and preservation of the natural environment with the area" immediately after "shall be administered by the Secretary".

Other relevant laws

- *Federal Noxious Weed Act of 1974 (7 U.S.C. 2801 et seq.)*
- *Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.)*
- *National Historic Preservation Act of 1966 (89-665; 16 U.S.C. 470 et seq.)*
- *Clean Water Act of 1975 (33 U.S.C. 1251 et seq.)*
- *Arizona Native Plant Law (EA 180)*

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[2] Final Saguaro Restoration Management Plan, Environmental Assessment
http://parkplanning.nps.gov/document.cfm?documentID=57136

[3] http://www.gpo.gov/fdsys/pkg/STATUTE-108/pdf/STATUTE-108-Pg3467.pdf

[4] http://www.wilderness.net/NWPS/specialProvisionsResults?WID=0&PLID=72&SID=0&AID=0&CID=0&key=

Policies and Management Directives

Executive Order 13112 on Invasive Species[5] *(1999)*

Section 2: Federal Agency Duties. (a) Each Federal agency whose actions may affect the status of invasive species shall, to the extent practicable and permitted by law, (1) identify such actions; (2) subject to the availability of appropriations, and within Administration budgetary limits, use relevant programs and authorities to: (i) prevent the introduction of invasive species; (ii) detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner; (iii) monitor invasive species populations accurately and reliably; (iv) provide for restoration of native species and habitat conditions in ecosystems that have been invaded; (v) conduct research on invasive species and develop technologies to prevent introduction and provide environmentally sound control of invasive species; and (vi) promote public education on invasive species and the means to address them.

National Park Service Management Policies[6] *(2006)*

4.4.1 General Principles for Managing Biological Resources

The National Park Service will maintain as parts of the natural ecosystems of parks all the plants and animals native to park ecosystems…The Service will successfully maintain native plants and animals by (1) preserving and restoring the natural abundances, diversities, dynamics, distributions, habitats, and behaviors of native plant and animal populations and the communities and ecosystems in which they occur; (2) restoring native plant and animal populations in parks when they have been extirpated by past human-caused actions; and (3) minimizing human impacts on native plants, animals, populations, communities, and ecosystems, and the processes that sustain them.

4.4.4 *Management of Exotic Species*

Exotic species will not be allowed to displace native species if displacement can be prevented.

4.4.4.2 *Removal of Exotic Species Already Present*

All exotic plant and animal species that are not maintained to meet an identified park purpose will be managed-up to and including eradication-if (1) control is prudent and feasible, and (2) the exotic species interferes with natural processes and the perpetuation of natural features, native species or natural habitats, or damages cultural resources, etc.

4.4.5.2 *Integrated Pest Management Program*

The Service conducts an integrated pest management (IPM) program to reduce risks to the public, park resources, and the environment from pests and pest-related management strategies. Integrated pest management is a decision making process that coordinates knowledge of pest biology, the environment, and available technology to prevent unacceptable levels of pest damage by cost-effective means while posing the least possible risk to people, resources, and the environment.

5.3.1 *Protection and Preservation of Cultural Resources*

[5] http://www.fws.gov/policy/601fw3.html

[6] http://www.nps.gov/policy/MP2006.pdf

The National Park Service will employ the most effective concepts, techniques, and equipment to protect cultural resources against theft, fire, vandalism, overuse, deterioration, environmental impacts, and other threats without compromising the integrity of the resources.

Other relevant policy not discussed

- *Director's Order 12: Conservation Planning, Environmental Impact Analysis, and Decision-making*

Site Specific Planning Documents

- *SNP Fire Management Plan (2007)*
- *SNP General Management Plan (2008)*
- *SNP Comprehensive Trails Management Plan (2009)*
- *SNP Exotic Plant Management Plan and Environmental Assessment (2004)*
- *SNP Restoration Plan and Environmental Assessment (2014)*

State of Arizona Laws/Policies

- *Arizona Administrative Code Regulations*
    - *AZ R3-4-244 Regulated and Restricted Noxious Weeds*
    - *AZ R3-4-245 Prohibited Noxious Weeds*
- *The State of Arizona requires monitoring and eradication/control of non-native plants that are listed in state law as Arizona noxious weeds*

Restoration Objectives and Mandate to Preserve Wilderness Character

In 2014 Saguaro National Park released a Restoration Plan and Environmental Assessment to allow several types of restoration implementation to combat buffelgrass using aircraft. These include aerial herbicide application with a helicopter, aerial seeding and aerial mulching with a helicopter or fixed wing aircraft; all methods were proposed to allow flexibility in controlling buffelgrass-infested areas as well as to restore native ecosystems. Efforts by park managers to control buffelgrass degrade the untrammeled quality of wilderness character because these actions are an intentional manipulation of the ecological community. However, the park's enabling legislation specifically mandates the protection of the saguaro cactus and surrounding habitat, and controlling buffelgrass is consistent with that mandate; it would also improve the natural quality of wilderness character.

The restoration treatment to control non-native invasive buffelgrass using aerial herbicide application has several objectives. The overall objective is to maintain saguaro cacti and its habitat which will subsequently improve the natural quality of wilderness character. This will in turn protect wildlife habitat and reduce the risk of wildfire. Both target (buffelgrass) and non-target vegetation (native plants) will be monitored to determine the effectiveness of treatments and potential impacts. The data collected each year will influence how the project progresses and thus, this project is designed to be adaptive.

The range of restoration actions proposed in the Environmental Assessment includes the use of a helicopter to treat patches of non-native invasive species with herbicides in difficult to access locations, as well as the use of aircraft to spread seed or mulch over burned areas following wildfires. Being able to quickly spread seed and mulch over large areas facilitates restoration by providing soil cover; reducing raindrop impact, erosion, sedimentation, nutrient loss; and, improving infiltration and re-vegetation of native species (Napper 2006, Robichaud 2009). A variety of herbicide application techniques using new

technology were utilized for this project. These new methods allow for more precise application of herbicide, resulting in lower levels of accidental herbicide application to native vegetation (NPS 2014).

On the ground knowledge and experience, professional judgment, scientific peer-reviewed literature, and monitoring data are all integrated into the decision to restore an area infested with buffelgrass.

Restoration Treatment and Affected Environment

In 2005, scientific literature identified glyphosate as the preferred herbicide for buffelgrass treatment because of its effectiveness with treating non-native grasses and herbaceous plants (Dixon et al. 2002). This non-selective chemical works by affecting a plant-specific enzyme pathway that inhibits growth, and therefore has minimum impact on other biological resources. Glyphosate binds to organic soil material, resulting in negligible levels of movement into the local watershed because of the lack of soil mobility. Studies show that systemic herbicides are absorbed into the ecosystem within fifteen minutes of application (NPS 2012a). The park used a glyphosate concentration of 1.54 pounds acid equivalent/acre with a 10 gallon/acre carrier rate.

Although glyphosate was a viable solution for controlling buffelgrass, being able to access and treat remote stands of dense buffelgrass in rugged terrain was a persistent challenge. Aerial application of herbicide had been used in other places to treat invasive species and SNP determined this would be an effective tool for treating buffelgrass; however, before aerial treatments were used in SNP, preliminary tests were completed to determine their effectiveness in treating buffelgrass in their specific environment. The results from this testing sparked the development of a Restoration Plan and Environmental Assessment in 2014 that allowed for aerial application of herbicide in steep terrain that is densely covered with buffelgrass.

During the testing, the use of a helicopter with a boom affixed to apply the herbicide showed positive results, including a significant decrease in buffelgrass greenness in dense stands, with minimal damage to native vegetation. Testing also highlighted potential drawbacks for using aerial methods of treatment. For example, during the testing of aerial herbicide application, there was variability of deposition due to several factors such as when aircraft fly up a slope they go more slowly, thus increasing the amount of material being applied. The varying altitude of the aircraft, combined with variability in turning on and off the spraying can create under-spraying in the beginning of the plot and over-spraying beyond the selected plot, and therefore the potential for damage to native species. Despite automated systems for the initiation and termination of spraying, pilot reaction results in variability in the consistent delivery of herbicide (NPS 2012a). These factors have led to a change in methodology for the project which requires use of a differential global position system (DGPS) called SatLoc®, which also logs if the spray boom is on or off, speed, and location. The equipment also has a flow regulator that changes the product output as aircraft speed fluctuates. These changes were implemented ahead of the first treatment in Saguaro Wilderness in the summer of 2014.

To minimize impacts on visitor safety and wilderness character (such as the wilderness quality of solitude and primitive and unconfined recreation), aerial application of herbicides do not occur within ¼ mile (.4 kilometers) of any road, occupied structure, campground, trail or picnic area; within 1/8 mile (.2

kilometers) of private land; within 165 feet (50 meters) of any surface water; or above 6,000 feet (1,829 meters) in elevation. Aerial application is restricted to dense patches where more than 50% of plant cover is buffelgrass, and the restoration strategy is tailored to each specific area. The targeted time of year for the application is the summer monsoon, generally in August, when buffelgrass is at its peak green stage. The park estimates that approximately 600 acres of infested land will be treated in any given year and the application will take place during approximately six days per year (NPS 2014).

Monitoring

Monitoring is a major component of the buffelgrass removal project both to determine the existing scope of the current invasion, and also to document the effects of ground and aerial based herbicide treatments. 90 plots, 33x98 feet (10x30 meters) in size, were monitored before and after the treatment by crews of three to seven people every four weeks during the first aerial application of herbicides in the summer of 2014. Spray cards were used to monitor the effectiveness of aerial application and one spray card per plot allowed for qualitative measurements to document the cover of the herbicide, as well as belt and line transects and photo monitoring. Plant damage, mortality, and regrowth are some of the key variables that are measured as part of the overall monitoring effort (NPS 2012a).

Management Alternatives

- Manual herbicide application using backcountry crews
    - One alternative that was considered to control buffelgrass at Saguaro National Park was the use of backcountry crews to apply the herbicide in remote areas. The crews would work for four to six days at a time, traveling each day from their camp to the restoration site. Due to the remoteness of these locations, and the inability to use stock support, helicopters would be used to deliver and retrieve supplies such as large quantities of water needed both for herbicide mixing and personal use, food and camping gear. The impact of such a large group on the natural vegetation would be substantial and this method would leave roughly 1,500 acres of non-native invasive plant infestations out of reach due to the steep and rugged nature of the terrain. The window for applying herbicides is also the hottest and most humid time of the year which poses significant safety concerns for the crews. For these reasons, along with the inability to meet the project objectives of targeting the most densely populated buffelgrass infestations, this alternative was dismissed (NPS 2014).
    - The ground-based herbicide application would involve significant impacts to the untrammeled quality of wilderness character, but would not achieve desired improvements to the natural quality of wilderness character. There could also be potential impacts to the natural quality of wilderness from the impact of the ground crews trampling native vegetation unintentionally during the buffelgrass control activities.

- Aerial herbicide application to non-wilderness lands
    - Another project alternative that was considered was to limit the use of aircraft application of herbicides to non-wilderness areas. Since 78% of the park is wilderness, that would only leave 22% of the park available for aerial treatments. The park

expressed that the degradation of the natural quality that would result from not treating buffelgrass in wilderness areas would ultimately harm the wilderness character more than the cost of short term trammeling to achieve a more natural wilderness (NPS 2014). This alternative was therefore dismissed for further consideration.

- The aerial herbicide application to non-wilderness lands would avoid impacts to the untrammeled quality of wilderness character, but would not address increasingly significant impacts to the natural quality of wilderness character.

Stakeholder Values

Following National Park Service Policy to preserve native species such as the iconic saguaro cacti, the park pursued a comprehensive response to restore the rapidly degrading ecosystem and preserve the natural quality of wilderness character. The national Invasive Species Coordinator for the National Park Service has an Invasive Species Coordinator who advised the park and other land management agencies controlling buffelgrass, that herbicide treatment may be a method to assist in the effort to control buffelgrass (NPS 2012a).

In November 2010, a scoping meeting commenced with local organizations to inform them of the proposed restoration initiative. Members of the Center for Biological Diversity, National Parks and Conservation Association, The Nature Conservancy, Public Employees for Environmental Responsibility, Sierra Club, Southern Arizona Buffelgrass Coordination Center, Tucson Mountains Association and The Wilderness Society were invited to attend and provided comments on the proposed restoration. Overall, there was acknowledgement and consensus that native plant communities in the Saguaro Wilderness and the surrounding park needed protection from non-native invasive plants, however, there were concerns about herbicides related to both human and environmental health. The park addressed these concerns and respond to questions about herbicide application techniques and the scientific evidence for using the specific chemicals (NPS 2014). Overall, there was little concern over the degradation of the untrammeled quality of wilderness.

Park managers value the existence of the saguaro cacti and surrounding habitat, as well as the preservation of wilderness character. They view the continued spread of buffelgrass as a direct threat to both wilderness character and the park's purpose, therefore their preference would be a strategy that involves the greatest chance of success for removing buffelgrass across large and difficult to reach areas in order to preserve wilderness character and protect park resources. This means utilizing the aerial application of herbicides. The Environmental Assessment states, "Despite short-term adverse impacts to the untrammeled nature of the area, undeveloped character, and feelings of solitude, this alternative would help preserve naturalness and other wilderness values, such as scientific and educational values, thereby providing more long-term benefits to Saguaro National Park's wilderness character" (NPS 2014, p. 77).

Effects Analyses

In the following effects analysis section, we observe how the restoration activities affected the five qualities of wilderness character. The five qualities are derived from the legal definition of wilderness cited in The Wilderness Act of 1964, and are used as a management tool for agencies to comply with law

and policy, and improve wilderness stewardship by assessing the implications of management actions (USDA Forest Service 2008).

Untrammeled

- This action degrades the untrammeled quality due to the fact that it is attempting to control the wilderness, albeit from an invasive non-native species introduced to the region by humans.
- Thus far, specific trammeling actions include the intentional manipulation of 350 acres of Saguaro Wilderness by applying herbicide to combat non-native invasive buffelgrass. There have also ground efforts to remove buffelgrass since 1995.
- The aerial application of herbicides expands the area being controlled by human forces instead of natural forces.
- This project requires staff to work in wilderness at various times to supplement the aerial application of herbicides.
- Non-native plants would be removed, and re-vegetating certain sites may occur post-treatment.

Natural

- Natural conditions would improve as a result of restoration activities due to the removal of non-native invasive species and the improvement of native plant communities. It is estimated that restoration efforts using aerial application will more than double current efforts, thus improving a greater area overall.
- Some non-target species will be affected by the action.
- Minor vegetation trampling from field crews who will monitor the buffelgrass plots will degrade the natural quality of wilderness.
- Minor air quality impacts will be experienced from the exhaust of mechanized equipment.

Opportunities for Solitude and Unconfined Recreation:

- The use of aircraft will be limited to mid-week when there are generally less visitors. Overall the audible and visual impairment from this action will only be observed when herbicide application is taking place during a few days and up to two weeks per year. However, it is likely that this action will be recurrent due to the persistent nature of the invasive species and the need for continual action is inevitable into the future which could potentially accumulate degradation of this quality.
- Recreational users may still be negatively affected by the sound of aircraft, even if they are well beyond the ¼ mile (.2 kilometer) closed off area.
- By using aerial treatments instead of prolonged ground-based treatments from field crews, the temporal impact to visitors would be lessened.

Undeveloped

- This quality was not affected by the action.

Other Effects:

There are three endangered species in Saguaro National Park, the lesser long-nosed bat, yellow billed cuckoo and southwestern willow flycatcher, as well as one threatened species, the Mexican spotted owl. It was determined that the proposed action would not affect these species because the aircraft would avoid flying near known roosting sites and the aircraft activity would be limited to daylight hours (NPS 2014). Other non-target species have the potential to be impacted; however the target of aerial application is dense buffelgrass patches where little native vegetation remains. Due to the waxy cuticle protecting the skin combined with the stomata closing during the day, cacti would generally be immune to the absorption of herbicide (Mayeux and Johnson 1989). Other plants that use shrubs or trees for canopy would also be protected from the herbicide and it has been documented that larger woody plants are not significantly affected by the proposed herbicides (NPS 2014). The environmental assessment states,

> *"None of these herbicides contain organochlorides that can cause egg-shell thinning in birds, bio-accumulate in animal tissue, or have other harmful, long-term effects to the environment or wildlife. Nevertheless, three of the eight herbicides proposed for use in SNP can be highly to very highly toxic to certain classes of animals, depending on their formulations and use. (Note that toxicity tests are conducted in lab settings with the undiluted herbicide or active ingredients, not the diluted mixture used in the field.) These herbicides include dicamba; amine salt and ester formulations of triclopyr; and acid, amine salt and ester, and aquatic and non-aquatic formulations of 2,4-D"* (NPS 2014, p. 74).

Water quality is also a consideration when using herbicides such as those proposed. The environmental assessment states that impacts to water quality from ground-based manual herbicide spraying will have indirect, short-term, negligible and adverse effects on the environment (NPS 2014).

Risks and Uncertainties of the Restoration Treatment

There is little uncertainty about the effectiveness of using glyphosate to combat buffelgrass, because of multiple studies and observations confirming the success (Dixon et al. 2002). However, buffelgrass will continue to expand in the surrounding landscape because it is still planted in nearby Sonora, Mexico and in some parts of Texas for cattle forage. In addition, the ability for Saguaro National Park to ensure the resources and logistical support for aerial treatments into the future is uncertain due to the variability of budgets and personnel. The environmental compliance for this project will not extend beyond ten years, until future planning is needed again[7]. Long-term buffelgrass control will likely require ongoing impacts to the untrammeled quality of wilderness character.

RESTORATION OUTCOMES

SNP used aerial methods to treat buffelgrass for the first time in the summer of 2014, with 350 acres of dense buffelgrass patches targeted. The application occurred over six days in August which was a crucial time when the buffelgrass was mature after the summer monsoon. Coincidentally this is also a time

[7] Personal communication, Dana Backer 2/3/15

when visitation is extremely low in the Saguaro Wilderness, and because of this, the impact on the solitude quality of wilderness character was reduced.

It still remains to be determined whether project goals were accomplished. Documenting the restoration objectives and efficacy will depend on monitoring during the summer of 2015, when the response of perennial plants to monsoonal rains can be ascertained. At this time it is unknown whether the aerial application of herbicide succeeded in improving the natural quality of wilderness; at a minimum, however, some buffelgrass mortality will be documented which would increase the natural quality. Current treatment options will not fully eradicate buffelgrass in the short-term or mid-term. However, restoration efforts by the park in the past ten years have successfully controlled buffelgrass and facilitated native re-vegetation. According to park managers, this success is due to their proactive management technique by preventing buffelgrass from changing the fire regime, resulting in significant and irreversible impacts to the Saguaro Wilderness.

CONCLUSIONS

> *"Increased complexity, due to the global movement of people, plants and the dramatic increase in human population since late the 1950's and early 60's, has challenged wilderness managers to maintain an untrammeled approach in managing wilderness. In the case of the Saguaro Wilderness, the saguaro cactus is threatened by buffelgrass; an African grass brought to the region as forage for cattle. If "wildness" takes precedence over "naturalness" in this instance, the saguaro cactus may cease to exist in the near future. Given this, the park plans to more aggressively manage invasive species through the use of helicopters to apply herbicide to large and inaccessible areas. Decisions to participate in controversial actions, such as these, are not made lightly among park staff. There is a highly involved bureaucratic process to determine the effects on nearly every aspect of the park, including wilderness character, through an MRDG and an Environmental Assessment." (NPS 2012b, p. 12)*

The Rocky Mountain Climate Organization and the Natural Resources Defense Council listed Saguaro National Park as one of 25 National Parks most at peril due to the buffelgrass infestation (NPS 2014). The predicted increase of non-native flammable grasses such as buffelgrass was a main contributor to this assessment. The intent of the aerial application of herbicide is to remove the non-native invasive buffelgrass that threatens the enabling legislation of the park which, in turn, ensures protection of the iconic saguaro cacti and surrounding habitat. Due to this legislation, as well as National Park Service policy urging removal of non-native species, Saguaro National Park Managers have a strong prerogative to take action. By doing so, the park is seeking to safeguard the saguaro cacti and surrounding habitat to avoid irreversible impacts from invasive plants. This action would inevitably increase the natural quality of wilderness while degrading the untrammeled quality of wilderness. Here, a management decision trade-off is recognized because although the Wilderness Act mandates that the Saguaro Wilderness will preserve the untrammeled quality of wilderness, the enabling legislation of the park, as well as park policy, directs the park to restore the landscape by removing non-native species.

A critical component of this restoration action was that it was designed to allow for adaptive management. Future decisions regarding the target area for herbicide application, the amount being applied and the method of application will be adjusted based on the success of each treatment. Future

decisions of treatment and monitoring will be based on the data collected from the summer 2015 field season as a starting point, and adjusted throughout the implementation.

In discussing the site-specific pressures to intervene, Restoration Ecologist Dana Backer writes, "Buffelgrass is spreading exponentially within the park. Research has documented unprecedented fuel loads, ranging from 1 to 4 tons per acre (907 to 3,629 kilograms per hectare). Buffelgrass is out-competing native plants and converting a nearly fire-proof desert plant community into a highly flammable non-native grass-scrubland. The continuous, heavy grass produced by buffelgrass is a serious threat to natural biodiversity and human safety and property because of the potential for intense wildfires."[8] It is clear that the buffelgrass infestation has reached a high potential to dramatically and irreversibly change the ecosystems for which Saguaro National Park was established.

All of the factors limiting the success of the project are not fully known at this point in time. Backer states that one limiting factor is the narrow treatment window for application because it is highly dependent on when, where, and how much rain falls on the infested sites, and timing this with the availability of a skilled helicopter contractor. Another limiting factor is the continued presence of buffelgrass in the local area that is not being targeted for removal. The root cause of the problem is beyond the scope of park staff and because of this, restoration activity will most likely continue into the future with no end in sight.

[8] Personal communication, Dana Backer 2/22/15.

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