LEARNING FROM THE PAST, PLANNING FOR THE FUTURE: EXPERIENCE-DRIVEN INSIGHTS INTO MANAGEMENT, CLIMATE ADAPTATION, AND FIRE ADAPTATION ON THE COLORADO PLATEAU

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ABSTRACT

LEARNING FROM THE PAST, PLANNING FOR THE FUTURE: EXPERIENCE-DRIVEN INSIGHTS INTO MANAGEMENT, CLIMATE ADAPTATION, AND FIRE ADAPTATION ON THE COLORADO PLATEAU

ANNA LYNN VAUGHN

Current adaptation strategies utilized by federal, state, and local land management agencies face a great deal of challenges. Ecosystems have and will continue to undergo transformations due to ecological stressors. Natural resource managers have experienced varying degrees of wildfire and drought intensification. Findings from interviews conducted with over 37 natural resource managers from federal, state, and local agencies across the Colorado Plateau of the Western U.S. are discussed and analyzed. Primary takeaways from these interviews include discussions with respondents related to ecological stressors, ecosystem response, strategies and decision-making related to drought and wildfire, primary barriers and limitations, perceptions surrounding adaptation, facilitation and implementation of adaptation, and identification of needs to support effective adaptive management. Results from a survey of managers and decision-makers across the Southwest based on the insights and perspectives gathered in interviews are discussed. Several key findings include: 86% of participants citing lack of resources as the primary limiting factor for effective management, 89% of participants reporting that disturbances are happening at scales and timeframes outside of what managers perceive as “normal,” and that 63% of participants found that ecosystems have been substantially or completely stressed by

ecological changes including drought, wildfire, and/or climate change impacts. This study concludes that for adaptation to be an effective management practice, there needs to be greater consensus among managers surrounding the meaning and application of the term.

Key Words: climate adaptation, ecosystem stress and transformation, drought, wildfire, climate change, resilience, wilderness, southwest, public lands, natural resource management

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CHAPTER ONE

INTRODUCTION

This research project aims to examine how natural resource managers perceive the impacts of climate change and ecological stressors including drought and wildfire on landscapes they manage, as well as how they define and approach climate adaptation. This introduction will discuss how climate change at the global scale impacts the ecosystems on public lands in the Southwest U.S., with a focus on federally and state managed landscapes on the Colorado Plateau. Natural resource managers in this region have the opportunity to learn from each other and increase collaborative efforts based on a stronger understanding of how decisions are made, through the sharing of experiences and insights gained managing climate-induced ecological changes.

In order to understand the impacts of climate change and the implications it has for adaptation efforts in the Colorado Plateau region, it is important to consider the broad climate change context. The following introduction introduces the issue of climate change and how it contributes to the intensification of ecological stressors at various spatial scales, beginning with how climate change will lead to impacts at the global scale, followed by the continental scale, narrowing further to examine the Western United States. Finally, the introduction will connect the broad global scale impacts of climate change, particularly in relation to the intensification of drought stress and wildfire, to the narrower scale of focus for this thesis: the Colorado Plateau of the Southwestern U.S.

This thesis aims to gain insights from natural resource managers and scientists in the Colorado Plateau region of the Southwestern U.S., who have already begun to experience substantial wildfire and drought intensification. It is important to consider how climate change is driving other ecological stressors, primarily drought and wildfire in this region. A region-specific approach to this study allows for better understanding of the ecological changes occurring, as climate change leads to a multitude of environmental impacts, depending on the existing climatic conditions and ecology of a given geographic area.

I. Causes and Global-Scale Impacts of Anthropogenic Climate Change:

The IPCC (Intergovernmental Panel on Climate Change) Sixth Assessment, released in 2021, extensively shares crucial findings related to the changing global climate and the challenges humanity will face in the coming decades and beyond, even with reductions in greenhouse gas emissions. In developing the Sixth Assessment, 782 scientists from across the world analyzed the findings of over 66,000 peer-reviewed studies, including new findings and expanding upon the conclusions of earlier assessments (IPCC, 2021). The climate system as a whole has shifted on a planetary scale, and even under the most optimistic scenario, these changes will be evident for at least the next century and have the potential to be present for thousands of years to come, dependent on mitigation efforts and whether policy changes are enacted rapidly to address current emissions levels. As of 2021, emissions are still rising globally despite increased investment in renewable energy (IPCC, 2021).

There is irrefutable evidence that human activities have directly caused warming atmospheric conditions, leading to warmer oceans and land areas (IPCC, 2021). These widespread atmospheric changes have occurred as a direct result of human activities which emit greenhouse gasses such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (IPCC, 2021). Carbon dioxide (CO_2) accounts for the largest amount of greenhouse gas emissions (74%), with 92% of these emissions being contributed through human use of fossil fuels for the purposes of generating electricity and heat, transportation, manufacturing and consumerism (IPCC, 2021). Land use changes follow fossil fuels in creating greenhouse gas emissions, primarily due to deforestation and development and contribute to 3.7% of humanity's total carbon emissions (IPCC, 2021). Agriculture, waste management, fossil fuel and natural gas production are driving methane (CH_4) and nitrous oxide (N_2O) emissions into the atmosphere, with methane accounting for 17% and nitrous oxide accounting for 6.2% of greenhouse gas emissions (IPCC, 2021). The largest carbon emitters by country in the world are China, the U.S., and India (Ritchie & Rosser, 2021). The United States has emitted more CO_2 than any other country since 1750, responsible for 25% of all historic emissions (Ritchie & Rosser, 2021). Of all industrial emissions, ninety companies (oil, gas, coal, or cement) contributed 63% of cumulative, worldwide emissions of industrial CO2 and methane from 1854-2010, with half of the GHG-emissions occurring after 1986 (Heede, 2013). Without a rapid, large-scale decrease in greenhouse gas emissions, limiting warming to 1.5°C will be unlikely, with temperatures expected to reach or exceed 1.5°C in the next two decades (IPCC, 2021).

Widespread, large-scale weather and climate extremes are becoming increasingly abundant as a result of human-caused climate change (IPCC, 2021). This includes increases in both intensity and frequency of heatwaves, droughts, heavy precipitation, and tropical storms, as well as a reduction in sea ice, snow cover, and permafrost (IPCC, 2021). The current rate of warming has already been shown to have caused irreversible damage and planetary changes for “centuries to millennia,” specifically with sea level rise, ocean acidification, and loss of sea ice globally (IPCC, 2021). As warming continues, the water cycle will continue to intensify, leading to both increase in rainfall leading to flooding as well as worsening droughts, depending on the region (IPCC, 2021). Increases in droughts and floods will lead to instability for agriculture and lead to human health and safety risks (IPCC, 2021). As one example, climate change will drive ocean warming, increased frequency of marine heatwaves, ocean acidification, and reduced oxygen levels, which destabilize ocean ecosystems (IPCC, 2021). This destabilization is projected to decrease fisheries catch potential, contributing to increased malnutrition and loss of livelihoods across the globe (IPCC, 2021).

The majority of the impacts of climate change will disproportionately impact individuals who did not contribute to the climate crisis yet will face the most severe impacts of droughts and/or flooding (Miller, 2017). Island communities across the world are already in peril due to rising sea levels and increased storm frequencies and magnitudes (Miller, 2017). There is still no formal legal definition or protection for “climate refugees” under international law, despite a recent GRID (Global Report on Internal Displacement) stating that 5.9 million people were displaced due specifically to

climate-related disasters in 2021 alone (GRID, 2022). The largest burden of responsibility for the impacts of climate change is falling on individuals that do not have the ability to create policy changes or the necessary societal transformations that will stop the crisis (Miller, 2017). Climate-driven warming temperatures are projected to increase heat related deaths globally (IPCC, 2021).

A major area of uncertainty at the global scale is the timing of when planetary boundaries will be crossed and to what extent we can prevent boundaries from being crossed. Planetary boundaries are nine boundaries with set biophysical thresholds that must not be crossed in order for humanity to continue to operate within a functioning planetary system (Rockstrom et al., 2009, Steffen et al., 2015). The crossing of planetary boundaries may trigger abrupt, non-linear, disastrous impacts, ranging from the continental to the global scales (Steffen et al., 2015). Presently, the following six planetary boundaries have been crossed: climate change, biogeochemical flows, biosphere integrity, land-system change, novel entities (plastic, heavy metals, and man-made chemical pollution), and most recently, freshwater use change (Wang-Erlandsson et al., 2022). In addition to planetary boundary thresholds, several climate “tipping points,” which occur when a small change leads to a nonlinear response in the climatic system and can lead to irreversible consequences and state change of the system (Lenton, 2011), are in danger of being crossed (Lenton et al., 2019). These thresholds include ice sheet instability, biosphere tipping (ocean heat waves, Amazon deforestation, Arctic permafrost thawing, shifting of carbon sinks to sources), and global tipping (where one system tipping could increase the crossing of tipping points in other systems, which was determined to be possible for 45% of interactions between tipping

points) (Lenton et al., 2019). Both planetary boundaries and climate tipping points highlight the spatial and temporal uncertainties associated with climate change and the impacts it will have at various scales, from globally to regionally.

The global climate change context is important to consider as it is necessary to understand how the impacts of crossing planetary boundaries and climate tipping points can lead to significant land management challenges, particularly for adaptive planning and responses to shifting ecological conditions.

II. Climate Change Driving Drought Conditions:

Drought is caused by a combination of two factors, which include low precipitation levels, warm temperatures and/or vapor pressure deficits (VPD), which is a measure for how much water vapor the atmosphere is holding versus its total capacity, and higher VPDs are associated with warmer climatic conditions (Mankin et al., 2021). Higher VPDs for longer periods of time will contribute to increased aridification of the Southwest (Mankin et al., 2021). As the atmosphere warms, it holds more water vapor, leading to increased evapotranspiration and drier soils and vegetation (Overpeck & Udall, 2020). Climate change has led to an increase in the severity and frequency of droughts on the global scale, as the water cycle has shifted with rising temperatures and atmospheric changes (IPCC, 2021). One such change is that the hydrological cycle is beginning to accelerate, leading to more intense periods of drought in many regions around the globe (Muhkerjee et al., 2018). Many regions throughout the world have been experiencing increased frequency and severity of droughts (De Cáceres et al., 2015). This combination of increased drought frequency and severity is occurring

across a multitude of spatial scales, impacting ecosystems at the global scale, continental scale, and regional scale.

Water-related impacts for North America due to extended periods of drought include water shortages due to drought and earlier snowmelt runoff, caused by warmer temperatures occurring earlier in the year, which lead to agricultural challenges, increased water scarcity, and increase the pressure on remaining water resources (IPCC, 2021). Temperatures across North America are currently expected to continue increasing, leading to a trend of further decreases in both snowpack and soil moisture in the coming decades (IPCC, 2021).

Based on drought reconstruction and soil moisture analysis, drought severity has been predicted to increase over the next few decades, particularly in the Southwest and Central Plains regions of the U.S. (Cook et al., 2015). In the Southwest, the 2020-2021 drought was due to natural climatic variations that created multiple low precipitation seasons, combined with human-caused warmer temperatures (Mankin et al., 2021). In addition to changing precipitation patterns, warmer temperatures also contribute to increased aridity, which leads to decreased soil moisture, greater temperature extremes, and increased hydrological stress across ecosystems (Overpeck & Udall, 2020). In the Southwestern U.S, models show that the magnitude and intensity of severe droughts has been shown to increase as greenhouse gas emissions increase, and climate mitigation was only shown to minimally reduce risks of severe 21-year megadroughts, such as the 2000-2021 Southwestern drought, because of precipitation decline occurring across models (Cook et al., 2021).

Despite minimally reducing long-term droughts, climate mitigation was shown to reduce single-year extreme drought risk and to reduce severity of future droughts (Cook et al., 2021). Monitoring drought-induced changes, particularly changes considered to be caused by global climate change, has been challenging for scientists due to the complexities and interconnected factors which lead to drought conditions (Muhkerjee, et al., 2018). In order to distinguish natural variation versus human-caused climate causes of droughts, scientists use climate models and projections, as well as considering additional anthropogenic forces that may be impacting water supplies and soil moisture are important considerations (Muhkerjee, et al., 2018). Creation of water balance models has been helpful in determining what changes can directly be attributed to drought conditions and drought induced ecosystem stress (De Cáceres et al., 2015). Calculation of water balances allows researchers to better exclude other potential anthropogenic causes, such as wasteful irrigation methods or mismanagement of water resources (De Cáceres et al., 2015).

In the Western U.S. and Mexico, declines in freshwater resources, “exploitation of limited water supplies,” and poor water management and infrastructure are projected to contribute to water shortages (IPCC, 2021). Drought conditions across the Southwest have been widespread and significant, with the most recent megadrought conditions not being experienced in this region for over 1,200 years (Mankin et al., 2021). In a study of climate-caused aridification across North America, hydrological stresses associated with warmer temperatures have led to declining water flows and soil moisture of the Colorado River, which is alarming as the Colorado is the largest water supplier in the Southwest region and home to over 40 million people (Overpeck & Udall,

2020). Drought conditions in the Southwest are expected to worsen due to a reduction in both late spring and summer soil moisture levels (Cayan et al., 2010).

III. Increases in Wildfire Frequency and Severity in the Western U.S.:

Due to a combination of climate change and land-use changes, wildfires are projected to increase by 50% by 2100 and this increase will disproportionately impact the world's poorest communities (U.N. Environment Programme, 2022). As wildfires increase across the world, they contribute to climate change by causing an additional source of greenhouse gases (IPCC, 2021). Warmer temperatures and increased frequency and duration of droughts leads to drier conditions that are optimal for more severe wildfires across the Western U.S. (Overpeck & Udall, 2020). The Western U.S. has experienced increases in frequency, size, and severity of wildfires for a multitude of reasons including a century of fire suppression, warmer temperatures, particularly in the spring and summer, below-average winter precipitation, and earlier spring snowmelt (Westerling et al., 2006). Fire suppression policies for over a century have led to high fuel loads and increased risk for severe fire, especially when combined with warmer, drier conditions caused by climate change (Hurteau et al., 2014).

Wildfire activity has increased substantially in the Western U.S. since the mid-1980s, with increased numbers of large wildfires, longer durations of fires, and longer wildfire seasons (Westerling et al., 2006), Drier conditions contribute to greater fire frequencies, while cooler conditions contribute to lessened fire frequencies (Sweetnam et al., 2016). ENSO (El Niño Southern Oscillation) leads to warming of surface waters and increased cloud-cover over the Pacific Ocean and strong winds move clouds inland

over the United States, as well as Central and South America, causing more frequent rains and wetter conditions (Sweetnam et al., 2016). El Niño events typically occur around every two to seven years, as the warm cycle of El Niño alternates irregularly with La Niña, a cooling pattern in the eastern Pacific (Sweetnam et al., 2016). La Niña years produce drier weather conditions, particularly in the Southwestern United States (Swetnam et al, 2016).

Reconstruction of historic fire regimes throughout the Southwest region has shown changes in fire frequency and severity in response to human activities (Swetnam et al., 2016). Increased forest fire frequency, particularly surface fires and forest regeneration occurred following the forcible removal and exclusion of large populations of indigenous people from their lands (Liebmann et al., 2016). Subsequently, modern fire suppression as well as historic human activities on the landscape, including fire exclusion for the purposes of grazing, timber harvesting, and the expansion of transcontinental railroads contributed further to build-up of unnaturally high densities of trees and ground fuels (Liebmann et al., 2016). Human activities, particularly the controlled burning to manage understory vegetation, increase agricultural productivity, and facilitate hunting, as well as the harvesting and gathering of trees practiced by indigenous communities, though historically were seen as intrusive, have been determined to be extremely beneficial to reducing the of severity of wildfire (Liebmann et al., 2016). More recently, global climate change has resulted in more frequent drought cycles in the region, contributing to an increased availability of dry biomass to fuel fires (Loehman et al., 2018).

Since 1985, over 50% of the increase in total burned areas across the Western U.S. has been attributed to anthropogenic climate change (Schoennagel et al., 2017). In the southwest U.S., the trends of warmer temperatures and extended drought periods in high-elevation forested ecosystems are projected to increase over the next century, leading to increased frequency and longer fire seasons (McCauley et al., 2019). However, in lower elevation fires in the Southwest, periods of drought need to be interspersed with wet conditions to create the fuel loads capable of carrying fire, and larger fires were associated with wet conditions prior to the fire season (Crimmins & Comrie, 2004). Wildfires in the Western U.S. have not only increased in terms of longer seasons, but they have also been able to advance upslope to high-elevations that were previously too wet to burn, caused by increased aridity due to climate change as well as fire carried by increased fuel of introduced species as lower elevations (Alizadeh et al., 2021) In the Western U.S., increased wildfires have led to increased forest mortality, higher carbon emissions, degraded air quality, and economic costs related to suppression (Abatzoglou & Williams, 2016).

The forests of the U.S. serve as carbon sinks for approximately 25% of total GHG emissions in North America, but this number could decrease as climate change related impacts, for example, increased wildfire severity may lead to reduced forest productivity (Law et al., 2013). Low and mixed severity wildfires have been shown to contribute lower amounts of direct emissions than high-severity fires (Wiedinmyer & Hurteau, 2010). A study conducted by Abatzoglou & Williams (2016) examined climate through modeling and projections in the Western U.S. and found that climate change was the driving cause of doubling the cumulative forest fire area since 1984. Climate

change was also determined to be responsible for increasing fuel aridity in the Western U.S., due to higher temperatures and VPD, in the Western U.S from 1979-2016 (Abatzoglou & Williams, 2016). In the future, wildfires are predicted to be influenced by climate-vegetation-fire interactions, along with direct changes resulting from drying of fuels and changing vegetation types, including introduced species such as invasive grasses increasing fire frequencies (Hurteau et al., 2014). Increased levels of tree mortality contribute to larger, higher-severity wildfires, and rising temperatures and drought-induced stressors are predicted to cause increased tree mortality due to bark beetle infestations (McDowell et al., 2015). Restoration of wildfire, through prescribed fire and managed fire, as essential ecological processes can increase ecological resilience, slow vegetation change and impacts to biodiversity that result from vegetation-type changes (Hurteau et al., 2014). Restoring wildfire in historically fire-frequent forests will allow for better resistance to high-severity fires and greater ability for ecosystems to bounce back post-wildfire disturbance (Hurteau et al., 2014).

IV. The Colorado Plateau Region:

The Colorado Plateau spans across the Four Corners region of Colorado, New Mexico, Utah, and Arizona, ranging in elevation from around 2,000 feet to over 12,000 feet at its highest mountain summits. The boundaries of the Colorado Plateau follow major mountain ranges and faults, beginning in the south along the Mogollon Rim in Arizona, across the western Rockies in Colorado to the east, along the edge of the Basin (valleys) and Range (mountains) province to the west, and extending to the north below the Uinta Mountains of Utah. The main vegetation types of the Plateau include

grasslands and shrublands at low elevation, pinyon-juniper woodlands, ponderosa pine and mixed conifer forests at higher elevation, with riparian vegetation along river corridors (NPS: Southern Colorado Plateau Network I&M, 2011). The Plateau consists of fire-adapted vegetation including mixed-conifer, pinyon-juniper, and ponderosa forest stands (Allen, 2002). Due to the immense variety of ecosystems, biodiversity, and large size of 150,000 square miles, the Colorado Plateau region presents challenges for management and decision-making under increasing climate change impacts, with certain ecosystems, such as dry grasslands, shrublands, and woodlands becoming more vulnerable to stressors including wildfire and drought (Schwinning, 2015).

The Colorado Plateau (Utah, Colorado, Arizona, New Mexico) encompasses more national parks and public lands by area than any other region in the continental U.S. Over half of the Colorado Plateau (55%) is composed of public lands, including 27 NPS units, 17 national forests, 26 wilderness areas, over 1 million acres of BLM land, and several of which have been designated as UNESCO World Heritage Sites. These public lands include internationally known and heavily visited parks such as Grand Canyon National Park, Arches National Park, and Zion National Park, as well lesser visited, but equally as culturally and ecologically significant park units, such as Chaco Culture National Historical Park, which was designated a UNESCO world heritage site in 1987 to preserve the culture, architecture, and traditions of the Chacoan people (NPS, 2015).

The public lands across the Plateau preserve a wide range of biodiverse ecosystems, including geologic formations such as canyons, mesas, buttes, arches, hoodoos, volcanic mountains, and natural features including montane grasslands,

rivers, freshwater springs, and hanging gardens. Biological soil crusts are integral to low elevation ecosystems found on the Plateau, and are composed of microfungi, lichens, mosses, and cyanobacteria, and provide numerous ecological benefits, including enhancing soil fertility, moisture, and stability (Schwinning et al., 2008). The Plateau is home to multiple threatened and endangered species including the Mexican spotted owl, Southwestern willow flycatcher, humpback chub, desert tortoise, the black footed ferret, the Utah prairie dog, the San Francisco Peaks Ragwort, and Wright's fishhook cactus (NPS, Northern Colorado Plateau Network, 2010). In addition to ecological preservation, the public lands on the Plateau also protect a tremendous number of archaeological and cultural heritage sites of indigenous groups, with the Bears Ears region of the Plateau alone protecting over 100,000 archaeological and cultural sites (NPS, 2015). Additionally, plant species richness has been found to be more substantial in and near archaeological sites, with 31 plant species of cultural significance to five local tribes discovered at sites, despite being rare otherwise, showing the interconnectedness of indigenous groups to the ecological history of this region for thousands of years (Pavlik et al., 2021).

Climate change induced warming and droughts in already arid climate conditions increases the vulnerabilities of ecosystems in this region (NPS: Southern Colorado Plateau Network I&M, 2011). The Colorado Plateau is no exception to having experienced extended periods of drought, with these conditions presenting many challenges and concerns for the availability of freshwater in the region, particularly when it comes to the future of the Colorado River (Cayan et al., 2010). Extreme drought conditions have occurred and persisted over a number of years, and soil moisture in the

Colorado River Basin has been decreasing (Cayan et al., 2010). In a precipitation decline experiment conducted on the Colorado Plateau, prolonged drought conditions led to significant declines in dominant plant functional types, along with declines in plant cover, biological soil crust cover, and warmer, drier conditions of the soil itself (Finger-Higgens, 2023). Decline in precipitation in the region has led to the loss of lichens and mosses, which absorb carbon dioxide, absorb rainfall, and help the soil retain moisture (Schwinning et al., 2008). Declines in grass species vegetation cover has been observed widely across the Plateau and biological soil crusts may struggle to survive in drier conditions (Finger-Higgins, 2023). Observed and predicted declines in precipitation, leading to reduced soil moisture on the Colorado Plateau have and will continue to lead to increased plant stress and tree mortality (Schwinning et al., 2008).

The Colorado Plateau regional ecosystem has been shaped by interactions between people and nature for thousands of years (Allen, 2002) and fire is an essential, natural ecosystem process in the Southwest (Hurteau et al., 2014). The combination of drought, fire suppression, and climate-induced changes has significantly contributed to the accumulation of biomass capable of fueling larger, more destructive wildfires than seen historically in the region (Stephens et al., 2009, Muhkerjee et al., 2018). Tree mortality is predicted to become more substantial and widespread due to the combined influences of drought and a warmer climate, with the sole stressor of drought reported as contributing less to widespread tree mortality (Schwinning et al., 2008). In particular, drought-induced pinyon pine die off has increased substantially, with 90% or greater mortality at high elevation sites in Mesa Verde National Park and Flagstaff, Arizona and

attributed to low soil water content, bark beetle infestations, which is related to drought stress (Breshears et al., 2005).

There is a wide diversity of groups of stakeholders residing on the Plateau, often with conflicting interests, values, perspectives, and experiences (Duniway et al., 2016). Stakeholder groups in addition to federal and state managed land agencies, include tribal entities, domestic livestock ranchers, farmers, recreational tourists, other private landowners, and energy developers, with drilling increasing to three times as much as in the past (Duniway et al., 2016). This high density of public lands on the Plateau provides plentiful opportunities for outdoor recreation, with visitation increasing throughout public lands in the region, particularly at well-known park units and trails, leading to challenges related to managing heavier tourism in ecosystems that are becoming more fragile due to climate change (Copeland et al., 2017).

Increased land-use on the Colorado Plateau increases vulnerability in the region because low water availability even without climate change causing drought conditions are characteristics of the Plateau (Copeland et al., 2017). Additionally, arid drylands ecosystems often take hundreds of years to recover following a disturbance because of their inherent low productivity (Schwinning et al., 2008). Increased land use has changed the ecology of the region, and introduced species have outcompeted native vegetation, shifting fire regimes throughout the Plateau (Schwinning et al., 2008). One such land use is high intensity grazing throughout the region, which has led to the degradation of grasslands on the Colorado Plateau (Copeland et al., 2017). This has contributed to disturbances such as increased soil erosion, lower plant productivity, and declining biodiversity (Neff et al., 2005). Energy development, including oil, gas,

renewables, and uranium mining have also contributed to environmental degradation (Copeland et al., 2017).

V. Scope of Research:

The primary objective of this research project is focused on gaining a deeper understanding of the wide variety of perspectives and strategies of natural resource managers and scientists who have faced major ecosystem transformations on the lands they work due to drought, wildfire, and/or climate change. The aim is to share these insights to better prepare resource managers on the Colorado Plateau that have yet to experience such large-scale changes. Managers who have experienced large-scale change have gained important insights as to how ecosystems have responded to these stressors, as well as firsthand experience in managing with the objective of building ecological resilience in the face of worsening conditions, and these insights can provide guidance and support for other managers and stakeholders in this region.

The Colorado Plateau region is an ideal study area due to the combination of the high density of public lands managed by a multitude of agencies throughout the region, along with an abundance of ecological factors that increase the region's vulnerability to ecological stressors and change. The Colorado Plateau region was chosen due to its relatively large size along with the large number of public lands it encompasses, which will allow for more insights to be gathered from a wide range of individuals from a variety of management agencies. The Colorado Plateau is home to a large number of public land managers that can benefit from learning from the experiences and

perspectives of other land managers that have experienced large-scale changes. Interviews were conducted with 37 natural resource managers and scientists from federal, state, and local agencies across the Colorado Plateau of the southwestern U.S. that identified themselves as having experienced large-scale ecological changes due to drought and/or wildfires on the lands they manage. A survey was conducted to better understand how a larger sample of natural resource managers and scientists use adaptation strategies to address climate change related impacts they have experienced, or plan to experience, on these landscapes.

The regional scale of this research project allows for a selection of a diverse group of respondents, with varying perspectives and insights, which will be applicable to others working in the Colorado Plateau region, whereas a larger study may be too broad to provide specifics to those that would benefit from sharing knowledge. A more focused, narrow spatial scale may not represent the many perspectives and experiences of natural resource managers. The multitude of perspectives shared through interviews and surveys provide a stronger understanding of management challenges and opportunities for implementation adaptive strategies in the Colorado Plateau region. There are a range of perspectives of natural resource managers and scientists that have dealt with ecological changes due to wildfire and/or drought. Current adaptive land management strategies utilized by federal and state agencies pose challenges, and this study seeks to better understand the extent to which these strategies are able to be successfully implemented on a broader scale.

Natural resource managers have much to gain from broadening the scale of management approaches, perhaps through collaboration on larger-scale projects, and

from sharing perspectives on land management. Following the conclusion of this thesis, the findings from this research project will culminate in a workshop, bringing together and creating a structured information exchange between managers that have already experienced threshold changes and those who have yet to experience them. The facilitation, sharing, and communication of existing knowledge and experiences will allow managers to better prepare anticipatory climate adaptation strategies for current and future challenges.

VI. Research Statement and Research Questions:

This research project seeks to examine how management decisions are made when preparing for and responding to the ecological stressors of drought and wildfire on the Colorado Plateau, and to what extent managers are implementing climate and fire adaptation on the ground. The aim of this thesis research will be to understand the primary barriers and potential opportunities for greater facilitation of adaptation actions through a political ecological theoretical framework. The region-specific approach also provides a better way to understand the experiences and perceptions of managers by focusing on how the institutional structures of agencies play into the power dynamics and management approaches of agencies operating across a particular region. A primary objective of this project is to share the wide diversity of experiences and insights of managers in this region who have experienced large-scale changes with managers who have yet to experience changes to such a large extent, with the goal of creating greater collaboration and communication between agencies. The research

questions which have served as the guidelines for the project and will be answered within this thesis project include the following:

1. What are natural resource manager perceptions related to adaptation and ecological change, including climate change, and what is their definition of adaptation?

a. What are the knowledge, attitudes, and practices of land managers related to adaptation strategies?

2. How do natural resource managers create adaptation plans under conditions of uncertainty?

a. How does decision-making occur with respect to drought and wildfire-induced ecosystem stressors?

3. What are the primary barriers to preparing and responding to ecological change, and climate change?

a. What are adaptation actions and are they happening?

b. What supports are needed to facilitate responses to ecological change?

c. What are the conditions that allow for good adaptation decision-making?

VII. Thesis Organization

This thesis has been organized into seven chapters beginning with this introduction to the research project, through an introductory overview of climate change, and ecological stressors such as drought and wildfire, and the impacts they have across various spatial scales. This broad overview will become more focused in Chapter 2, in which the theoretical framework of political ecology will be explored as a crucial lens in which to examine the multitude of challenges, barriers, and limitations managers face in their attempts to implement climate adaptation. This includes the challenges managers face when implementing climate adaptation on public lands throughout the Colorado Plateau region, due to the global scale impacts caused by climate change. The literature review will investigate the concept of climate adaptation, which leads to variations of responses on the ground, and will dive deeper into the opportunities that proactive climate adaptation strategies can provide to managers experiencing worsening drought and/or wildfire impacts on their landscapes. Additionally, the frameworks of a social-ecological systems approach and resilience theory will be explored as secondary tools to further investigate the opportunities to enact adaptive actions that address the numerous climate-related challenges unfolding for managers on the Colorado Plateau. Chapter 3 discusses the methodology used for this research project, highlighting the importance of a mixed methods approach. In this case, a combination of qualitative interviewing and quantitative/qualitative surveying was used to address the research questions. Chapter 4 shares the extensive and insightful results from 37 interviews with managers and scientists in the Colorado Plateau region. The key findings from the interviews were used to develop survey questions, the results of which are explored in Chapter 5. The survey was sent to natural resource managers

across the Southwest, to examine the extent to which managers are experiencing ecological changes, as well as to understand how managers are understanding climate adaptation at a broader spatial scale. Chapter 6 ties the two previous results chapters together, with the use of the theoretical framework of political ecology as a lens to better understand the many complexities and contradictions of the findings within the results chapters. Chapter 8 concludes this thesis, acknowledging limitations of the study, directions for future research, providing recommendations both for natural resource managers and scientists in this region and recommendations for policy changes at the federal level.

VIII. Positionality Statement:

I am a white female and lifelong resident of the Western U.S, in Southern California, and more recently, in Flagstaff, Arizona. I was raised in a working-class family, and I am a first-generation college student. I hold two degrees, a Bachelor of Science in Environmental Science and a Bachelor of Arts in Philosophy from the University of Redlands. After college, I spent four years as an elementary educator in a low-income area. I have never worked for any of the federal or state management agencies or NGOs that are a part of this research project. I acknowledge my privileged access to certain resources that allowed me to pursue an education and complete this research project. I continue to strive to recognize and address how my personal experiences and biases may shape my research.

CHAPTER TWO

LITERATURE REVIEW

I. Concepts and Understandings of Climate Change Adaptation:

The concept of climate change adaptation has become increasingly used in planning for the impacts of climate change in recent decades. One of the earliest definitions of climate change adaptation was presented at the U.N.'s Framework Convention on Climate Change (UNFCCC) in 1992, which defined adaptation as "practical steps to protect nations and communities from the likely disruption and damage that will result from the effects of climate change." Later global climate mitigation agreements, including the Kyoto Protocol (1997) and the Paris Agreement (2015) built upon this convention. Climate adaptation has also been defined by the IPCC (Intergovernmental Panel on Climate Change) over several iterations, including this definition in the Fifth Assessment Annex: "The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2014). The 2014 IPCC report defines adaptive capacity as "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences," which will be important for consideration over the course of this research project. In response to earlier definitions of climate adaptation which did not as clearly connect humans and nature, the definition of adaptation was expanded upon as the following: "adaptation involves changes in social-

ecological systems in response to actual and expected impacts of climate change in the context of interacting non climatic changes. Adaptation strategies and actions can range from short-term coping to longer term, deeper transformations; aim to meet more than climate change goals alone; and may or may not succeed in moderating harm or exploiting beneficial opportunities" (Moser & Ekstrom, 2010). Despite the similarities shown in these definitions, the concept of "adaptation," as applied to climate change, is understood by various agencies and individuals in a multitude of complex ways (Adger, 2013). Cultural dimensions of climate change have impacts on how adaptation research is conducted (Adger, 2013).

Despite definitions of climate change adaptation existing for several decades, there are still misunderstandings surrounding the meaning and application of this concept. Climate adaptation has been mischaracterized as synonymous with climate change mitigation, which is the reduction of greenhouse gas emissions to reduce the pace of climate change (IPCC, 2014) as well as confusing climate adaptation with biological adaptation in relation to species adapting to changes over long periods of time in the process of evolution.

II. Climate Adaptation, Adaptive Capacity, Vulnerability, and Resilience:

The concept of resilience has existed in literature related to ecology since the 1970s, coined by Holling, a Canadian ecologist (Gunderson, 2000). Since the 2000's resilience theory has been implemented across many disciplines (Allen et al., 2019) but in the context of ecology, it is important to consider from a management standpoint in particular. Holling's adaptive cycle model can be extremely useful when considering

ecological resilience, and one of the major challenges is understanding where along the adaptive cycle a particular system is, and this can help facilitate a better understanding and responses to hopefully create a more resilient system (Berkes et al., 2003). Distinguishing when, and why a system is in the exploitation phase (where resilience is high and the system can handle many disturbances) versus when the system is locked in a rigidity trap and reaching limits to conservative growth, the system is far more fragile and smaller disturbances can threaten the entire system, thus increasing vulnerability (Gunderson, 2000). Within a given system, addressing and trying to pinpoint to the best of abilities where the system is along the adaptive cycle, is a helpful place to start when attempting to locate vulnerabilities and potential threats to the system's stability (Gunderson, 2000).

Reviewing the history of the origins of resilience, the concept distinguishes itself from the concept of stability because resilience focuses on dynamic, changing systems that are "far from equilibrium" and goes on to explain that resilience should be defined as "the amount of disturbance that a system can absorb without changing state" (Gunderson, 2000). Ecological resilience considers disturbances and attempts to understand when thresholds are crossed and a system is transformed into a new state (Allen et al., 2019). On the other hand, stability refers to a system persisting close to equilibrium (Gunderson, 2000). It is important to reflect on how the idea of resilience shaped ecology, especially how management and applied decision-making is often based in a discipline's prevailing theoretical framework (Gunderson, 2000). Increasingly, restoration efforts seem to be constrained by larger landscape scale change, which leads to the question of how natural resource managers should best plan for and take

measures to build resilience in higher levels of uncertainty as the climate crisis increases change at the landscape level (Gilby et al., 2018).

The concept of “adaptation” also has challenges when being applied, in addition to the challenges associated with vulnerability and resilience (Ribot, 2011) The use of the concept of adaptation shifts attention away from causal forces to discussion of response. (Ribot, 2011). Discussions about vulnerability and hazards have the potential to run into issues of recognizing causality in addition to focusing efforts on a response, because this leads to a focus on hazards/risks that are more immediate rather than the underlying, broad stressors that people face (Ribot, 2011). Both adaptive capacity and resilience can lead to the question of: which state is the most desirable and for whom? It is important to consider the role of power and who is included/excluded from determining when the system is considered stable.

Nelson et al. (2007) defines adaptiveness as “a state in which a system is effective in relating with the environment and meets the normative goals of stakeholders.” This is interesting to note because not all stakeholders will have the same values and define their normative goals and objectives in the same way. As Ribot (2011) points out, a system’s adaptive capacity and resilience can be measured from the perspective of economic well-being, which can often exclude other important aspects of human well-being such as cultural and religious well-being. There are risks in application of the terms “adaptation,” “vulnerability,” and “resilience” because the interpretations of such terms often leave many people out of the conversation, limiting groups and communities to being seen as vulnerable and often powerless over the risks imposed onto them.

Another major issue that stands in the way of creating meaningful adaptation strategies is that climate change is often viewed as a problem at the global level, which can lead to the lack of understanding or cognitive dissonance and disconnection from the impacts being felt at smaller scales, such as regional and community levels (Ribot, 2011). Additionally, there is a lack of visibility of climate-caused impacts until the risks and threats are extremely apparent at the community level. In the case of drought and wildfire, the warning signs are often incremental, until the threshold-level ecosystem disturbance occurs. On the other hand, climate change is also shifting cultural values and perspectives, which may lead to a positive outcome for recognition of the need for adaptation strategies.

By determining the values, concerns, and perceptions of community members, it is more possible to address uncertainties and build resilience by encouraging community participation and preparedness for future drought and wildfire related stressors and impacts. The resilience approach focuses on both bottom-up (community to institutional) and top-down (institutional to community) strategies for improving resilience, with special emphasis on how the climate crisis will create a need for interventions across various scales (Norris et al., 2008). Resilience has been defined by many scholars over time, with a common theme of ability to successfully adapt in after various stressors, disturbances, or times of adversity (Norris et al., 2008). Community resilience builds upon this by emphasizing social capital and building a sense of community in order to strengthen resilience and adaptive capacity (Fazey et al., 2018). The literature shows that there is a need for greater emphasis and research focused on the application of resilience approaches to determine what works and does not work.

This is especially relevant because with climate change comes uneven risk and harm, often in the form of natural disasters, to marginalized communities that have done little to nothing to contribute to the problems and have little ability to respond to the increased risks and vulnerabilities imposed on them by climate-induced impacts (Fazey et al., 2018).

There is a need for social transformation as opposed to simply focusing on reforms and mitigation as a way to build resilience within both human and natural communities (Fazey et al., 2018) The necessity of increasing "social capital" to prepare for and reduce impacts/risks to communities in times of crisis is crucial, as opposed to the current focus on infrastructure developments and policy as primary risk-reduction strategies (Aldrich et al., 2015). Strengthening community ties can be done through applications such as information sharing, participatory community meetings (Alderich et al., 2015). By considering resilience through a community-based approach, it empowers individuals with more tools and means to be self-sufficient and "bounce back" from disaster situations, and importantly, allows for disaster readiness (Norris et al., 2008). Much of resilience is focused on the idea of bouncing back, but the community-based approach advocates for disaster readiness, so communities can better withstand shocks and stressors (Norris et al., 2008). Collaborative work across sectors, including communities, NGOs and government agencies, in order to "address issues of power, control, and ensure support." (Fazey et al., 2018). This is crucial, especially as the idea that resilience thinking itself has been critiqued as it has been utilized to reproduce and reinforce ideologies of institutions and political structures that led to inaction, apolitical

narratives surrounding causes of environmental and social issues, and inadequate institutional and governmental accountability (Ingalls & Stedman, 2016).

III. Climate Adaptation: Strategies, Actions, Challenges:

The ability to effectively prepare and respond to climate change, drought, and wildfire, is often determined from a top-down approach by the successes of climate adaptation strategies created by policymakers and implemented by natural resource managers. A major issue that stands in the way of creating meaningful adaptation strategies is that climate change is often viewed as a problem at the global level, which leads to a lack of understanding or cognitive dissonance and disconnection from the impacts of a changing climate (Adger, 2013). Additionally, there is a lack of visibility of climate-caused impacts until the risks and threats are extremely apparent at the community level (Adger, 2013).

Climate adaptation is necessary for biodiversity conservation now and into the future, as climate-related impacts are predicted to intensify in scale, frequency, and severity (IPCC, 2021). Climate change adaptation research has presented managers from federal, state, tribal, local agencies, as well as private businesses, with strategies and approaches to actions that are novel and forward-thinking in comparison to business-as-usual management practices (Bierbaum et al., 2013). Management of natural resources across these agencies will have to adapt their policies and practices in order to strengthen ecosystem resilience and prepare for current and projected challenges presented by a changing climate (Bierbaum et al., 2013). As both the scale

and magnitude of climate impacts continue to increase, natural resource managers have found it difficult to plan and enact widespread climate change adaptation due to worsening ecological conditions in combination with socio-political limitations and barriers (Bierbaum et al., 2013). Climate change related impacts have created numerous challenges for natural resource managers tasked with managing for the preservation of ecosystems and species conservation while experiencing the intensification of stressors, which can lead to ecological transformations (Lynch et al., 2021). Scientists and managers cannot fully predict the extent of human-caused climate change impacts and have been limited by this uncertainty combined with lack of funding, policy and institutional constraints, and conflicting information about which actions will be the most well-suited and effective for the lands on which they work (Bierbaum et al., 2013).

According to Bradford, et al. (2018), climate patterns are becoming increasingly novel and dynamic, especially in relation to historic conditions. Natural resource managers are tasked with managing ecosystems and promoting conservation efforts as novel ecological conditions and changes emerge (Bradford et al, 2018). Novel ecosystems, also known as “emerging ecosystems,” arise when species occur in numbers and combinations that were not previously seen within a given biome (Hobbs et al., 2006). Importantly, these changes to species and distribution of biodiversity arise through both environmental change and human actions and influences on the existing environment, leading to novel conditions that can present challenges to management efforts (Hobbs et al., 2006). As novel conditions emerge within ecosystems, land management of these systems can become both difficult and expensive, as mounting

challenges and changes lead to difficulties in returning ecosystems to their previous states (Hobbs et al., 2006). Biodiversity is not static and unchanging, instead, it is both generated and maintained by natural processes, as well as human influences (Pressey et al., 2007). Anticipatory preparedness can allow managers to more effectively prepare for future novel ecological changes, including short-term forecasts and multi-year climate patterns (Bradford et al., 2018). However, even with the best predictive climate modeling and on-the-ground management efforts, scientists cannot predict what the climate will look like in the coming decades with complete accuracy, due to the inherent uncertainty of the timing and severity of climate-related impacts in different regions (IPCC, 2021).

Natural resource managers must make difficult decisions under conditions of unpredictability when managing ecosystems towards novel, desirable ecological conditions (Lynch et al., 2018). Environmental conditions often change before ecological transitions occur, so looking at short-term and near-term climate change is essential for management decision making (Bradford et al., 2018). Anticipatory strategies are often the most successful in the beginning stages, once it has been recognized that ecosystem transitions are beginning to occur (Bradford et al., 2018). Natural resource managers are advised to compare short-term and near-term changes in climate alongside evolutionary history and previous knowledge of the ecosystem (Bradford et al., 2018). Effective conservation planning efforts are influenced and limited by change and uncertainties, particularly due to human-caused climate change impacts (Pressey et al., 2007). The ability to create effective land management strategies to conserve landscapes and biodiverse regions is especially challenging when considering current

uncertainties. As uncertainties related to climate change present increased challenges, a need for a thorough understanding of how natural resource managers make decisions, how they perceive ecological stressors on their landscapes, and how they are understanding existing strategies and tools for climate adaptation.

IV. The National Park Service:

The National Park Service began addressing climate change beginning in the 1990s (Runyon et al., 2020). A study looked at how climate change will impact visitation patterns in national parks, in addition to natural and cultural resource preservation, limiting the ability for the NPS to carry out its agency mission which "preserves unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations" (Fisichelli et al., 2015, National Park Service, 2022). Climate change and ecological stressors have previously been studied in relation to management of national parks and found to operate at especially rapid rates that outpace the ability of management response and also at a scale that surpasses park boundaries (Monohan & Fischelli, 2014). Climate adaptation in national parks faces institutional barriers and a study reported that few examples of completed adaptation plans that were deemed as successful exist (Runyon et al., 2020). The National Park Service has several agency-wide adaptation toolkits, including a handbook "Using Scenarios to Explore Climate Change: A Handbook for Practitioners" (National Park Service, 2013). This handbook begins with an insightful quote into the agency's narrative surrounding climate planning: "Since you never know what lies around the next corner with climate change, scenario planning is a tool to help

parks prepare for this uncertainty.” The theme of uncertainty in decision making is prevalent throughout the document, with this term being used twenty times (National Park Service, 2013).

V. The U.S. Forest Service:

The USFS has developed a climate change strategy focused on adapting land management planning and activities to changing conditions, developing scientific information, form partnerships, and educate agency staff and stakeholders (Timberlake & Shultz, 2017). The USFS is an example of an organization that has evolved throughout its history and has started to embrace new paradigms and has increased climate adaptation planning and management efforts over the past decade (Timberlake & Shultz, 2017). The USFS has an opportunity to understand the dynamics of governance change in the context of climate change adaptation. Based on a study in the Western U.S., authors found that through interviewing USFS employees, that the USFS may need to reorganize and update its policies, partnerships, and organizational structures to support climate change adaptation efforts (Timberlake & Shultz, 2017). The USFS frequently uses ecological resilience but rarely incorporates social-ecological resilience considerations into adaptation planning and management, and the authors suggest that resilience is more frequently used than adaptation (Timberlake & Shultz, 2017). On the other hand, the study found that the USFS in the Rocky Mountain region is increasingly engaging in adaptation through planning activities (Timberlake & Shultz, 2017). In 2022, the USFS developed an 88-page climate adaptation plan that covers sections on climate change impacts, climate change adaptation actions,

implementation, foundations for adaptation, intended outcomes, and threats to the USFS's mission, infrastructure, and operations (USFS, 2022). This adaptation plan is extremely comprehensive, insightful, and adaptation actions are outlined in a clear, applicable way for managers (USFS, 2022). One especially interesting aspect of this document is that it includes not only primary adaptive actions for managers to implement on the landscapes on which they work, but also includes secondary actions in each category, known as "supporting activities." (USFS, 2022). This is one of the clearest examples of a useful adaptation action document, detailing actions in a way that is easy to understand and for managers to apply actions on the ground, with an entire section detailing implementation strategies.

VI. The RAD Framework:

As climate change leads to worsening ecological conditions, natural resource managers have started to use adaptive management strategies to better prepare for landscape-scale changes. While many adaptive frameworks and approaches exist, one adaptive management and decision-making framework in particular has become more widely used by land managers across federal agencies to address transformational ecological change (Lynch et al., 2021): Resist-Accept-Direct (RAD). Created by the National Park Service Climate Change Response Program, in collaboration with other agencies, including U.S. Fish and Wildlife Service and United States Geological Survey (Schuurman et al., 2020).

The RAD framework suggests that natural resource managers are eager to find new ways to approach climate change adaptation. The RAD framework explores

distinct, tangible management options that managers can use when experiencing ecological changes, and a process for decision-making to guide whether the best approach is to resist, accept, or direct changes (Schuurman et al., 2020). In managing for the trajectories of ecosystem change, the RAD framework defines “resist” as working to maintain or restore ecosystem processes based on historical or current conditions, “accept” as allowing ecological processes to change without intervention, and “direct” as actively shaping ecological processes towards new, desirable future conditions (Lynch et al., 2021). The RAD decision-making framework is a tool used to assist natural resource managers in making informed choices in the face of rapid, novel, and often unpredictable, ecological changes (Schuurman et al., 2020). The RAD framework emphasizes that managers should strategically consider anticipatory, forward-thinking actions for their approaches, rather than managing based on goals of returning to historic conditions (Schuurman et al., 2020). Potential limitations of implementing strategies based on the RAD framework include multiple combinations of difficulties including: the possibility of financial impracticability despite being ecologically feasible and supported societally, being ecologically and financially feasible but being met with societal disapproval from groups of stakeholders, or the action may be socially and financially feasible but present ecological challenges, particularly in terms of long term management interventions in the ecosystem in order to sustain the effort (Lynch et al., 2021).

VII. Social Construction of Nature and the Historic Management of Public Lands

It is important to consider the social construction of nature and the ideologies which have shaped the management practices of organizations historically and into the present-day. In order to gain a better understanding of how public lands are managed, and what strategies would be the most effective moving forward, it is crucial to understand the historic socio-political and economic contexts in which public lands, particularly national parks and monuments, were established. From the beginning, private and corporate interests played a role in the foundation of parks, with the railroad industry and conservationists working in unison to establish them (Runte, 2010). Human perception surrounding what constitutes “nature” and the “environment” contains numerous meanings, and the diversity of meanings humans create for landscapes are reflections of culture and how people understand themselves and the physical environment, as environments change, so do these definitions and understandings (Greider & Garkovich, 1994).

Tourism and outdoor recreation can be considered forms of exploitation, which is an important aspect of the “wilderness imaginary” (Runte, 2010). There does not seem to be an example of true wilderness within U.S. public lands, meaning a wilderness that is entirely removed from human impact and societal forces that change the landscape. Historically, wilderness was thought of as “deserted,” “savage,” “barren,” and “desolate” but these ideas have shifted over time to an idealized concept of wilderness as sublime, pristine, and the frontier (Cronon, 1995). The main issue with viewing wilderness as both desolate and pristine is the idea that wilderness is something that exists entirely separate from humans, whether individuals perceive wilderness as sacred or as primitive and simplistic like that of life on the frontier

(Cronon, 1995). When individuals view wilderness and nature as separate from humans, problems can arise with how both wilderness and those living in regions surrounding these “wilderness” areas are perceived and cared for. The perspective of humans as separate from nature can lead to negative outcomes in both wilderness and urban environments, especially when those living on the peripheries of protected areas are not included in the conversations and considerations about how to manage these landscapes (Proctor, 1998).

The establishment of National Parks can be understood from a political economic standpoint (Runte, 2010). National parks were founded despite many conflicts at varying levels of power, both from private industry and the prominent environmental organizations at the time (Runte, 2010). Many arguments for the establishment of public lands deal with the investment of capital in order to create infrastructure, including roads to many of the most scenic park destinations (Runte, 2010). Increasing infrastructure and development was encouraged in national parks even during the earliest considerations of their establishment, as a way to promote economic growth (Runte, 2010). Tourist impacts on parks are not at the forefront of public discussion when it comes to national parks. Additionally, when considering impacts of drought and wildfire on public lands, it is important to remember that parks have been managed for development and as dynamic landscapes from the very beginning (Runte, 2010). Without a strong foundational understanding of how and why public lands were developed, it will be difficult to examine how to move forward with land management strategies.

The U.S. development of national parks is the subject of a great deal of conflict, due to the fact that they emphasize the “separation of nature and culture” in order to promote the idea of nature as wilderness, untouched by human interference (West et al., 2006). These designations can cause nature to be seen as existing in a pristine way, completely separate from society and humans (West et al., 2006). This leads to negative consequences, such as perpetuating the idea that all human impact on nature is inherently negative or perceiving any human interaction with the landscape as a “threat” to the wilderness (West et al., 2006).

Denevan (1992)’s argument related to wilderness imaginaries is centered around the ways in which indigenous people managed a great variety of landscapes in the Americas, despite the widespread misconception of a pristine, untouched wilderness, where humans had no greater impact on the land than that of wildlife. The language used to describe the Americas prior to colonization was particularly interesting, with key phrases such as “forested glory” and “ancient, primeval, undisturbed wilderness” being used to describe lands that had 50-80 million inhabitants (Denevan, 1992).

There are many troubling origins of Americans’ common discourse around the ideas of “wilderness” and “frontiers,” that have led to idealized landscapes (Denevan, 1992). When examining public land management between agencies and tribal leaders, as well as the possibilities for climate adaptation strategies, it is important to understand the way these lands have been conceptualized and why. What we think of as “primitive” and “untamed” wilderness areas are often constructed spaces that benefit certain groups at the expense of indigenous people (Denevan, 1992).

There are very few untamed wilds that meet the idealistic notions of wilderness that were promoted by early public lands officials. These lands are the native, ancestral homes of indigenous people, who have been historically excluded, and erased from these natural environments by this exclusion. Indigenous people were often removed by colonization in the form of “Westward expansion” or by forced evictions in pursuit of creating an untamed, untouched wilderness aesthetic for the sake of preservation and tourism (Denevan, 1992).

What humans perceive as “landscapes" are actually symbolic environments that are created by humans by placing meaning, values, and definitions on the natural world (Greider & Garkovich, 1994). There is such a thing as the physical, natural world, but how humans perceive nature is based on culturally defined definitions, and that these landscapes are socially constructed as opposed to being objective, empirical realities (Greider & Garkovich, 1994). An important aspect of this process of meaning-making involves a sociocultural group constructing a landscape through symbols that are valued and important within their culture, and this meaning is reconstructed and expanded upon over time (Greider & Garkovich, 1994). How we relate to the natural world is directly connected to our experiences, values, and belief systems (Greider & Garkovich, 1994). One physical location can represent a multitude of landscapes, depending on values and perspectives of those interacting with that landscape (Greider & Garkovich, 1994).

VIII. Historic and Current Management of Public Lands on the Colorado Plateau:

Understanding the historic practices of land management is important in order to understand how the landscape has been shaped by human activities for thousands of years, and how management practices along with land use changes have impacted the landscape and will influence adaptation practices. The Colorado Plateau region has been shaped by humans for centuries with significant transformations driven by human-nature relations. Pre-colonial arrival, traditional indigenous land-use was defined by humans interacting within nature, as part of the system, leading to a holistic approach rather than a dualistic system (Kimmerer et al, 2001). Following postcolonial arrival and indigenous extirpation from lands, contemporary institutional management began, whereas humans are actors/controllers of nature and thus outside the system (Kimmerer et al., 2001).

Within indigenous communities, fire was respected and revered for its beneficial effects on the landscape and used as a tool (Kimmerer et al., 2001). As actors within nature, indigenous people on the Colorado Plateau interacted within nature through wood harvesting for domestic fuel and architectural material, reducing forest density and ground fuels, especially near villages (Kimmerer et al., 2001). Fire was used to establish agricultural fields and to manipulate habitat for hunting or improve natural harvests (Roos et al., 2021). Through frequent use of small, interspersed surface fires, indigenous communities also increased landscape resilience to large severity fires (Roos et al., 2021). Land close to tribal villages had higher reduction of fuels and more frequent low-level fire occurrence, creating a linear distance effect of fire risk across the

landscape corresponding to villages (Roos et al., 2021). This management approach, which allowed fire to have a role in the landscape changed with land use practices shifting post-colonial arrival.

Western colonization extirpated indigenous communities and altered the existing indigenous strategies of land-use and burning in the 1800's-1900's (Liebman et al., 2016). Additionally, the establishment of national parks and monuments created contemporary institutional management across the Southwest region (Liebman et al., 2016). National Park Service natural resource managers and decision-makers have implemented federal strategies for fire management and post-fire restoration efforts (NPS, 2016). Modern management and land-use practices operated on the natural system, as actors outside of nature. This established institutional policies with low tolerance for fire and smoke and implemented fire suppression and preventative management strategies. Such practices led to worsening fire conditions by creating high density forests and ground vegetation that dries out in the summer. Such conditions established unprecedented fuel loads across the landscape and were intensified by climatic changes resulting in warmer temperatures, especially in the arid southwest environments (Sommer, 2020). The devastating Las Conchas Fire in Bandelier National Monument was a partial result of contemporary institutional management altering land use practices of indigenous communities, who previously managed and operated within the natural system to create fire resilience and fire-tolerant ecosystems (Sommer, 2020). In the context of fire across the landscape, shifts in human-nature relations have transformed fire regimes from frequent low-severity fires to historic, large-scale, high-severity fires, such as the Las Conchas fire in New Mexico, which transformed the

landscapes of Bandelier National Monument and the Jemez Mountain region (Roos et al., 2021). This is just one example of many significant ways in which wildfire has altered the landscapes within the Colorado Plateau. Burn severity was lowest, and tree survival was highest, in areas that had experienced both prescribed fire and prior wildfire, while sites lacking any recent prior fire burned at the highest severity and were overwhelmingly converted to non-forested vegetation (Walker et al., 2018). Due to increasing drought conditions resulting from a changing climate, fire severity and frequency is increasing (Walker et al., 2018). The combination of fire, drought, and warming temperatures are leading to greater, more complex challenges in terms of ecosystem recovery (Walker et al., 2018).

IX. Political Ecology Applied to Natural Resource Management:

The political ecological approach is well situated to provide an analysis and explanations for the challenges faced when planning adaptation, as well as for natural resource management more broadly. Political ecology is a field of critical research that examines the relationships between politics, economics, and nature (Robbins, 2012). One of the earliest definitions of political ecology describes the field of study as understanding ecological concerns through a “broadly defined political economy, examining the role of the state critically, as well as understanding the dialectics between society and natural resources (Blaikie & Brookfield, 1987). Political ecology centralizes the analysis of a given environmental and social issue around key considerations including: concepts of scale (regional/local to national and global), property relations, uneven distribution of risks and benefits, unjust exclusions from conservation areas, and

power dynamics, all while taking into account the perspectives and experiences of those living through the conflict/environmental issue (McCarthy, 2005). In political ecology, power is defined as how it operates across scales in society and nature and is characterized as: “a social relation built on an asymmetrical distribution of resources and risks... [located in] the interactions among, and the processes that constitute, people, places and resources” (Paulson et al., 2003). The political ecological approach is used across disciplines to better understand the connections between society and the environment, with particular attention focused on power relations between actors (Zimmerer et al., 2003). Political ecologists argue that ecology is always political and our thoughts and ideas surrounding the environment are shaped by existing political and economic structures (Robbins, 2012). Asymmetrical power relations led to increased ecological degradation through creating pressures of production on the environment, particularly the “environments of the poor and powerless.” (Paulson et al., 2003). Political ecology closely examines causation and the influences of money, power, and control on both politics and the environment, as well as how dominant institutions and political systems shape and transform the environment (Robbins, 2012). Nature cannot exist separately from society and vice versa (Robbins, 2012). Political ecology has historically been used to analyze environmental issues in developing countries but has increasingly been used to examine how power relations unfold in industrialized nations (McCarthy, 2002, Zimmerer et al., 2003). Dominant approaches for analyses of environmental issues often leave out important questions and concepts that are central to the socio-ecological issue being examined (Robbins, 2012). Political

ecology examines the lack of discussions of power within social-ecological systems in social-ecological resilience studies (Ingalls & Stedman, 2016).

Political ecology has the explicit goal of being an “emancipatory” study, with the normative objectives of creating change, promoting social justice, and improving lives (Robbins, 2012). Political ecology addresses issues of inequity and marginalization on both political and economic systems (Robbins, 2012). A political ecological approach to environmental issues is uniquely situated to examine the power relations, ability to manage lands efficiently, and vulnerabilities of both public lands and those working within them, as well as those living on the peripheries of them (Robbins, 2012). A political ecological approach asks crucial questions to determine what underlying power dynamics are at work when examining environmental issues (Robbins, 2012). Political ecology asks questions related to the political, economic, and societal drivers of environmental problems, with an emphasis on having normative goals of a more just, equitable world that are often lacking in dominant approaches (McCarthy, 2005). Dominant approaches to environmental issues are often focused on legal structures, rational choice models, and environmental science-based reasoning (McCarthy, 2005). A political ecological approach uses theories such as political economy and considers how capitalist production and profit motive shape both the environment and human lives (McCarthy, 2005). When examining a given issue with a political ecology lens, differences in class, race, gender, and power become evident, and reveal varying levels of ability to make decisions regarding an issue based upon these social factors (McCarthy, 2005).

Without looking at the causal forces behind environmental problems, the dominant approaches fail to address all of the complexities of the issue, which will not result in lasting, effective, just, or transformative solutions (Zimmerer et al., 2003). In examining the nature society relationship, environmental change comes with unequal distributions of both the costs and benefits of this change, and these costs and benefits reproduce power asymmetries that led to these unequal distributions (Okereke, 2006) Environmental degradation is both the cause and the result of social marginalizations (Ingalls & Stedman, 2016). Dominant approaches are often apolitical, meaning that they do not investigate the root political and economic forces behind environmental degradation and pollution (Robbins, 2012).

A political ecological approach to the examination of adaptation, resilience, and management in times of growing uncertainties due to climate change, has the potential to uncover both the limitations and the possibilities to create change within our existing socio-political system. The political ecological approach aims to achieve normative goals, including creating positive changes for both ecosystems and humanity (Robbins, 2012). Political ecology is well suited to analyze the political and economic motivating factors behind environmental policy (Walker et al., 2006). As political ecology has expanded its focus since its development, it has been used to examine a wide diversity of issues, such as the role of discourses, social movements, and government policies in shaping present environmental issues (Walker et al., 2006).

The approach of political ecology addresses the limitations of individual resource managers and ecologists to strategize and implement climate adaptation strategies especially when a given administration denies the reality of a changing climate. Political

ecology allows for a critical examination of how natural resource managers face the challenges of managing multiple uses and balancing the needs of diverse interests while making decisions related to ecological preservation (Ellenwood et al., 2012) This includes ecosystems that can benefit from adaptive management strategies and interagency collaboration, as well as human beings can benefit from having the ability to experience public lands and a natural world that is not severely devastated and impacted by climate-induced ecosystem stresses (Ellenwood et al, 2012). Political ecology has the potential to benefit from a more analytic framing of ecosystem processes and how these processes interact with society (Ingalls & Stedman, 2016). Analytical framings of social-ecological systems that are prioritized in resilience could be combined with political ecology's emphasis on power relations to create a stronger approach when examining social-ecological systems (Ingalls & Stedman, 2016). This combined approach could lead to a more thorough investigation and understanding of challenges for socio-ecological systems, especially when applied to institutions in the industrialized world, which has presented challenges for the political ecological approach (McCarthy, 2002, McCarthy, 2005).

CHAPTER THREE

METHODS

I. Mixed Methods Research Design Approach:

One of the primary aims of this study is to facilitate the sharing of knowledge between natural resource managers that have experienced large-scale ecological changes with managers in the Southwest region that have yet to experience such changes.To better understand the perspectives of land managers and scientists on strategies to adapt to climate change, fire, and drought on Colorado Plateau ecosystems, I chose to use a mixed methods research approach which involved first conducting qualitative interviews. This was followed by the implementation of a survey which contained a combination of primarily quantitative questions and several, short-answer qualitative questions for the purpose of deepening the understanding of the concept of adaptation and addressing important specifics which may be overlooked in a multiple-choice question, such as what resources are needed to facilitate adaptive action or novel ideas a manager has for how to best adapt. A mixed methods research design approach brings qualitative and quantitative research methods together in order to create a greater depth of understanding and a comprehensive examination of results (Johnson et al., 2007, Cresswell & Clark, 2011). A mixed methods approach can be designed in a multitude of ways. the approach for this project is known as “exploratory sequential design,” which includes a phase of gathering qualitative data and analyzing it, followed by a subsequent phase of gathering quantitative data and performing an analysis, with the purpose of enhancing, validating, and/or expanding upon the first

results (Teddlie & Tashakkori, 2009). A primary benefit of utilizing a mixed methods research approach is that results are integrated and are able to draw out insights in a flexible, adaptive manner (Schoonenboom & Johnson, 2017).

To begin, I designed a set of questions used in the interviews based on the review of the existing literature related to ecological change, management, and adaptation (Chapters 1 & 2) and following discussions with USGS scientists. Initially, I conducted and analyzed a total of 37 semi-structured interviews. I next developed and distributed a survey with a total of 153 participants. The rationale behind conducting interviews first was to implement the knowledge gained from main themes and key conclusions that emerged from the interviews to better design the focus of the survey questions. The interviews were conducted with participants who identified themselves as experiencing large-scale ecological changes induced by drought and fire on the landscapes in which they work, while the survey was distributed to a larger number of natural resource managers, and those in related fields, who may not identify as having experienced large-scale ecological changes. The insights from one approach can be used to inform the other, with the strengths of each approach building upon one another to form strong conclusions and build understanding (Schoonenboom & Johnson, 2017). The qualitative interview results and both the quantitative and qualitative results of the survey were analyzed in comparison with one another to identify key commonalities and differences between the perspectives of decision-makers that had experienced large-scale changes (interview results), with participants that may or may not have experienced such changes (survey results).

II. Qualitative Interview Methods:

Qualitative interviews are a frequently used method in many disciplines due to the fact that through interviewing, researchers are able to gather data that is open-ended, investigate the countless nuances and details of personal thoughts, emotions, values, experiences, and perspectives surrounding any given topic, and gain a strong understanding of an issue through the experiences and perception of the interviewee (Fujii, 2018). Structured interviews follow strict guidelines and questions must be asked in the same order with the same wording for each interview, while semi-structured interviews allow for more flexibility over the course of the interviewing process (Hay, 2021). The semi-structured interview approach allows for prompting of interviewees, rephrasing of questions, and changes to be made on a case-by-case basis depending on the situation of the interview and what ideas emerge over the course of the interview process (Galletta & Cross, 2013). One of the most important considerations when conducting semi-structured interviews is the attention paid to the participant's narrative, particularly what they emphasize as the most important and where they direct the conversation surrounding the initial question (Fujii, 2018). Semi-structured interviews provide the ability for both the researcher and the participant to gain clarification throughout the interview process (Galletta & Cross, 2013). For example, if the interviewee feels uncertain about the questions being asked, it may be helpful to rephrase the question (Galletta & Cross, 2013). It is important to ask for clarification when needed, especially when dealing with interviewee's personal perceptions and values, as this will form the bulk of the data and information collected (Fujii, 2018). The semi-structured interview approach allows for clarification, elaboration, and redirection of questions if needed (Galletta & Cross, 2013). In a semi-structured interview, the

researcher's ability to ask for clarification or to elaborate on unexpected topics that arise over the course of the interview provides crucial information and new insights, and also reduces the likelihood of the need to send follow-up questions at a later time (Galletta & Cross, 2013).

Qualitative interviews are often conducted based on a snowball sampling approach (Noy, 2008), and this approach was used in the interview process for this project. The snowball sampling method for gathering contacts and identification of potential interviewees is based upon initial participants and respondents providing contacts and helping researchers identify and reach out to new participants (Schutt, 2019). The interview guide, which was used as a starting point and outline for the overall direction and purpose of the interview questions, was developed based on the social science research methods approach of snowball sampling and guided interview strategies (Noy, 2008). The snowball sampling approach relies on participants to lead the researcher to more contacts and individuals who have insight and are willing to become participants in the interview process themselves (Noy, 2008). The snowball sampling approach has been frequently used in social science research approaches (Biernacki & Waldorf, 1981). Snowball sampling is especially useful for social scientists when the subject of study is on a private or potentially controversial matter, as well as when knowledge from insiders is imperative but privacy issues may arise, making it necessary to utilize insider knowledge to gain access to more respondents (Biernacki & Waldorf, 1981). When studying employees of federal government agencies, especially when employee perspectives may differ from or contradict the official standpoint, mission, or actions of the agencies. The snowball sampling approach allows

researchers to communicate with other potentially qualified participants for the research, as they are discovered through the interview process of the initial key informants (Noy, 2008). The snowball sampling approach of interviewees allows for selections based on qualifications, expertise, and knowledge of experiences relevant to the research (Noy, 2008). In this study, the sharing of potential interviewees to contact by existing respondents is based on insider knowledge of others who have also been tasked with decision-making under large-scale change. The snowball sampling approach is preferable because the general public and those outside of this field may not have this insider knowledge of others that would qualify for the interview. Through this approach, potential new interviewees are contacted following the initial respondent's suggestion, with this respondent often serving as a liaison, providing the potential interviewee with greater assurance that the research project is credible, and their participation is worthwhile (Galletta & Cross, 2013).

Prior to conducting interviews, I completed the IRB human researcher training for social, behavioral, and educational research through CITI and we obtained IRB human subjects' approval for the project. For the interview component of the project, I reached out to potential interview subjects based on a snowball sampling approach, beginning with gathering initial contacts from project PIs at the USGS. Due to their existing knowledge of natural resource managers and scientists that had experienced challenges in the face of adapting to landscape-scale ecological changes, the USGS project PIs were instrumental in facilitating connections to interested and qualified respondents. Once respondents expressed an interest in participating, I obtained their consent and ensured anonymity of our discussions, through a written agreement via

email correspondence before scheduling interviews with them. I developed a comprehensive interview guide in collaboration with my advisor and our project PIs which included questions divided into three overarching subsections, each of which addressed my three primary research questions (RQs). These included: part one - perceptions on ecological change (RQ1), part two - perceptions on adaptation and management (RQ2), and part three - perceptions on respondents' ability to prepare for and respond to landscape-scale change (RQ3). Staying within the guidelines of a semi-structured interview format, the guide for this project was able to be adapted to better address the vocational, organizational, and personal life experiences of the individual respondent over the course of the interview. The decision to follow a semi-structured interview format allowed the interviews to focus on areas of particular interest, expertise, or concerns of the interviewee and allow the researcher to follow up on interesting and novel ideas and perspectives as they come up in conversation. This interview format allows the interviewee the opportunity to create and contribute new knowledge for the researcher, surrounding the topics they are being questioned on, with the directionality of the interview having the ability to shift in different directions based on the individual's interpretation and insights (Noy, 2008). The finalized interview guide which was used for the 37 interviews completed can be viewed in the appendices (Appendix 1).

III. Interview Participant Selection and Demographics:

Demographics provided by interviewees were recorded in order to understand the range of agencies, vocations, years of experience, and regions in which the

interviewees work. Respondents worked for multiple resource management agencies including the National Park Service (18), U.S. Forest Service (10), and Bureau of Land Management (3); state/local agencies such as Arizona Game and Fish and Coconino County (4), ; and non-government organizations, such as Grand Canyon Trust and The Nature Conservancy (2). To the best of my ability, I aimed to send email requests for interviews from a similar number of individuals from each agency and vocational backgrounds but was somewhat limited in this due to not being well-connected with land management leaders in the region. The uneven distribution of agencies is due to initially identifying interviewees based on discussions with USGS researchers who work with multiple land management agencies. The USGS operates within the U.S. Department of the Interior that collaborates with a large number of staff within the National Park Service, which may account for larger numbers of connections to individuals willing to be interviewed within the National Park Service.

In addition to snowball sampling, I specifically sought interviewees that experienced large-scale stressors such as drought and/or wildfire in the Colorado Plateau region and subsequently sent email requests to individuals working at agencies that I had received fewer responses from in the beginning of the interview process. This approach had limited results, with only two interviews arising from emailing without an established liaison. This was less successful than the snowball sampling approach, as most emails are not publicly available, and it took a great deal of time to get through the general park email contact information to the individual I wished to interview.

Interviewees held a wide range of vocations, including park superintendents, climate planners, senior research coordinators, program managers, resource

specialists, directors, science advisors, recreation specialists, resilience coordinators, fire ecologists, district botanists/ecologists, natural resource managers, restoration specialists, resource program managers, and park rangers. The respondents identified themselves as natural resource managers and/or natural scientists with decision-making and management responsibilities as a part of their regular job duties. The level of experience of respondents ranged from a minimum of one year to over 30 years.

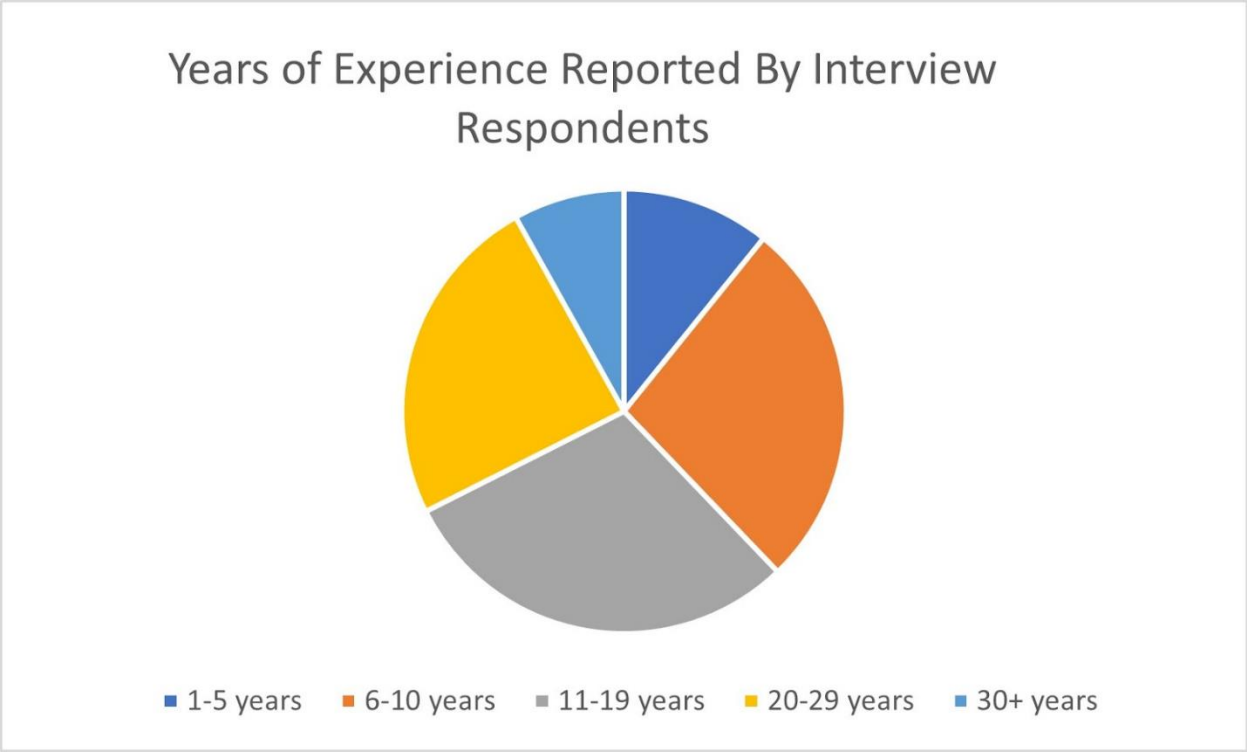

Figure 8.1: Years of Experience as Reported by Respondents

The gender distribution of respondents was nearly even, with 18 males and 19 females. The geographic distribution of employment was across the Four Corners region of the Colorado Plateau, with the majority of respondents currently working in Arizona (21), followed by Colorado (6), Utah (5), and New Mexico (5). This uneven distribution is most likely attributed to the USGS Southwest Biological Center's primary physical location being in Arizona, as well as my physical location at Northern Arizona

University, as it proved easier to make contacts and connections with individuals in closer proximity. The primary focus of interview participant selection was to choose respondents working on the Colorado Plateau who identified themselves as having experienced landscape-scale changes due to ecological stressors, so while demographic factors are important to consider, these were secondary to the primary objective of having qualified interviewees.

The Interview Process:

Between June 2021 and May 2022, I conducted a total of 37 interviews, the majority of which were completed over Zoom instead of in person, due to the pandemic (29), with a small number of participants being interviewed over the phone without the use of video-calling (5) or in person (3). Interviews ranged from 23 minutes at the shortest, to 1 hour and 48 minutes at the longest, with the average being approximately 45 minutes. Interviews were recorded through a digital recorder or through a laptop. During the interview, I took notes in the form of timestamps or key phrases I could refer back to later, choosing this concise approach in order to remain present and focused on the interviewee, which is essential for an effective semi-structured interview. Immediately following the interviews, I documented important points, emergent themes, and novel/previously unheard ideas in a separate document, including timestamps to refer to in subsequent interviews as well as to have a summary of ideas to reference and revisit during the analysis. The creation of such memos following the interviews allow the researcher to quickly understand the themes of the interview and adjust subsequent interview questions as these themes emerge (Fujii, 2018). Each interviewee was assigned a random number, beginning with R1 for anonymity purposes. All memos,

transcriptions, and handwritten notes taken during the interview process did not include personal, identifying information, instead they were kept track of using the random number assigned to them. In order to protect confidentiality, personal, identifying information such as the name of the interviewee, or names mentioned by the interview, were removed from transcripts following each interview.

The transcription of interviews is essential to the qualitative interview process. Transcriptions allow for the development of key takeaways and enhance the researchers understanding of the interview themes by providing documentation to re-read for clarification and to provide greater research accuracy and reliability, as the written transcripts can be analyzed and reviewed by other researchers (Fujii, 2018). For this project, the interviews were transcribed with the use of the Otter software program, which streamlined the transcription process. Otter software, though a useful tool, does not create transcriptions which are free from error, so following inputting the interviews into the software, I read through each transcription, and made revisions to the software's grammar errors and provided clarity as necessary. Once interview recordings were uploaded, the Otter software transcribed the full-length interviews, allowing the interviewer to search through the transcriptions easily for key phrases, allowing the user to assign percentages of specific phrases to document how often certain phrases were used over the course of the interview. For instance, the program shows the frequency with which terms such as adaptation, drought, and wildfire occur with percentages, and allows the user to click the term and refer to it quickly in-text, as well as listen to the interview beginning at that specific timestamp. This provided an easily understood overview of the key themes in each interview, allowing for me to quickly reference key

phrases within the transcription text and better prepare for subsequent interviews. Otter is also a helpful tool for comparison of phrases and themes with the memos I created, verifying that I did not miss any important key points discussed frequently in the interview.

IV. Data Analysis:

Once interviews were fully transcribed and reviewed for errors and additional insights, I began the data analysis process through a process known as coding. The process of coding is crucial to qualitative analysis because it provides methods to identify, organize, analyze, and build and/or expand upon theory (Williams & Moser, 2018). Coding interviews is a qualitative research method that allows the researcher to identify themes and commonalities that arise through a multitude of interviews (Hay, 2021). In qualitative analysis, a code is a word or short, often abbreviated, phrase that is assigned to phrases and passages in interview transcripts, field observation notes, journals, documents, open-ended, or short answer survey responses, academic literature, policy, and more (Saldaña, 2021). Coding allows researchers to quickly analyze and notice commonalities across different interviews, making patterns more easily understood and recognizable (Oakes, 2021). Coding is used to enable themes discussed to become readily apparent, through the use of highlighting passages or lines of an interview (Saldaña, 2021). For the purpose of this project, coding was used to analyze the transcripts of the interviews.

I used Nvivo Pro 11 software (QSR International) for the coding of the 37 interviews. For the coding process, I used a grounded theory approach, which emphasizes inductive reasoning, allowing the researcher to develop additional codes as

novel themes emerge in the analysis (Saldaña, 2021). With a grounded theory approach, the researcher does not begin the analysis with a strict set of preconceived codes that cannot be expanded on, instead, the researcher can create a codebook based on a combination of insights from memos written following the interviews and new themes that arise when close reading and analyzing the interview transcripts (Saldaña, 2021). I coded one interview at a time, referring to my notes that I created immediately following the interviews. I assigned a specific code for phrases and passages that fell under an emergent theme. This is done in Nvivo by highlighting a sentence or short passage and then either assigning an existing code to the relevant passage or creating a new code representative of the response. As I completed the coding process, I created a reference list, also known as a codebook, which provides a short description of each code entails and what qualifies a response to be assigned with that particular code (Appendix 2). The first step of the coding process within a grounded theory approach is called “open coding,” in which the researcher codes each piece of data (for this project, words, phrases, and short passages), with an identifying code and descriptive label which is used for all codes that fit this description (Saldaña, 2021). I repeated this coding process for each of the 37 interviews. When new themes emerged, necessitating the creation of new codes in the interviews during the process, I would make a note of which interview I added new code(s), and later revisited and re-read previous interview transcriptions to code additional relevant data. This revision is an essential part of the coding process within the grounded theory approach (Williams & Moser, 2019). It allows researchers to interpret data in an adaptable way which facilitates theory development, expansion of ideas and meaning making, the creation of

broader themes and reinterpretation of existing ideas as new interview data is analyzed (Williams & Moser, 2019). The extensive breadth of topics covered throughout the interviews necessitated the creation of many distinct codes, and there is no limit to the number of codes a researcher can create, it is dependent on the content of the data (Oakes, 2021).

Once all of the interviews were fully coded and reviewed, I compiled the related codes into categories that addressed my three primary research questions and sub questions, as shown in the category headings (Table 1). This compilation is based on the axial coding process, within the grounded theory approach (Saldaña, 2021). Axial coding involves determining the connections and relationships between distinct codes and assigning “parent codes" that encompass multiple codes within a larger code (Saldaña, 2021). Through axial coding, patterns and related codes within the data become more apparent (Saldaña, 2021). Individual codes were sometimes applied to more than one category, or parent code, and were often applied to multiple groupings in order to analyze not just the individual code, but its relation to other codes (for example, the code “DEGCHANGE,” which represents the interviewee’s characterization of the extent to which drought, wildfire, and climate change have affected the landscape they work on is applicable to multiple relational groups encompassed within the larger “Ecological Change” category). Relational grouping of distinct codes is important to the coding process because it allows for clarity and analysis of coding families (Glaser & Strauss, 1967). A coding family is a set of related sociological concepts, which are organized into groups called “families” in order to provide theoretical frameworks to use in analysis (Glaser & Strauss, 1967). While coding, I developed themes/larger,

overarching categories that encompassed such “families,” based upon frequently used codes representative of themes that emerged which expanded upon my existing codes and/or contributed novel, sometimes unexpected, perspectives and valuable insights. To keep the codes organized and easily analyzed within the parent codes and larger themes, I created the following reference to showcase the coding families (Table 1). Refer to Appendix B for a descriptive key for each individual code.

Ecological Stressors and Change:	**Land Management Response to Ecological Stressors and Change:**	**Implementation of Adaptation Strategies**	**Perspectives Related to Climate Adaptation & Proactive Strategies**
Ecological change: “ECOCHNGE” “ECOSTRESS” “ECOTRANS” “ECOTYPE” “DEGCHANGE” “TYPECON” “COPLATEAU” “UNCERTAIN” **Climate:** “CLIMATE” “IMPTCLIM” “DEGCHANGE” **Wildfire:** “WILDFIRE” “IMPTFIRE” “FIRESUP” “CLIMATE” “HISTCON” “DEGCHANGE” **Climate change:** “IMPTCLIM” “CLIMATE” “UNCERTAIN”” LIMITSCI” “LIMITCLIM” “LIMITAD” “CRITRES” “RESILIENCE” **Drought:** “DROUGHT””IMPTDROU” “DEGCHANGE” “CLIMATE” “HISTCON” **Introduced species:** “INTSPEC” “IMPTINTR” “CLIMATE” “HISTCON” **Additional indicators:** “EXSTRESS,” “HISTCON” “CLIMATE” “IMPTOTHER””IMPTWILD” “CRITRES” **Spatio-temporal:** “SPATIALSC” “TEMPORAL”	**<u>Management/Decision-making</u>** **Resources:** “LIMITRES” “CRITRES” “VULNER” **Staffing:** “LIMITRES” “LIMITGOV” **Leadership and Support:** “LIMITAGNCY” **Government and Policy:** “LIMITAGNCY” “LIMITGOV” **Knowledge-Action Gap:** “KNOWGAP” “LIMITAD” “REFER” “MNGCOMM” “PROJECT” **Uncertainty and Decision-Making:** “MNGDEC” “PREPARE” “PROJECT” “UNCERTAIN” **Public Perception:** “PUBLIC” “MNGCOMM” **Ecological Trauma:** “PSYCH”	**Examples of Implementation of Strategies:** “ADAPT” “RAD” “ASSIST” “INTERPOS” “MANFIRE” “MANINTR” “MANWAT” “MNGDEC” “MNGPOS” “MNGNEG” **Restoration Efforts:** “ADAPT” “CRITRES” “INTERPOS” “INTERNEG” “MANFIRE” “MANINTR” “MANWAT” “MANVEG” “MNGDEC” “MNGPOS” **Successful Adaptive Management Efforts:** “ADAPT” “CRITRES” “INTERPOS” “MANFIRE” “MANINTR” “MANWILD” “MANVEG” “MNGPOS”	**Definition of Adaptation:** “ADAPT” **Understandings of Adaptation:** “ADAPT” “AGENCY” “RESILIENCE” “VULNER” **Proactive Adaptation Strategies:** “INTERPOS” “MNGDEC” “MNGPOS” **Limitations of Adaptive Strategies:** “LIMITAD” “PREPARE” “PROJECT” “INTERPOS” “UNCERTAIN” “INTERNEG” “LIMITCLIM” “MNGNEG” “UNINTEND” “VULNER”

"HISTCON" "CLIMATE" "PROTECT"		**Novel Strategies:** "NOVEL" "REFER" "INTERPOS" "INTERNEG" "MNGDEC" **Specific Advice for Managers who Have Yet to Experience Large Scale Changes:** "ADVICE""AGENCY" "ASSIST" "INTERPOS" "INTERNEG" "LIMITAD" "MANFIRE" "MANWAT" "MNGDEC" "MNGPOS" "PREPARE" "UNINTEND"	
Needs to Support Effective Adaptation:			
Necessity for Effective Science Communication: "REFER" "MNGCOMM" **Necessity for Increased Resources and Support:** "LIMITRES" "NEEDRES" "NEEDLEAD" "NEEDSCI" **Necessity for Increased Collaborative Efforts:** "COLLAB" "AGENCY" "NEEDLEAD"	**Other:** "QUOTES" *I used this code to keep track of important quotes that support key themes, this code would be included in many of the previous categories		

Table 3.1: The table shows the codes drawn upon to inform the survey and these results are discussed in detail in Chapter 4.

V. Survey Design:

Based on key takeaways and emergent themes explored in the interviews with respondents that had experienced large-scale changes on their landscapes, I developed a set of 36 survey questions intended for a larger group of respondents. The surveys were based on similar topics and questions from the semi-structured interview guide, as well as themes that emerged through the interview coding process. The survey was designed to take approximately 10-15 minutes. The survey consisted of a variety of qualitative and quantitative questions, aiming to obtain perspectives related to climate adaptation, management, and ecological change. The format for qualitative questions included open-ended, fill-in-the-blank questions. This style of questioning was used when it was important to get the most distinctive insights possible, such as when asking the individual's personal definition of adaptation in the context of their work, to explain specific adaptive actions they had implemented on the ground, and to address information and resource needs in order to better prepare, respond, and adapt to ecological change. These are questions that would be difficult to be characterized in a multiple choice, generalized set of possible answers, therefore it was important to include open-ended questions when seeking to understand diverse perspectives that are not easily categorized. The quantitative questions included a combination of close-ended (yes or no) questions, select-all-that-apply questions, ranked choice questions, and 3-point, 5-point, and 11-point Likert-scale questions. The distribution of question types was as follows, from greatest to least: seven five-point Likert-scale questions, six close-ended questions, six qualitative short answer questions, five 3-point Likert scale questions, two general multiple-choice questions, four 11-point Likert scale questions,

four short fill in the blank questions, one ranked choice question and one select-all-that-apply question. This mixed variety of question types allowed for a more in-depth analysis that utilized both qualitative and quantitative methods, as well as changing formats of question type increasing participants' interest in the survey (Saleh & Bista, 2017). The survey was designed and implemented within the Qualtrics program used and hosted by the NAU server. Qualtrics allows users to create and host surveys, as well as track responses, easily download and data for descriptive and statistical analysis in other programs.

VI. Survey Participant Selection & Implementation:

In contrast to the interview selection process, survey respondents may not have experienced large-scale ecological changes on the landscapes in which they work. Instead, I targeted survey participants from a larger network of natural resource managers and those in related professions and fields across the Southwestern U.S. in order to examine how those in the field of natural resource management respond to questions developed from the original interview guide and key takeaways and novel themes that arose from interviews, specifically around their perceptions of adaptation. Having experienced large-scale landscape change was not a requirement to qualify for the survey, but participants that had experienced large-scale changes also completed the survey. The survey qualifications were only that participants were natural resource managers or had positions in which they carry out management duties with decision-making abilities and were located in the Southwestern U.S. region. The decision for the expansion of the region from the Colorado Plateau for the interviews to the larger U.S. Southwest was due to the desire to understand the challenges surrounding the spatio-

temporal scale of ecological changes identified by interview respondents, as well as to gain a better sense of how managers across a larger region have experienced climate, drought, and/or wildfire induced changes. After reviewing the results and key themes from the interviews, it was determined that it would be important to get a stronger sense of how adaptation is being understood and what actions are being implemented, or what is limiting adaptive action, across a wider region. Since the ideal participants for this survey are from a highly specialized network of individuals, both in terms of vocation and regional location, it became apparent that broadening the pool of respondents would be necessary. This was the case because over the course of the interviews, perspectives beyond what the small sample size of interviews allowed, would allow for better understanding of adaptation and related perceptions. Thus, the best approach to target participants strategically to gain those qualified to respond was through the use of organizational listservs, newsletters, and internal networks, including Southwest Climate Adaptation Science Center, USGS, Southwest Fire Science Consortium, and Arizona Game and Fish Department, all of which focus on the Southwest more broadly than the Colorado Plateau region alone. This provided the opportunity to draw spatially focused comparisons between the interview results and the survey results, such as whether or not the challenges which were identified on a smaller spatial scale were echoed more broadly throughout the larger region. In order to encourage participation I used strategies which were proven effective in maximizing responses by Saleh & Bista (2017), including ensuring the confidential nature of the survey in the introduction, targeting individuals that would be the most interested in providing responses to the content of the survey through organization supported outreach, offering explanations of

how the data will be used and providing a space for interested participants to receive a summary of the results, and sending two reminders (but no more than three) to encourage participation. The survey questions were reviewed, revised for greater clarity, and approved by my advisor, committee members, and project PIs before distribution to participants, as it is suggested that review by experts and individuals who themselves would be qualified to take the survey, is helpful in maximizing responses from participants (Saleh & Bista, 2017). The survey was distributed through newsletters, listservs, and internal networks, opening in early April 2022 and closing in October 2022. As suggested by Saleh & Bista (2017), the wide range of time that the survey was open was to account for the time constraints of the targeted participants during the summer, due to the demands of a busy fire season, which keep participants away from their offices and emails. Two hundred and fourteen individuals opened the survey, one hundred and eighty-six submitted the survey, and of those one hundred and eighty-six, one hundred and fifty-three participants had their surveys counted in the dataset following the screening process. Individuals who opened the survey, browsed the questions, and submitted a blank response (no questions answered) were removed from the data set immediately. The next step was removal of any participants who did not qualify to take the survey based on the region they identified, with 33 total surveys excluded from the dataset.

The valid survey completion rate following the data screening process was 71.5% (153 out of 214 opened surveys). A survey completion rate differs from a response rate because the completion rate is calculated based on the ratio of individuals who viewed the survey versus the number of individuals who actually

completed the survey, while the response rate is the ratio between the number of completed surveys from the total number of surveys distributed (Schutt, 2019). The number of responses to each survey question varied, due to the fact that not every question was relevant to the vocational experiences of the individual survey participant. The number of survey responses completed may be attributed to the interest in participants who fulfilled specific qualifications and/or the sensitive nature of many of the survey questions, which asked individuals to speak candidly about their agency, in which their personal views may not always coincide, and could conflict with the views of their employers.

VII. Survey Data Screening and Analysis:

Once the survey was closed in late October 2022, I began the process of survey data analysis, starting with data screening and data cleaning. Data screening is the process of reviewing survey data for inconsistencies, incompleteness, and inaccurate responses and data cleaning involves correcting, editing, or deleting incomplete responses in order to provide more accurate results, in terms of uniformity and proper formatting for analysis (Schutt, 2019). Managing data is an important technique in social science research methods because it establishes greater accuracy and trustworthiness of results and creates a more rigorous process of analysis (Desimone et al., 2015). A consistent limitation of survey data is that researchers cannot directly observe the participant taking the survey to ensure that they are paying attention to the survey questions and putting effort into responses (Schutt, 2014). I followed the screening methods of archival techniques for screening survey data prior to analysis. Archival screening involves reviewing answers, looking for patterns and inconsistencies in

responses survey participants through examination of response time, semantic synonyms/antonyms, and long string or invariant responses following the closure of the survey (Desimone et al., 2015). Qualtrics automatically stored data on the survey participants' response times and I reviewed these, eliminating "completed" survey responses that took under 5 minutes. This was based on the average completion time being 21 minutes total, and the unlikelihood that survey participants are able to answer individual questions faster than 2 seconds per question (Huang et al., 2012) guaranteeing responses under 2 minutes as inaccurate for a survey with 36 questions. The 21-minute total average time also included several outliers that took excessively lengthy amounts of time to finish (over 4.5 hours at the longest), suggesting that the survey may have been left open on the computer and completed slowly or revisited over time. Setting under 5 minutes as a guideline, accounted for questions that involve rearranging statements and choosing from descriptive word lists, and short answer questions taking longer (completing four short answer questions, even at 30 seconds each would account for 2 minutes of time). I also examined semantic antonyms, in which participants select contradictory statements, through the analysis of responses to the descriptive question on how they view their organization's response to stressors (Figure 3.2), looking for contradictory choices in the responses, such as choosing both "adequate" and "inadequate." However, semantic antonyms were not present in any of the results, indicating that the participants were reading through the answer selections carefully when contradictory statements were present and available for selection. The final data screening method I employed was examining the results for invariant responding, which is when the same option is selected repeatedly, with the standard

being a minimum of 6 responses in a row being identical as indicative of invariant responses (Huang et al., 2012). Based on the fact that incomplete responses reflect lack of effort and investment in the survey, these responses were considered "unfinished questionnaires" and excluded from the data set (Schutt, 2019). The majority of the excluded responses were from individuals who submitted a blank survey with no data (18 of 33 total of exclusions were for this reason), followed by excessively short response times suggesting inaccurate, incomplete, or careless responses, all of which had completed less than 20% of the survey questions (7 of the 33) besides one participant which completed nearly all of the survey, but had consistently marked "1" (the first choice on multiple choice questions) or wrote in "NA" on short answers. Eight additional participants were excluded for not meeting the basic qualifications of the survey, either due to stating themselves they had lack of any relevant vocational experience, no experience in management and/or science, or due to stating they are employed outside of the Southwestern U.S. and no indication that they had ever worked in the Southwest.

Through Qualtrics, the survey was set up to provide an anonymous link which participants clicked to gain access to the survey. According to IRB protocol, I increased the security of the participants' anonymous responses by enabling two-factor authentication for administrative login and enabling account lockout in the case of too many failed attempts to login to the administrative account. Qualtrics automatically uses Transport Layer Security (TLS) encryption for all data transmitted over the program. Additionally, the Qualtrics setting "Prevent Multiple Submissions" was turned on, which prevents participants from taking the survey twice, by placing a cookie on the

participants' browser that Qualtrics would recognize and disallow the participant from retaking the survey.

One final aspect of the data cleaning process was to create uniformity and consistent formatting of results in order to complete an accurate analysis. To do this, I reformatted demographic information from short answer format to numerical data for comparison. For example, one question asks the participant's agency of employment, which was valuable data to have for a comparative analysis between agencies, so I assigned each agency a number 1-9, as well as the corresponding abbreviated text (NPS, BLM, USFS, etc.). One limitation for the comparison between agencies was that 47 participants (31% of the total) did not provide their agency affiliation, leaving this question blank. After coding the provided demographic data, I exported the data and began my analysis in the IBM SPSS statistical program.

I obtained a preliminary understanding of overall patterns, trends, and perspectives of the survey participants through creating visualizations and reviewing the results of each of the 36 survey questions. For the quantitative survey questions, I used the "frequencies" tool in SPSS, allowing me to gain insights on frequencies of response counts, average mean, standard deviation, and percentages (descriptive statistics) for each question. I also examined the chi-square and correlations (inferential statistics) for each data set through the SPSS cross tabulations tool. Standard deviation is important to examine because it measures the variability surrounding the mean, with low standard deviations showing that responses are clustered around the mean (average) and high deviations showing that data is more spread out, implying that responses have a higher degree of variability, and responses were more widespread across participants (Schutt,

2019). A frequency distribution generated in SPSS provides a broad overview and visual representation of the data (Kulas et al., 2021). I primarily created bar-graph visualizations through a combination of both Excel and Qualtrics. Bar graphs were used in order to represent the findings and communicate them efficiently, clearly, and concisely to a wide audience. Bar graphs were chosen as they are one of the most frequently used data visualizations and have been shown to improve the retention and comprehension of information for an audience (Kulas et al., 2021). Next, I analyzed the quantitative data through the cross tabulations tool in SPSS, which allowed me to conduct chi-square tests in order to determine if there is a relationship between two variables or if the difference existing between variables is due to chance (Schutt, 2019). Chi-square tests are statistical tools which analyze the relationship between expected and observed values, as well as analyzing differences between variables and determining if their relationship is related or independent (Kulas et al., 2021). I conducted chi-square tests on all of the questions in relation to the variables of agency affiliation, in order to determine whether agency affiliations had an influence over individual perspectives. The results of the chi-square tests had limitations because multiple participants opted out of answering the demographic questions. Through chi-square testing, I determined statistically significant relationships between the variables of several questions.

For the qualitative survey questions, I analyzed each response to the short answer question individually, placing it within a set of categories, based on qualifying factors for inclusion (Please see Table 4.1 in Chapter 5). For an example of an outline of participants' short answer responses and their categorizations for a qualitative survey

question, refer to Appendix D. From this outline, I condensed the short answer responses in each category into concise and specific examples, through a similar process to coding interview responses. This time, I evaluated each individual response, determining where that within a set of established categories, based upon criteria I created for each category. For example, when evaluating how managers defined adaptation in the context of the work they do, I established categories including adaptation (general), adaptation (specific), adaptation (comprehensive), and not adaptation (table 5.1). Following this analysis and creation of an outline, I created a table which includes descriptions of the categories based on the IPCC (2015) definition of climate adaptation, and specific examples of adaptation as provided by the IPCC, as well as percentages of total responses for quick reference and comparative efforts. I used this same method of analysis for table 4.1, table 4.2, and table 6.1., with categorizations relevant to the responses to the questions.

CHAPTER FOUR

INTERVIEW RESULTS

This section shares the results from semi-structured interviews conducted with 37 respondents from federal and state agencies across the Colorado Plateau between May 2021 and November 2022. Interviewees came from a wide range of vocations, all identifying as natural resource managers and/or natural scientists with decision-making responsibilities as part of their job duties. Respondents' level of experience ranged from a minimum of one year to over 30 years. The majority of respondents had 11-19 years of experience (11), followed by 6-10 years (10), 20-29 years (9), and 1-5 years (4) and 30+ years (3) of experience (Table 1.3). Respondents worked for multiple agencies including the National Park Service (18), U.S. Forest Service (10), Bureau of Land Management (3), state agencies such as Arizona Game and Fish (2), county agencies (2), and non-government organizations (2) (Table 1.1). It is notable that it was difficult to find Bureau of Land Management (BLM) employees through the snowball sampling approach that were responsive, available, and willing to be interviewed for this project. This may have been influenced by the BLM undergoing a reorganization and attrition process during the time of the interviews. National Park Service (NPS) and U.S. Forest Service (USFS) employees tended to recommend interviewees from each other's agency, when asked for contacts outside of their agency, which may suggest greater collaborative efforts and communications between these agencies in this region. The geographic distribution of employment was across the four corners region of the Colorado Plateau, with 21 respondents currently working in Arizona, 6 in Colorado, 5 in

Utah, and 5 in New Mexico (Table 1.2). The findings from these interviews will be analyzed and explored further in subsequent discussion chapters.

In this chapter, the key takeaways and themes that emerged from interviews are explored in the following subsections: stressors, ecosystem responses, management strategies and decision-making under drought and wildfire, primary barriers to responding to climate and ecological change, perspectives related to climate adaptation and proactive strategies, and facilitation and implementation of adaptive actions. Within these six subsections, I will cover the primary themes that emerged over the course of the interviews.

I. Stressors:

The primary ecological stressors that were in the interview guide and noted by respondents were drought and wildfire, both of which were discussed as worsening in both intensity and frequency due to climate change. The majority of respondents focused on drought as the stressor of greatest concern, with wildfire also being a major concern, but was discussed less frequently than drought-related stressors.

Climate:

Respondents across agencies and vocations agreed that anthropogenic climate change is leading to increased ecological stress across the lands they manage. It was unanimous among respondents that climate change is occurring and impacting the ecosystems on the lands where they work. There were no respondents that felt skeptical about climate change. The main differing points of discussion were related to

how respondents felt that climate change should be addressed and managed for, which will be addressed in later sections. Respondents also diverged in their perspectives related to how significantly climate change is impacting their landscapes, specific systems in particular, but it was unanimous that climate change is leading to an intensification of other stressors.

> **"I mean, the whole Southwest is going to be dealing with climate related issues. We're dealing with it now. I manage such a small park and it has been such a canary in the coal mine kind of situation. We're all in the same boat." - Resource Management Technician, National Park Service (R5)**

Changes in precipitation, both in severity and frequency in some regions, but decreases in other regions, are one of the main indicators of climate change (EPA, 2022), and was noticed widely by respondents. Increases in seasonal precipitation variation will lead to wet seasons becoming more wet, and dry seasons becoming drier (Konapala et al., 2020). A respondent with over 30 years' experience managing the same NPS park unit, noted that there has been increased variability in the monsoon season, and when they occur, the monsoon rains have become more "powerful" and "dramatic" over the past several years, and the amount of rain increased substantially (R30).

Climate change related drought conditions were a common area of focus for respondents, particularly concerns about the future of systems dealing with drought-induced vegetation losses and vegetation changes were a main topic of discussion. Increases in evaporation, caused by rising temperatures, will lead to less water retained by the soil, increasing soil moisture deficits and worsening drought conditions. Respondents discussed their concerns related to the noticeable decrease in snowpack and impacts that sublimation has had, and will continue to have, on their landscapes. A

NPS manager working in the same park for two decades observed that “there would be snow and ice patches all the way into May when I got here 20 years ago, now we hardly ever have snow after March” (R26). Other similar statements from respondents highlighted concerns related to declining snowpack: “I have definitely noticed that the snowpack has declined, it’s gone earlier in the year every winter” (R27). Respondents shared similar experiences in noticing snowpack decline, attributing it to increased sublimation. This included one NPS employee with a background working in hydrology, who mentioned that “snow doesn’t melt to water any longer, it just evaporates” (R4).

In the Southwest, a trend of warmer temperatures and drier conditions is expected to continue (Thoma et al., 2018). Broader questions posed to respondents about climate change often evoked concerns related to water shortages and drought conditions. An NPS superintendent felt that while historic fire suppression has contributed to increased wildfire severity in the West, climate change was the “dominant” cause for worsening wildfires, stating that “the reality is, it’s getting warmer, it's getting drier” (R28).

Drought:

Concerns related to drought and impacts stemming from drought conditions were mentioned by every respondent in the interviews. Respondents pointed out that decline in precipitation, water levels, and snowpack have led to major ecological change across the Colorado Plateau and Southwest. Respondents discussed their concerns related to how the monsoon rains, an important occurrence on the Colorado Plateau, have become more variable, with recent years experiencing nearly zero summer monsoons (R4, R5, R7, R10, R13, R18, R23, R31).

Respondents discussed the noticeable changes in water levels across the regions where they work. A BLM ecologist discussed how ranchers on public lands have experienced firsthand how significantly the water table has dropped over the past 60 years, noting that, “these wells are a fraction of what they used to be, it used to be that eight months out of the year you could have running water, now it has gone down to three months” (R19). This BLM employee felt that drought had the most measurable impacts across the landscape, noticing a major decline in precipitation patterns on the Arizona Strip. A restoration and vegetation specialist for the National Park Service discussed how species that were once considered drought-tolerant species, such as juniper, are dying off more rapidly than anticipated (R23). A park superintendent experiences a large-scale die-off of juniper that he attributed to drought conditions stating that “it takes a lot to kill a juniper. It wasn’t bugs, it was moisture.” (R28). Another superintendent found that the most obvious drought-related impacts in his park unit were vegetation changes on the landscape, in particular, the pinyon die-off (R30). While other ecological stressors were viewed as important by respondents, the discussion was primarily focused on water resources and drought impacts.

> **“I can be more proactive with fire. When it comes to drought, there's just not much you can do to be proactive. I mean, you can be proactive in a sense of trying to keep the ecosystem healthy before a drought, but there's just not much in your control when it comes to drought.” - Monument Manager, Bureau of Land Management (R35)**

Multiple respondents across all agencies expressed concern for the ability for systems to be able to adapt under current and projected drought conditions.

> **“Aquatic systems are getting hammered the most immediately, right now. Less snow on the mountain, less water in the reservoir, less releases from the reservoir into the streams and creeks and rivers. So right now, that's very obvious. We now have five river miles of a river in our park, but it**

doesn't even flow all the way through our park every year anymore." - Chief of Natural Resources, National Park Service

In addition to concerns for riparian habitats, vegetation changes in other ecosystems were also noted. A manager working for the U.S. Forest Service described a shift in forest ecosystems towards grasslands, which she attributed to decline in moisture, particularly snowpack (R27). Another respondent, a wildlife biologist from the USFS, noticed that many of the wetlands have dried up and this has impacted marsh bird populations (R24).

"The vegetation is dried up and largely dormant as a drought response and not supple and not edible. So their forage and their browse is all stressed out at lower elevation. So we used to always see them there, starting around June and July when the rainy season came in, but now they're up there as early as March or April. They're overwintering because there's not enough snow to drive them down to lower elevation anymore. The pronghorn have just dwindled and dwindled and dwindled almost to the point of disappearing from the grassland habitat. It seems like they are going to abandon the lower elevations" - Chief of Science and Resource Management, National Park Service (R6)

Along with amphibian species and the pronghorn antelope, respondents expressed concern for species such as the Mexican spotted owl, which is threatened in the Colorado Plateau region. Respondents have noticed shifts in behavior and distribution of common species, such as elk and deer.

Wildfire:

A common theme of discussion in the interviews was that wildfire is increasing in both severity and frequency. Respondents were unanimous in the view that wildfire is natural and necessary for ecosystems to function. A majority of respondents had a strong understanding of how the increase in high-severity wildfires is related to a

combination of ecological stressors and human interference with the historic fire regime through suppression.

Responses related to synergistic impacts of multiple stressors were common when discussing wildfire with interviewees. Discussions related to wildfire often came back to growing concerns about drought conditions and type conversions. Multiple respondents experienced wildfires on the lands they managed and expressed how the ecosystems did not recover to previous conditions. Although fire is natural and necessary in an ecosystem, the frequency and severity of fires, and the ability for landscapes to recover, was the main concern for respondents. A natural resource manager for the NPS described how the pinyon-juniper woodlands are not recovering following five large fires in their park over the past two decades, despite restoration efforts taking place (R2).

> **"Wildfires are not a surprise, I think what has been surprising is the frequency and the intensity has changed, I think that has surprised me and the realization that these systems may not succeed back to their later seral stages."**
> **- District Ecologist, U.S. Forest Service (former NPS employee)**

Though historic conditions show that large fires are often a natural and necessary ecological force on the landscape, one National Park Service manager with over a decade of experience managing the same park unit, expressed concerns that the fires occurring in this region are becoming more intense, burning hotter, and larger than the entire succession of fire history on that landscape (R28). A district wildlife biologist for the USFS felt that it has been noticeably harder for the land to recover following wildfires (R24). An NPS fire archaeologist and resource advisor (READ) with over two decades of experience noticed that fires burn more consistently through the pinyon-

juniper woodland than it did 15-20 years ago, where the pinyon-juniper used to act as an effective barrier to slow fire (R34).

Numerous respondents noted that private entities such as utility companies have played a role in the wildfire landscapes across public lands on the Colorado Plateau. A National Park Service superintendent who experienced a devastating wildfire on the landscape he managed noted that electric companies failed to update their infrastructure, leading to the fire (R30). This has been the cause of several major wildfires in the Western U.S in past decades, leading to concerns about mismanagement and negligence of industries.

> **"If we would bury the powerlines it would completely eliminate that threat. The problem is it costs over a million dollars a mile to bury. If you look at the expense of doing that versus what that fire cost us, the fire cost us millions of dollars. And that time and time again, powerlines are the culprit that started the fire." - Superintendent, National Park Service (R28)**

Many respondents noted the importance of understanding that the increased frequency and severity of wildfires in the West are a result of a combination of ecological stressors and human activity. Respondents noted several factors, including a century of land management agencies promoting fire suppression tactics, increased residential development of the WUI (wildland-urban interface) bordering public lands leading to increased human activity, and mismanagement of infrastructure, leading to powerline-caused fires (R28).

> **"The majority of the fires that we experienced out here have been human caused, and that's something that could have been stopped ultimately, if people were considering their actions a little bit more" - Fire Ecologist, U.S. Forest Service (R3)**

Synergistic Impacts of Stressors:

While respondents responded to questions related to stressors more generally, respondents tended to focus the discussion on the many synergistic effects of stressors. Multiple respondents noted that synergistic effects are coming into play to create a combination of worsening ecological conditions and management challenges. Respondents recognized the primary synergistic influences of climate-induced ecological stressors as drought, wildfire, and introduced species as areas of main concern. Ecological stressors combining and influencing one another, leading to intensification of ecological changes, was a common theme across interviews.

In one example, several respondents from the same National Park Service unit stated that multiple factors including declining snowpack, increased and prolonged drought conditions, as well as introduced species such as tamarisk and wild horses, have contributed to the decline of riparian ecosystems in their park. A USFS natural resource specialist pointed out the concerning synergies of pine beetles and drought conditions leading to woodland die-off, drought and warming temperatures, leading to shifts in fire regimes (R26). A USFS fire ecologist found that large fires today are a result of such synergies including more intense and longer La Niñas, a century of fire suppression practices, and increased drought stress (R23).

> **“It's synergistic, overall everything's coming together culminating and creating these really challenging, really dynamic fires that we're not used to and weren’t anticipated.” - Fire Ecologist, U.S. Forest Service (R23)**

A NPS Chief of Natural Resources found that a combination of increasing variability, specifically decline of precipitation, has made it more difficult for managers to predict conditions and has led to some restoration efforts being less successful (R2). A

BLM manager mentioned that the main synergy she has noticed is the combination of drought and bark beetles leading to the increased stress of tree species, which increased fuel loads due to dead and dry trees, increasing the intensity of wildfire on the landscape (R19). Many respondents noted a noticeable change in the greater amounts of post-wildfire tree mortality that is the range of natural variability. A plant ecologist working for the state determined that most of the listed rare plants and animals in the state of Arizona are greatly threatened by both drought and wildfire (R37). A frequent topic of discussion mentioned by nearly all of the respondents was how multiple ecological stressors, particularly climate change, drought, and wildfire, have combined in various ways to create positive feedback loops and worsening impacts.

Other Indicators - Introduced Species:

A vegetation specialist working for NPS responded that altering the fire regime has created a “downward spiral” of ecological impacts because introduced species such as annual invasive grasses “seem to thrive off of disturbance and fire” and management should attempt to break that cycle (R17). The same respondent felt that increases in introduced species can be attributed to construction and development, both for new park infrastructure such as campgrounds due to increases in visitors bringing new species with them on their outdoor equipment (R17).

Introduced species of concern noted by many respondents include cheatgrass and tamarisk, both of which contribute to increased wildfire threats. Several respondents mentioned that one of the main problems with introduced species is that they have the tendency to outcompete native species, which transforms “a landscape filled with heterogeneity to a landscape filled with homogeneity” (R2).

“So the tamarisk had grown for years and years and years, which is an invasive species, this tamarisk beetle was released. And within 20 years, we've seen a huge die off of vegetation along the edges of the river through the park. And tamarisk has become the only shade down there. So now we've got to get rid of the dead tamarisk from the beetles, because that becomes a fire hazard.” - Lead Research Coordinator, National Park Service (R16)

Introduced species were often viewed as stifling biodiversity and creating a significant increase in wildfire and drought related challenges. A plant ecologist with the USFWS identified the biggest changes in the landscape being the invasion of introduced grasses that thrive in drought and expand following fire (R37).

A concern from several respondents, particularly those working for the National Park Service and Bureau of Land Management is the destruction of riparian habitat and loss of natural springs attributed to the presence of wild horses. Zero respondents working for the U.S. Forest Service did not mention wild horses as a species of concern.

Other Indicators - Human Impacts:

Visitor numbers that current park infrastructure is unequipped to handle, in combination with increased pressures on ecosystems due to a changing climate, has led to challenges beyond drought, wildfire, and introduced species. Several respondents, including a vegetation specialist for the National Park Service, voiced concerns related to the increase in park visitation leading to greater ecological stress, citing that warmer temperatures and more moderate climates than in the past have increased park visitation levels, which can lead to increased crowding and environmental impacts, especially in parks with fragile biological soil crusts (R17). A park superintendent for the NPS felt that visitation increases were largely due to social

media and the COVID pandemic and that these have led to difficulties in the park, from overflowing parking lots, traffic, and trail crowding to visitors creating their own trails and trammeling fragile ecosystems (R21).

A respondent working at Zion National Park, one of the most heavily visited park units in the U.S. (NPS, 2021), felt that climate change is leading to increased visitation due to warmer, more temperate conditions, in not only Zion, but in many park units that are already facing management challenges related to visitation (R17). Respondents who discussed climate change and visitation noted that once a certain temperature threshold is crossed, visitation will decrease, but currently as temperature increases, risks to visitor safety also increases as more health incidents related to heat stress have been noticed.

Several park officials from USFS, NPS, and BLM argued that large increases of people moving into forested ecosystems near public lands and in the WUI (wildland-urban interface), including in high-hazard regions, has led to additional challenges. One USFS biologist felt that the increase in population in the WUI was less of a concern than the loss of water resources due to agricultural growth near public lands, which has "transformed the landscapes surrounding managed natural areas" (R8).

II. Ecosystem Response:

Ecosystem Stress and Transformation:

Every respondent indicated experiencing ecological transformation on the landscapes they work, due to drought, wildfire, or a combination of both influences, along with climate-induced changes to the landscape. Respondents also reported that

introduced species and human-related factors play a role in ecological stressors. Also, the majority of respondents viewed stressors as impacting all of the ecosystems on the lands they manage, but to varying degrees. A natural resource manager for the National Park Service felt that it was important to address that certain systems and species are more vulnerable to ecosystem stressors and are going to change very quickly in comparison to other systems, meaning that the impacts of stressors will be more noticeable in these ecosystems (R8). Another respondent mentioned that systems which were previously thought of as “resilient” and “adaptable” have experienced noticeable stress and suggested that these systems may be becoming less “adaptable” due to increased stress (R26). Respondents echoed similar perspectives when discussing how many systems and species are failing to recover or had started to recover at a slower pace following a disturbance such as wildfire, when previously these systems and species tended to recover faster.

Worsening wildfires across the region were attributed to human causes, in addition to ecological ones such as drought, including increased development in the WUI, mismanagement of power lines, and increased visitation to public lands have led to greater numbers of human-caused fires. Drought was discussed by more respondents as a primary driver of ecological change than wildfire, primarily because drought impacts had been more widespread and noticeable on landscapes that have yet to experience a high-severity wildfire. 15 of the 37 respondents had personally experienced the impacts of large-scale, high-severity wildfires on the lands they work. Wildfire was viewed as a primary stressor that contributes to rapid ecological transformation on landscapes.

“This human caused fire ended up burning [nearly all] of the park’s landscape, which was really intense to see” - Restoration Specialist, National Park Service (R7)

“We're looking at this drastic change that's occurring, we can see how the system doesn't bounce back from even minor fires, trees that used to survive a little bit of heat, now they just die completely. In the trees, abilities to resprout after fire events have definitely diminished in the past 10 years.” - Fire Archaeologist, National Park Service (R33)

The rest of the respondents attributed the changes they are noticing on the landscapes they work to drought conditions, with several mentioning the combined impacts of introduced species, such as cheatgrass, red brome, and tamarisk, and drought as the major contributors to observed changes. Climate related stressors were associated with exacerbating existing drought conditions, with respondents noting warmer temperatures, changes in precipitation patterns, and declining snowpack on their landscape. Following disturbances, particularly wildfire, respondents noticed that the ecosystems are struggling to recover. There were no respondents that felt that ecosystems are recovering post-disturbance as expected.

While ecological stressors may be noticed across systems that are more vulnerable and less resilient, “that transformation is massive as the magnitude is high,” yet other systems may be more resilient to stressors so the changes caused by ecological stressors may be less noticeable as these systems have a higher range of variability that they can tolerate (R8). This does not mean that the stressors are not impacting the landscape, but that the changes are taking place more slowly.

A common theme among respondents that have experienced large-scale ecosystem change on the lands they manage is that certain systems will be able to be more resilient and adaptable than others, but only to a certain threshold. There were no

respondents that felt that continued ecosystem stress would have a minimal impact on the lands they work.

> **“There's no doubt there will be transformation. If you want to put in terms of winners and losers, there'll be certain species and ecosystems that gain and then certain systems and species that lose.” - District Ecologist, U.S. Forest Service**

> **“Many commercial species may fall, ponderosa is not going to be in northern Arizona in 100 years, the models show that ponderosa is already leaving lower latitudes here - Silviculturist, USFS (R1)**

> **“The way the ecosystems adjust to dealing with extremes is something that we're starting to see in our data. The level of variability and how that impacts native plants and animals is kind of unbelievable.” - Program Manager, National Park Service (R4)**

Additional examples of ecological transformation were focused on type conversion of ecosystems, with 26 respondents mentioning examples of type conversion occurring on their landscape or in the Colorado Plateau region. Respondents discussed models and projections of increasing vegetation type conversion, with drought and wildfire being noted as the primary stressors for these changes (R1, R2, R3, R9, R11, R12, R16, R24, R25, R31, R33, R34, R36, R37). Increased tree mortality and vegetation die-off have been observed by respondents.

While some respondents felt that the magnitude of changes would be larger and more abrupt than other respondents, especially related to how soon we can expect to see transitions of species like ponderosa, pinyon, and juniper, there were no respondents that felt existing species and landscapes will be largely unaffected. Multiple respondents discussed experiences dealing with pinyon-juniper woodlands not re-establishing in the years following wildfire. One respondent working as a vegetation specialist for the NPS, noted that a fire in 2015 burned a significant area of pinyon-

juniper woodlands, and as of 2022, the pinyon-juniper is not recovering in the burned area, instead he found that they are establishing in higher elevations (R17). The rapid pinyon-juniper woodland and ponderosa pine die-off due to drought and warming temperatures commonly came up as a point of concern from respondents across agencies, vocations, and regions. While respondents were also concerned about wildfire and climate change related stressors, drought and drought impacts were consistently found to be the most pressing concerns of the participants, as they arose the most frequently in the interviews.

Sixteen respondents discussed the rapid pace of pinyon-juniper die-off in the region as an area of major concern, and discussed how the pinyon-juniper die-offs have been taking place more abruptly over the past two decades. Riparian ecosystems were also addressed as being vulnerable to drought-stress, with respondents observing water resources drying up faster than projected (R2, R4, R10, R11, R13, R24, R27). Drought conditions on the Colorado Plateau are understood to be widespread and severe by respondents. Respondents reported that drought has led to increasing loss of biodiversity on the lands they manage, and key concerns were related to specific ecosystem types and the uncertainty regarding managing for changing conditions. Declining reservoir levels such as Lake Powell and water levels of the Colorado River were mentioned as areas of major concern. One respondent, an NPS monument manager, discussed how the springs were at 20% of their historic levels since they began being monitored in the 1970s (R5). In a later chapter, I will present a case study of a river that is projected to completely disappear from a national park despite significant efforts to preserve the riparian ecosystem.

Multiple respondents across regions have noticed declines in wildlife populations that they attribute to drought conditions more than other stressors. A respondent found that reports in the 1990s showed salamanders as very common in many regions throughout the park landscape and in many seasons, whereas now sightings of salamanders are only found in one small area of the park in the summer, “sometimes” because “our springs are drying up, the river’s drying up” (R2). Respondents also noted declines in mammal populations, related to drought. The pronghorn antelope was noted as being particularly sensitive to changes in vegetation due to drought and may be an indicator for other species experiencing similar challenges.

When respondents were asked to rank the degree of ecological stress they have noticed on the landscapes they work on a scale of 1-10 with 1 being no change and 10 being severe transformation, they replied with a minimum of 5, with the majority of responses being in the 7-8 range. Respondents expressed feelings of uncertainty surrounding the extent to which ecological stressors will continue to impact the lands and regions they work in. The large-scale ecosystem transformations experienced by respondents led them to feel that there are limits to the ability to prepare and respond to changes, which will be discussed in later sections. However, despite an overall consensus that ecological stress is occurring and will continue to pose challenges, multiple respondents felt that the extent and magnitude of ecosystem stress occurring on a landscape may be an area in which greater resilience can be created by managers and scientists.

Spatio-temporal Scale of Changes:

A common concern identified by 21 respondents was that of implementing effective management efforts in relation to the spatio-temporal scale of landscape changes. Managers of relatively small park units, in comparison to respondents of larger park units, often felt that their efforts were constrained by the small spatial scale of their landscape. Respondents working on smaller public lands felt limited in what proactive choices they could make and expressed feelings of discouragement, describing how decisions made outside of park boundaries, including other agencies or private landholders, impacted their landscape and they had little power over decisions (R5, R21, R30, R37). Managers discussed the limitations of adaptation efforts across a small landscape, but recognized the opportunity that increased collaboration could provide for expanding the amount of impact their efforts could have. These respondents cited the critical need for increased interagency and community collaborative efforts.

Several managers of smaller park units felt that it is imperative for management agencies to take a landscape scale, cross-boundary approach because from experiences managing a small park unit across a few thousand acres. Respondents noted there are many spatial limitations to enacting strategies that promote conservation of species on their landscape due to the relatively small landscapes they manage (R21). A manager of a small NPS monument expressed concern with noticeably worsening drought conditions on their landscape and felt that their water conservation efforts were limited due to the spatial scale of the park, expressing hope for greater collaboration with surrounding park units managed by other agencies, nearby ranches, and private landowners (R5). Respondents working on larger

landscapes discussed the challenges in being able to understand the scale of changes across the multiple ecosystems they work with in a single park, and how ecological stressors will have varying impacts, and sometimes cascading effects, across ecosystems (R3, R4, R7, R16, R22, R34).

> **"Trying to address the role of topography and the spatial variability of drought and also addressing extreme climate events is something that we've struggled with and that's because we work on some giant landscapes" - Program Manager, National Park Service (R4)**

Respondents noted that climate induced stressors, particularly drought and wildfire, are being experienced at a larger spatial scale than in historic conditions. While recognizing that fire is not only natural, but an essential part of the landscape, multiple respondents expressed a concern that wildfires are not only larger than historically, which can also be attributed to fire suppression. Respondents were concerned that they have observed how the ability for ecosystems to recover post-wildfire has been in decline (R1, R2, R5, R8, R10, R11, R17, R20, R31, R33, R35, R37).

> **"Historically, we did see high severity fires in forests, but they were very, very small, usually less than 200 acres or something like that. Whereas now, these high severity patches and these type conversions are 1000s of acres. So historically it was much smaller, whereas now their footprint is just much bigger. So, the spatial scale has really changed from historically." - Ecologist, U.S. Forest Service (R33)**

> **"It's a race between what we're trying to do with fuel treatments and prescribed burning, seeing if we can become caught up in a reasonable timeframe to something like the historic fire regimes. Before we find out what the new normal is, we're trying to play catch up on things that are old problems. And, you know, to be at the point where we at least kind of stabilize these ecosystems so that resilience that kind of like built-in system resilience is in play better for whatever lies ahead." - District Botanist, USFS (R31)**

Another common theme among respondents' concerns related to spatio-temporal scale is that the landscapes are already changing due to climate induced stressors, and

there is uncertainty about the magnitude of change that will occur in the coming decades. Respondents discussed their concerns with ecosystem changes occurring more quickly than models predicted and felt that management had often not been able to prepare for changes as quickly as necessary to keep up with the rate of ecological change (R1, R2, R13, R16, R18, R19, R22, R26, R30, R33). Another related point of discussion was the overall impression from respondents that it is challenging to address international scale issues at the landscape scale.

> **"So, the natural change of forests due to climate change is definitely rapid. But the question is, can managers adapt that rapidly? And the answer is, no. Most management agencies are federal, and the federal government changes very slowly" - Geospatial Ecologist, Bureau of Land Management (R19)**

> **"I sometimes think climate change and modeling is too big of a concept. It doesn't leave managers knowing what to do. This is going to happen, let's say this model is exactly correct. What do we do about it as one organization? There's obviously global stuff, we can eliminate fossil fuels, we should do that, but that's not really what your individual can do about it, you know, we can all make quick decisions and stuff and try to put our money where our mouth is, but the global nature of the situation is not actionable." - Employee, NGO (R15)**

> **"The [planetary] system is changing, far, far more rapidly than it would have been thought possible a few years ago. So, it's changing in the matter of years, what they thought would take decades, or centuries to happen." - Branch Chief, National Park Service (R13)**

A common theme related to spatio-temporal scale is the respondents' sense that climate change is occurring at a large-scale, moderate to abrupt pace, and that both federal policy-making and management decisions within a single park unit often occur at a slow pace, which may not be able to keep up with the current and projected rate of change. Several respondents were more encouraged with the ability for short term

actions to address drought and wildfire having the ability to impact long term, large-scale impacts from global climate change (R9, R12, R17, R18, R25, R29, R32).

III. Management Strategies and Decision-Making Under Drought and Wildfire:

Management Approaches Following Differing Levels of Ecosystem Response (from stress to transformation):

Across agencies, generally respondents that had experienced transformation on their landscapes wished to take more proactive approaches to prevent worsening ecological conditions, but felt limited in their ability to respond, and felt more reactionary than adaptive. Even among respondents that felt they had successfully implemented adaptation actions, they shared that following a disturbance, they struggled to restore ecosystems to their previous condition. Respondents that perceived their restoration efforts as successful often discussed concerns that these efforts cannot counteract projected changes.

Multiple respondents who experienced landscape-scale changes discussed type-conversion and frequently shared the viewpoint that some ecosystems will not be able to return to their historic state. Respondents felt that managing with the mindset of keeping the greatest amount of biodiversity intact was crucial, though there were differences in how they felt management should best approach biodiversity preservation. Ultimately, respondents that had experienced large-scale changes had an acceptance that some level of change is inevitable and approached management with this perspective.

“People want to protect the PJ so much, and we have PJ resiliency projects and all these things, and I think it's wonderful, but at the same time, I think

we need to be realistic, we really just think we're going to be able to engineer the same biological system to occupy the same ecological space when the fundamental patterns, the climate, has dramatically shifted."
- Chief of Natural Resources, National Park Service (R2)

"Change is a reality that we have to embrace. Ultimately there is value to people and to biodiversity and all these other natural resource needs. There'll be changes to landscapes, they're probably not going to support the exact same species, or behave the exact same way as they did historically. So if we want to make a change that preserves biodiversity, we have to accept that." - District Botanist, USFS (R31)

Variation in Management Approaches by Agency Mission, Vocation, and Training:

The necessity for a more interdisciplinary approach to drought and wildfire adaptation was expressed by individuals across vocations. Those with primarily management-related educational backgrounds discussed the need for greater collaboration with scientists. National Park Service and U.S. Forest Service respondents felt that they had adequate science-informed management within their agency, while several Bureau of Land Management respondents felt that their agency could benefit from development of more science-focused positions within their agency, as well as a branch of the agency focused on research (R18, R19, R35). Respondents with the BLM felt that they had success working collaboratively with research-focused institutions such as USGS and NGO organizations, but they expressed concerns related to the ability to manage vast amounts of acreage without enough researchers to understand what is happening on-the-ground (R18, R35).

When asked how they viewed other agencies' adaptive responses, respondents frequently shared the positive aspects of their own agency's management approaches and addressed the shortcomings they observed within other agencies.

“It’s easy to say Park Service is the best at conservation, because that's what we live and die by, obviously. BLM and Forest Service, they're going to continue to operate as they have, to a certain extent, but I'm sure they've adapted some.” - Natural Resource Specialist, National Park Service (R10)

“Bureau of Land Management, means the Bureau of Livestock and Mining, which people have, you know, pejoratively joked about, but that's what Congress has wanted it to be” - Science Advisor, National Park Service (R14).

“All these agencies are still multi-use, besides maybe the Fish and Wildlife Service, which has a pretty specific mission. The National Park Service is still a recreation and interpretation agency. BLM is still for cows and mining, and the Forest Service is still for forest products.” - Superintendent, National Park Service (R30)

Respondents from the National Park Service tended to view the management approaches of their own agency with favorability and viewed the strategies of their own agency as more proactive, in comparison to approaches of other agencies. One respondent felt that in their 15 years of experience on the Colorado Plateau, with over 25 years of working in natural resource management working for multiple federal agencies, they found the National Park Service to be the leader across agencies in proactive management, especially fire management, noting that the NPS has the most scientists working on the land, in comparison to other federal agencies. NPS and USFS respondents felt that other agencies would benefit from employing more natural scientists for monitoring and restoration efforts. Several respondents from NPS disagreed and felt that the USFS had comparable resources to the NPS for science informed management.

“Fish and Wildlife, Forest Service, they’ve all been gutted. There’s nobody out on the land. They’re all far more reactive [in comparison to the NPS].” - Chief of Natural Resources, National Park Service (R2)

“I feel like the other agencies are a little more on top of it, because they have, like, they're less like these little individual units and more of like a

landscape. It's like the forest services, has nationwide system enforcers, they have a big national strategy and BLM is nationwide, I feel like the Park Service is a little behind." - Monument Manager, National Park Service (R35)

Across agencies, respondents felt that the ways in which agencies manage can often be isolating, with a program manager from AZGFD feeling that in terms of collaboration, there is still progress that needs to be made: "everybody's making decisions in their own little kingdom" (R9). An NPS resource manager felt that NPS was behind BLM and USFS in terms of national strategic efforts, whereas the NPS is focused on individual units, rather than the larger landscapes of national forests or BLM lands (R5). Respondents expressed the necessity for increased collaboration across agencies in order to effectively adapt to the pace and scale of changes. Respondents across agencies discussed their views that a larger year-round workforce would allow for greater collaboration on current and planned projects. BLM managers, as well as an employee working for an NGO who directly facilitates collaboration between BLM and ranchers, focused on the management of the rangelands, particularly cattle. Discussions surrounding declines in water tank levels and balancing the needs of the landscape with the ranchers' desired cattle numbers, were common with BLM employees and two NGO leaders that work collaboratively with the BLM. One respondent with experience working at both the NPS and USFS, felt that the NPS's emphasis on visitation and recreation may deter greater investment into ecological research and planning efforts (R20). A BLM respondent felt that the NPS had less partnerships and collaborative efforts with the BLM than the USFS, feeling that the NPS has a greater focus on visitor experience than effective land management (R35).

The USFS and NPS respondents felt that preservation of pinyon-juniper woodlands is important, while BLM respondents focused on pinyon-juniper encroachment causing changes to grasslands and shrublands. A BLM monument manager discussed how managing pinyon-juniper through thinning also helps decrease wildfire risk, as it is more difficult for fire to spread through open grasslands than in pinyon-juniper systems (R35). NGO leaders that collaborate with BLM officials felt that the concerns related to pinyon-juniper may be related to the preservation of grazing lands for cattle, in addition to concerns for the sage grouse and BLM respondents did not discuss this aspect (R15, R29). NPS and USFS respondents expressed concerns with the BLM's position on pinyon-juniper, with a silviculturist for the USFS stating her concerns that the BLM approaches pinyon-juniper management this way: "there are truly people out there that believe that Juniper is just a weed" (R1). BLM respondents discussed the pinyon-juniper in a context of it needing to be thinned, prevented from expanding in order to preserve critical habitat for the sage grouse and restore historic conditions (R18, R19, R35).

Uncertainty and Decision-Making:

A common focal point of discussion was that overall land management agencies tend toward being reactionary in their management strategies rather than proactive, largely in part to the magnitude of the problems they are dealing with. The management challenges presented by this uncertainty were not addressed through a particular question in the interview guide, yet this concept emerged frequently as a topic of discussion. 17 of the 37 respondents discussed the challenges related to making management decisions under uncertain conditions, both at present and into the future.

Another common agreement was that a business-as-usual approach will not lead to solutions, yet there is a great difficulty in effectively addressing the many needs and management considerations for a wide-diversity of ecosystems, many of which are managed by a single park unit. Multiple respondents pointed out examples of changes happening far more rapidly than anticipated on the landscapes they manage than expected, particularly in regard to vegetation, such as pinyon-juniper, die off and/or drought conditions significantly reducing water resources and transforming the ecology of riparian habitats more quickly than projected (R3, R4, R8, R10, R11, R15, R16, R19, R22, R30, R33)

Additionally, respondents discussed the theme of uncertainty related to how these issues will impact ecosystems at the global scale. Respondents discussed how surpassing planetary tipping points may impact ecosystems globally and how many aspects of climate science and for example, how the implications of changes to oscillation patterns are still not fully understood (R13). Respondents discussed how there are still many distinct unknowns in regard to the lands they manage, including one respondent working a large park stating that only 6% of the park's cultural and archaeological features have been inventoried, leading to a lack of a complete understanding of the resources that they hope to protect in the face of ecological change (R16). This was identified as one area of critical importance for larger public lands to address, as in order to manage proactively, park leadership needs to have an understanding of the resources on the landscape.

One natural resource manager for the US Forest Service stated the concern that "we're never going to be prepared" and referred to adaptive efforts as a "large-scale

science experiment" (R36). Some respondents felt skeptical that current models are accurate predictors of future conditions (R2, R8, R19, R23, R36) Other respondents echoed a sentiment of concerns related to models and uncertainty, but they leaned towards wanting to use the best available science and models to take proactive action, as opposed to erring on the side of caution and taking minimal action (R4, R13, R22, R24, R26, R29, R35). These respondents felt that there is a struggle with the day-to-day management of the resources, much less trying to think into the future as to how they might be able to address or adjust their management approaches. The unpredictability of climate change and how it will affect ecosystems led several respondents to question how to best manage under uncertainty, and led one NPS superintendent to conclude that it is "nearly impossible" to manage proactively with how uncertain climate-related impacts will be (R30). Abilities to prepare proactive responses were often called into question due to existing uncertainties. A geospatial ecologist for the BLM felt that models cannot offer complete understanding, "right now, we can only go on models and who knows how well these are actually going to predict what the conditions are actually to be in ten years or more" (R19). Respondents felt the pressure of the temporal scale of climate change and worsening ecological stressors, arguing that changes are occurring rapidly and thus responses should be as proactive and rapid as possible.

Several respondents disagreed (R8, R15, R33), arguing that less intervention- especially in the case of planting introduced species- should be the preferred response, citing the resilience of ecosystems and preferring this approach due to potential for unintended consequences. The majority of respondents had noted changes they had already experienced on their landscapes, and felt that proactive, adaptive strategies

need to be implemented as quickly as possible, despite the potential for unintended outcomes. Multiple respondents felt that unintended outcomes are always possible, and perhaps unavoidable, but that inaction or a more reactive approach will lead to unfavorable outcomes.

IV. Primary Barriers and Potential Limitations:

Potential Limitations of Climate Adaptation:

Numerous potential limitations for proactive climate adaptation in relation to varied understandings of the concept of adaptation were mentioned by respondents over the course of the interviews. This section addresses limitations of adaptation due to the impacts of climate change on a global scale and how this can prevent planning and preparing landscapes to be more resilient. Lack of capacity to effectively manage ecological stressors, mainly due to economic barriers, was a major focal point of discussion around climate adaptation. In a broader context, proactive climate adaptation actions were seen as limited primarily by the fact that it is difficult to build lasting ecological resilience in a dynamic, changing environment that is constantly being influenced by global scale factors, like anthropogenic climate change. There was a theme of growing concern that adaptation will be limited by the fact that climate change causes global scale implications, and that adaptation at the landscape or ecosystem may not be possible in all cases. A USFS employee with decades of experience felt that even the most effective, large-scale efforts can only limit environmental degradation due to drought and wildfire to a certain extent, finding that worsening climate change

impacts will surpass even the most well-planned adaptation efforts (R25). Respondents felt that there are limitations of what can be accomplished at a smaller scale, when the causes of the ecological stressors are a result of planetary scale climate change.

> **“Globally, we've missed our chance to turn things around. I think that globally, we dropped the ball on changing the direction of climate change, and now we're dealing with a reaction.”- Fire Archaeologist, National Park Service (R34)**

> **“We're really working to be more proactive. But I do think it's a combination of both like, for example, kind of coming back to the water aspect of things like we know these resources have already been overused and are overtaxed and are highly degraded. Highly vulnerable ecosystems suffer from that historic degradation, and that ongoing development and use of those areas are still present. And so, whatever we're doing is frankly, reactive to those.” - Employee, NGO (R29)**

> **“These changes are going on everywhere but not all land managers have the capacity to respond to them. We all need to do adaptation practices that involve scientists, land managers, and really the public at large, because stationarity is dead, the past historic range of variability is no longer a good guide to the future.” - Science Advisor, National Park Service (R14)**

> **“So, you have all the disturbances, and then you throw climate change on it, and it's like a double-edged sword. Now things are harder, it is hard to reveg, it's hard to seed, it's hard to do all these things when you're not getting monsoon season and you didn't get any snowpack. So it's a double edged sword. And climate change exacerbates the other disturbances.” - Vegetation Specialist, National Park Service (R10)**

Respondents discussed the significant difficulties they found in attempts to determine which strategies and projects to prioritize over others and felt limited in their ability to implement on the ground interventions (R5, R10, R14, R23, R25, R27, R31). This was due to the number of projects they thought could facilitate ecological resilience and the lack of time and resources to implement all of them simultaneously. Additionally, respondents felt that there is a significant challenge in keeping up the momentum of projects over long periods of time, especially when there is a need for

more long-term, large-scale projects to address current and projected challenges (R9). Respondents discussed the challenges associated with getting planned projects approved, with the process often taking many years. Respondents addressed concerns that the project proposals will not keep up with the pace of change, so by the time a project is approved, the ecology of the landscape has changed and needs to be reassessed (R18, R22, R34). Issues related to ability to adapt within a timescale that keeps up with the pace of climate change was a common concern among respondents.

> **“A major challenge is how some of these projects can take many, many years to see through. With 50,000 acres it might take a decade to complete this project.” - Manager, Bureau of Land Management (R18)**

Several respondents addressed how short-term research projects can fail to provide the information needed to translate into effective management, but there is little funding and support available for long-term studies. There was a common theme of growing concern among respondents that worked in facilitation of adaptive action that the projects they are working on may be for systems that cannot adapt in the long-term under future climatic conditions (R10, R22). Respondents felt concerns related to the uncertainty of decision-making and proactive approaches to management when considering the longevity of certain species under a changing climate.

> **"We have some current projects, and we're like wait, are we managing for something that might not be here? But we have these projects, they're all short term, less than 10 years old. So I don't want to say they’ve completely failed.” - Restoration Specialist, National Park Service (R22)**

While some respondents found this to be a limitation, others felt that uncertainty of future ecological resilience encouraged their plans to promote proactive adaptation efforts on the lands they manage, Respondents across agencies expressed the desire to implement proactive strategies “we should be thinking about what happens if we don't

[take action], rather than what happens if we do" (R36), and "all we can do is train, educate, and prepare for changes" (R34).

Knowledge-Action Gap:

One of the most common themes that emerged when discussing primary barriers to implementing climate adaptation actions is known as the "knowledge-action gap," which is a significant issue that occurs when "research outputs do not result in actions to protect or restore biodiversity" (Roche et al., 2021). The knowledge-action gap can happen for many reasons, including barriers to action involving lack of resources, staffing, and/or agency and government policy, which will be discussed in the subsequent sections in this subsection. This section will focus on the important limitations of scientific research being able to be interpreted and translated into viable management strategies, due to gaps in existing scientific knowledge as well as managers feeling inundated with the amount of research available.

Respondents weighed in on the challenges created by the knowledge-action gap for their work, and approached this discussion in unique ways, some focused on current gaps and limits to current research and how these factors lead to inability to implement action. Others focused on the large body of knowledge that currently exists surrounding these topics and addressed concerns about why this existing knowledge is not being translated into action. For example, an NPS physical scientist felt that more long-range studies and more monitoring would provide a better understanding of what is happening on the ground with species, particularly with how decreased moisture and snowpack levels are impacting species (R21).

Multiple respondents across agencies, both those with vocational expertise in physical science and management, expressed that there are still knowledge gaps within the scientific literature, with a common theme emerging among these respondents being the need for greater amounts of long-term studies (R1, R5, R8, R13, R14, R15, R20, R21, R22, R23, R24, R27, R30, R33, R37). A respondent with experience in both science and management felt that knowledge is particularly lacking in how to best intervene in systems post-disturbance (R8). Within that larger conversation, multiple respondents mentioned how science is often focused on the short-term, and that short-term studies have the tendency to miss nuances that long-term studies can better document and address. A plant ecologist for USFWS felt that predictive models are important for future trends analyses, and specifically for plants, there is a need for long-term studies of germination, seedling survival, growth, reproduction, and pollinator changes to correlate with climatic changes experienced over the past several decades (R37).

It is worth noting that those with educational and vocations in physical sciences, such as biologists and ecologists, mentioned the need for increased studies more frequently than those with backgrounds and careers in management-focused positions, such as superintendents and natural resource managers. Those with management-focused vocations felt concerned about an overwhelming amount of scientific information, which they did not have time to study and interpret. A natural resource specialist for the NPS felt that reliable scientific information relevant to his management decisions is “out there” but is too limited by time and other responsibilities to stay up to date on the latest research (R26). Both respondents with vocations primarily focused on

management (R35) and those with science-focused vocations (R24) expressed a sense of being overwhelmed by the amount of research available and how it is a challenge to implement actions when studies often provide conflicting information. A district biologist for the USFS echoed this concern, stating that vast quantities of information are available and when the information is conflicting, she feels limited in her ability to make recommendations or take action (R24). A monument manager from the BLM felt that scientific studies often conflicted with one another and expressed that it can be confusing to know what research findings to use to implement strategies (R35). A fire ecologist mentioned how fire consortiums are helpful in actively publishing research in a manner that managers can implement and that there is lot of knowledge available, however, there are so many options and different ways to communicate findings can be "exceedingly overwhelming" for managers, especially those who may not have a background in a specialized field (R23).

Multiple respondents felt that there is already adequate scientific research and an understanding of what steps to take, and the main problem lies in getting actions to be taken (R3, R6 R31, R32, R36). While more studies are always beneficial to inform actions, the base scientific knowledge already exists and needs to be implemented. A manager for the USFS characterized the frustration of the knowledge-action gap and felt that managers often "bury their heads in the sand underneath all these articles and then never implement projects" and that "at a certain point you do just need to act and do something and just use the best available data that you have to make an informed decision" (R36). This echoed an overall theme of the difficulties of decision-making

under conditions of uncertainty, as well as with concerns about unintended consequences being a primary barrier to implementing adaptive strategies.

Respondents who identified a knowledge-action gap as a barrier to effective management noted that research often does not help managers in a practical way. A resource manager for the NPS felt that it was often difficult to determine how to get from "point A to point B" based on research findings that often fail to identify "actionable steps" needed to implement adaptation efforts (R5). He felt that natural resource managers need more identifiable, actionable steps on how to turn knowledge into practice on the ground (R5). Multiple respondents felt that there is too strong of a divide between researchers and practitioners, and both would benefit from increased collaborative efforts.

> **"I have that knowledge of the research side and how you can incorporate that into land management. I think there's a lot of people in land management who that's all they know. And so, they don't understand how to make that connection. Just like I think there are some people who just want to do research for the sake of research, not to answer a question that would actually help the land. So, you have two spectrums, and then you have some people in between. There's a disconnect for a lot of land managers on how you incorporate the research that's out there into what you're doing. It takes the right person to want to do it. I think those people are still heavily outweighed by the pure land manager." - District wildlife biologist, USFS (R24)**

Another respondent from the USFS, with a strong academic background in forestry research, identified another important gap that presents potential challenges, this being the gap between scientific knowledge and experience, "the experience that I had in terms of areas reburning and seeing extensive mortality, we've never published it, and nobody's ever published it. So that's in the scientific literature as still unknown, yet we've experienced it. So, there's two things going on: one is scientific literature and

the other one is experience" (R33). Multiple respondents expressed a sense of optimism that the knowledge-action gap is decreasing, especially over the past decade due to more effective communication between researchers and managers, but that there is still room for improvement, particularly in the areas of communication of research findings and providing practical, actionable steps for the managers to implement. Respondents indicated ways in which the knowledge-action gap is reciprocal in that managers are not currently utilizing the full potential of existing scientific knowledge, but at the same time, researchers lack a complete understanding and there is a need to address scientific questions and develop answers to communicate with managers.

Resources:

The lack of financial resources to implement adaptive strategies, to hire new staff, and to fund new projects was cited by 26 of the respondents as one of the primary barriers to more proactive management approaches. Multiple respondents discussed the difficulties arising from the competitive aspects of obtaining funding, leading them to feel that they had to spend a large portion of their work applying for funding for projects while wishing they had more time to spend on implementing projects and working with researchers and staff to better manage landscape changing. Building upon the knowledge-action gap, one respondent mentioned that there are recommendations made by researchers related to drought that are not working on the landscape, but the respondent, a fire ecologist for the US Forest Service, did not have funding needed to conduct a study and investigate the reasons why the recommended approach has been

failing (R2). Another challenge related to the knowledge-action gap is the lack of resources when there are often strategies and projects that managers would like to implement but are unable to because they do not have the funding necessary. Multiple respondents discussed how in order to address landscape-scale challenges, having the resources of funding and time necessary to implement strategies is crucial to effectively responding. Respondents consistently felt overburdened by the task of applying for grants and project funding, on top of their many other job responsibilities.

> **"The funding thing is weird. We have to find the funds. But should it really be that way? I mean, it should be easier than this." - Natural Resource Specialist, National Park Service R10**

An NPS park superintendent was concerned about the ability to implement large-scale interventions, especially as these issues become more pronounced on the landscape, stating park resources are already stretched thin and funding is limited and often more difficult to access for smaller, less visited park units (R30). Several other respondents from the NPS echoed the sentiment that there is a sense of competition for project funding between park units (R11, R16, R21, R28, R30). This competition leads to increased stress and leaders having to make unwanted decisions and tradeoffs. There was a consensus across agencies and vocations that decision-makers have projects they cannot enact on the landscape due to resource constraints.

> **"A lot of times the decisions that we make are really based on funding issues. Trying to prioritize what we're going to fund and what we have the staff to do. You know, some of the decisions are based on trade-offs. We know we have to put a lot of energy into certain things, meaning other things maybe aren't going to get as studied or monitored as we might want, because we have limited staff and resources. Some of the decisions I make include reviewing proposals every year. Which ones are we going to put forward? And which ones don't we have the staff to do?" - Chief of Science and Resource Management, National Park Service (R6)**

“I would say everybody wants to do more. I think that's across the board, especially in the natural resource profession.” - Program Manager, AZ Game and Fish (R9)

“I hate to say this, but reality is everything depends on money. We have to have the personnel and the funding available to do some of the things that we know would be beneficial.” - Fire Ecologist, USFS (R3)

Multiple respondents described the lack of financial resources and staff to implement strategies as a primary obstacle to understanding the extent of ecological change occurring, and predicted for the landscape (R5, R6, R8). A monument manager for the BLM found that often research findings of successful restoration could not be applicable to large scale landscapes, where the costs of implementing action would be unfeasible, and suggested that researchers consider focusing on more affordable strategies for managers of larger public lands (R35). Other issues related to resources include lack of resources to implement proactive fire management strategies, which several respondents felt is changing in a positive direction, but others argued that more resources are allocated to fire suppression and reactive management strategies. Respondents concluded that many management challenges involve finding the necessary financial support to get work accomplished on the ground and “current problems mostly come down to economics” (R12). Of the resource limitations, immediately following budgetary constraints and challenges for funding projects, are issues related to hiring and retaining staff.

Staffing:

Related to lack of financial resources, a major challenge when facilitating the implementation of adaptive strategies is the current need to increase staffing. There were no respondents that reported they had adequate staffing in their workplace.

Staffing issues were identified as one of the primary barriers to adaptation efforts by 19 respondents, over half of the total. Respondents frequently discussed the projects they would implement if they had the necessary staff. An issue raised by several respondents is the combination of the remoteness of many park units and a lack of affordable housing for new staff. Many public lands are bordered by smaller, often rural, communities that cater to tourists and do not have many housing opportunities for staff. Respondents noted that even when there are funds for hiring, it is difficult to fill positions for these reasons. In fire management positions, multiple respondents felt that it is hard to get applicants drawn to the career field. This is primarily due to competition from city and state agencies providing higher salaries for fire-related careers, as well as the remote location of many positions.

> **"A lot of those fire folks were getting paid off by City Fire or state agencies that pay more because the government rate just wasn't competitive" - Restoration Technician, Bureau of Land Management (R18)**

These issues lead to high turnover rates and a lack of the ability for seasonal staff to become familiar with the landscape and the challenges it faces. High turnover rates due to the seasonality of many positions and the encouragement of transfers to new locations for career advancement within the agencies were frequent topics of discussion. Respondents discussed how the ways in which agencies encourage employees to transfer in order to advance leads to a lack of knowledge and expertise about the landscape, as well as challenges in creating long-term collaborative efforts. Multiple respondents that worked in agency leadership and were involved in hiring decisions discussed the need for employees with a strong educational background in the ecosystems they are working in and how seasonal positions, with a difficult rehiring

process for previous seasonal staff, does not encourage development of region and park-specific knowledge (R19, R21, R26, R30). A manager for Arizona Game and Fish (AZGFD) discussed the difficulties that emerge with collaboration with high turnover across agencies, particularly he was concerned about how to effectively plan for long temporal scales and maintain collaborative approaches when people, jobs, and landscapes change and will continue to do so.

Another staffing-related issue raised by respondents across agencies and vocations is that both research and management positions are constantly short-staffed. In the BLM, one respondent mentioned that as people retire, their former positions dissolve and are not filled by new employees; instead, the respondent's job "is essentially three jobs" (R19). Challenges for implementing adaptive actions arise when duties that could be allocated to multiple employees are merged into one position.

> **"Our program's been pretty bare bones personnel wise for a bit. And it's hard to get work done - when there's less people asked to do more things. The things we really want to do, and maybe things that would kind of push us towards like actual restoration, are getting diverted for other things." - Natural Resource Specialist, National Park Service (R26)**

An NPS superintendent, in a park unit experiencing changes primarily due to drought conditions, found that it was a challenge to get approval for funding to hire a staff member in a new interpretive position focused on education and outreach to the public about the drought impacts in the park, as well as climate change (R21). This respondent also faced difficulties hiring new staff for ecology and biology positions focused on implementing adaptation projects (R21). A respondent employed as an NPS science advisor at a small monument (~30,000 acres) discussed how this position is rare for smaller park units and that both managers and scientists would benefit

significantly from creating similar positions at other parks, but that budget limitations prevent creating novel positions. Respondents across agencies echoed the urgent need for an increase in both research and implementation staff members in order to facilitate more effective adaptive responses (R3, R5, R6, R9, R13, R19, R21, R23, R26, R27, R30, R34, R36) A respondent working at a large national park (1.2 million acres) felt that the size of the park calls for at least a dozen new positions to even begin to somewhat adequately monitor changes on the landscape and to facilitate adaptation efforts, but explained that there are barely enough funds to support current park staff (R6).

> **"It [hiring] is based on what the superintendent's office wants us to do. Even when the funding level goes up, it's not keeping pace with the cost of staffing. So as the years go by, we just don't have the ability to hire the staff that we need. *So, it is a bit of a triage*. Since I've been here, we've combined a couple of different programs into one to be more efficient. Things like that have an effect on our staff, but we try really hard to have our staff balance what they can do feasibly without getting stressed." - Chief of Science and Resource Management, National Park Service (R6)**

Often, it is a combination of both financial constraints and the decision-making authority of agency leadership that determine the ability for managers to hire new staff.

Leadership and Agency Support:

Agency inefficiency was noted as a barrier to adaptation by 21 respondents, with 8 respondents specifically discussing struggles getting support for proactive strategies by leadership. Respondents often questioned whether their ideas and strategies for management were being addressed by agency leadership.

> **"It's important that we as managers have a say in bigger decisions. I feel like sometimes that opportunity is given to us, and sometimes it's not, or sometimes that opportunity is given to us, and we voice our concerns, and**

they're disregarded.” - Natural Resource Specialist, National Park Service (R10)

Another common theme that emerged is the need for more top-down federal leadership, support for novel adaptation strategies and actions, including novel approaches to restoration, and greater levels of top-down decision-making. An NPS superintendent stated that while lack of funding is a critical component in regard to ability to implement effective adaptive strategies, there also needs to be an increase of science-informed management at the federal level. Several respondents commented that certain administrations are less interested in funding long-term projects than others, leading to challenges in continuation of existing efforts, and inability to begin new projects.

“[Scientists] should go to Congress and should be part of the bill which says: “Park Service, here's 10 different types of projects for these 10 different latitudes and elevations. Here's the money to do them. And you can tweak it here or there.” I mean ground up solutions are great, but the problem is so big that I just see it as more direction, and funding, and maybe orders like you need to do this and here's the money to do it and this is what you need to do here. Because it's such a behemoth of a problem.” - Superintendent, National Park Service (R28)

There was a common sense of frustration with limitations placed upon implementation of adaptation action due to lack of support from agency leadership among many of the respondents, especially at the federal level. Respondents working in management positions often felt that there was a lack of support from decision-makers within their agencies and there was an overall sense that there is an unwillingness to transition from existing management practices toward more proactive approaches.

“There are definitely things where all it takes is one person in a position of power and there's no progress because they [the agency staff] just don't like making people deal with that.” - Superintendent, National Park Service (R21)

“And there's like a two-year gap between when a project gets funded and when the funding actually gets there. And so, you might have a totally different person giving this project in, like, what it sounds like they knew what they were talking about, but I don't know where they had this data. The details of the project are not enough to actually enact the project. And so, things get adaptive and changed by the person who's there at the time.” - Resource Management Technician, National Park Service (R5)

Another agency related concern deals with the difficulties in establishing institutional knowledge and place-based knowledge when federal agencies have high turnover rates and frequent shifts in leadership. This leads to difficulties in establishing long-term programs and the relationship building needed for effective collaboration. When leaders are frequently changing, respondents cited that it was difficult to have opportunities to collaborate and effectively manage, as new management may have different goals and priorities than previous leaders. There were no agencies that were viewed as having low turnover rates or consistent management goals over long periods of time. Instead, respondents often viewed their management abilities as dependent on the priorities of agency leadership, leading to instability and difficulties in creating long-term management efforts and with building lasting relationships with surrounding agencies and communities.

“There’s a lack of continuity in programs, lack of continuity and individuals in particular places who develop that long-term understanding and relationship with the landscape and lack of continuity with all of the land management partners around so that people collectively are on the same page” - Science Advisor, National Park Service (R14)

Government and Policy:

One of the main challenges discussed by respondents is the limitations presented by government administrations and federal policies. Of 37 respondents, 25

mentioned government and policy as primary barriers for effective adaptation. When government administrations change, policies and priorities often shift as well. National policy and administration decisions were characterized as having a strong influence over the ability to manage projects and prepare proactive strategies by a large number of respondents (R3, R5, R10, R13, R14, R21, R22, R24, R26, R27, R29, R30, R31, R32, R35, R37). During the Trump Administration, federal agencies were not able to discuss climate change, leading to a stalling of scientific progress, climate-focused projects, and funding for climate adaptation. Respondents expressed concerns that climate adaptation is limited by changing institutional priorities, as well as the funding and support that can be given or withdrawn by administrations (R2, R11, R13, R16, R17). One respondent felt optimistic the current legislation, the IIJA, should last for around 10 years, but when future administrations come into power, the funding could still be limited (R32).

> **“When the Trump administration came in, they hated science. It’s just “sorry, we're not gonna allow you to go to the scientific conferences anymore, except on very few occasions.” I say, well, we need to go, this is our job to do, we constantly had to ask for permission. It's just awful. So, I don't know if that'll change.” - Branch Chief, National Park Service (R13)**
>
> **“I'll just say the priorities change a lot, depending on whether there is a Republican or a Democrat in the presidency for anything having to do with the environment and land management. Just trying to keep programs alive during the Republican administrations has been a challenge, and sometimes even in the Democratic ones. It's because we're not all, we're not a long-term thinking society. In general, the politics are short run, the economics are short run.” - Chief of Natural Resources, National Park Service (R2)**
>
> **“We couldn’t say anthropogenic climate change” - Lead Restoration Specialist, National Park Service (R22)**

Only a single respondent, an ecologist for the BLM, had an opposing view related to the influence of government, stating that there is some variation depending on the administration, but more or less even though the previous administration did not believe in climate change, felt that there is consensus within her agency that drought and wildfires are real and that they pose a serious problem (R19).

Government policy has the ability to shape on the ground action, providing both opportunities and limitations for adaptation. Fire managers in particular discussed how restrictive federal and state policies have placed strong limitations on their ability to effectively manage prescribed fires (R1, R11, R12). Other respondents felt strongly opposed to the limitations that federal policies present for management and protection of resources, for example, “the idea that only a handful of streams in all the western states have any federal protection under the Clean Water Act is ridiculous” (R2) and that “sometimes policy can get in the way of action” (R34). Federal and state agencies, from Congress to local governments, also have the policy support and power to resist efforts for adaptive action, specifically prescribed fire efforts, as it is still perceived negatively by many decision-makers (R3, R12, R31, R34). Several respondents that work in upper-level management noted that agency policies often lack direction and can be general, and managers would benefit from more specific and focused directions for how to apply policy to their management decisions (R2, R21, R28, R36).

Managers’ View of Public Perception of Drought, Wildfire, and Management Decisions:

Respondents felt that the public had a better understanding of the drought than of wildfire. Respondents noted that the public seems concerned about the drought,

interested in water conservation efforts, and aware of dwindling water resources in the Southwest. However, there was a consensus that a decent portion of the public still has negative perceptions regarding wildfire, specifically management decisions related to prescribed fire. These negative perceptions were attributed to over a century of fire suppression tactics and fire being regarded as “bad” thanks to anti-fire campaigns, such as the infamous USFS campaign of Smokey Bear, beginning in the 1940s. Three respondents mention the public’s negative perception of wildfire due to health concerns related to increased smoke, decreased visibility, and worsening air quality (R12, R20, R25). Respondents discussed how negative views also surround wildfire due to the public’s concern about prescribed fires’ potential for escaping, as they have multiple times in the past, recently with the 2022 Hermit’s Peak/Calf Canyon wildfire, which was the largest in New Mexico’s history. These prescribed burns escaped due to miscalculations, including inaccurate models and an underestimation of the severity of drought conditions.

Respondents noted that there is significant pressure across all agencies to act based on what has positive social aspects and public support, even if it is not the most effective form of management. Often, the public demands interventions from natural resource managers following an ecological disturbance and respondents felt that ineffective, rushed decisions are often made as the outcome of the pressure placed on managers to act quickly. An example of this was a USFS employee discussing their perspective that planting trees is largely ineffective, but it makes the public feel reassured that the Forest Service is taking action following a wildfire, so it is promoted within the agency, when perhaps resources could be invested into more effective

strategies (R33). Respondents that discussed public perception placed a strong emphasis on the need for effective public education in order to gain support for planned management strategies. Public support was viewed as an important component of gaining approval to enact adaptive strategies, allowing for management strategies to be implemented more quickly, and decreasing the number of negative perceptions related to what can be considered controversial management decisions. A manager working for the USFS discussed how forest supervisors often face difficult choices and public scrutiny irrespective of the management decisions they make, for example, closing a forest so it does not burn can cause the media and the public to be hateful, but choosing to keep the forest open can have the same response if a large fire does occur and causes damage to the landscape or nearby properties (R3). Two additional USFS employees mentioned the negative public perception related to restricting individual behaviors, specifically decisions to ban campfires and prevent forest access (R25, R27). One main topic of discussion was the education of the public regarding fire ecology, particularly helping the public understand fire's natural and important role in ecosystems and how prescribed fires can help restore fire regimes to the forest. Public perception influences the support of agencies and government leadership. Support from the public was viewed by respondents as a crucial component of shifting political support and funding toward greater approval for proactive fire management strategies, particularly prescribed fire and thinning efforts. Greater public understanding of the science and rationale behind management decisions can lead to greater support and allow for actions to be taken on the landscape more easily.

> **"Until we educate the public to support those things, we're never gonna get anywhere. Congress is going to fight us. State and local politicians are**

going to fight us. Everyone's going to continue to live in fear of fire when we should be using it." - Fire Archaeologist, National Park Service (R34)

"It's a social license. So, if you get a lot of collaborative buy-in saying, "Yes, this should be done in this way," and everybody signs off on it, you're not going to have the controversy and lawsuits and litigation that stops these kinds of projects. So, it's a pathway to get things done on the ground. Some might say, "well, that might be more difficult, more time consuming." But if you get that level of consensus and buy in, you're going to have that social license, you're not going to have a whole bunch of people suing you, and you can actually get the job done." - Program Manager, Arizona Game and Fish (R9)

Another area where respondents felt that public education and outreach could be beneficial is related to how the public often seeks information and management solutions that confirm their worldviews. Respondents felt that making management decisions understandable and communicating rationales behind strategies in a way that is approachable and appropriate for the public could lead to more positive public perception. Several respondents felt that excessive use of scientific jargon when communicating to the public is often not well-received, and another respondent discussed how science denial and anti-science viewpoints negatively impact public perception of drought, wildfire, and management decisions. Several respondents discussed their plans for increased communication with the public, including installing more interpretive signs related to drought (R5) and/or wildfire (R3) on the lands they work, increased collaboration with the media and the public following a large wildfire (R7, R30), and expressing how drought and/or wildfire will impact the flora and fauna of the lands they manage, particularly if it involves a park's namesake species that it was set aside to protect (R26). Two respondents noted that archaeological sites such as Wupatki, Walnut Canyon, Bandelier, and Mesa Verde were identified as cultural resources that are valued by the public. Natural features such as the Grand Canyon,

Zion Canyon, and the arch formations of Arches National Park were mentioned as being important values to the public, as were flora and fauna species of importance including the ponderosa, pinyon, juniper, aspen, Mexican spotted owl, and pronghorn antelope. Respondents noted that iconic species and resources, some of which are the namesake for the park or region, are potential avenues to conduct outreach and inspire the public to learn more about how drought and wildfire have and will continue to impact the Colorado Plateau region.

Ecological Trauma:

One theme that emerged was the presence of ecological trauma, particularly the psychological impacts of management in times of uncertainty and presence of ecological stressors and change. One respondent stated that ecological trauma is a serious concern and reality of the job that is often overlooked (R26). This respondent noted that one of her coworkers ended up in the hospital due to stress and mental health struggles following response to a large-scale, high-severity wildfire which burned a majority of their forest in a single event. Multiple respondents became emotional during these discussions, and several interviews were paused to give respondents space to process their emotions, particularly during conversations related to crisis management or loss of species. In one interview, a respondent broke down in tears discussing the countless challenges of decision-making during a high-severity fire, while also accepting the loss of a landscape they had grown to cherish over two decades of managing the park unit and calling the region home (R28).

> **"I can remember that morning, I was the last person down in the canyon. And I turned around and basically this whole place is a bomb… Not the thing you really want to manage, to be honest. I really thought we were**

about to just instantly be gone the next morning. So that night, I remember at one in the morning, the fire's come in. That morning, there was this red glow. It looked like the fire was right on this side of the wall. And one o'clock that morning, I'm saying goodbye to that place… [interview paused]. Most of the park that we lost was burned in a single day. It was a very emotional experience." - Superintendent, National Park Service (R28)

These responses suggest the need for increased mental health support for agency staff, as ecological transformations and crises continue. One respondent from the USFS felt that the agency provided mental health support, in the form of healthcare and workshops to address these issues, but that agency culture made many staff members reluctant to take advantage of existing support. Climate anxiety was discussed by multiple respondents, but also a sense of despair and loss, for the places they manage.

"I feel like there is a lot of climate anxiety but also there's this sense of climate despair and just feeling like we're just throwing up our hands and not knowing what to do." - Physical Scientist, National Park Service (R20)

Another respondent discussed ecological trauma related to place-attachment and loss of landscapes that hold personal and emotional significance. One respondent noted that place-attachment, particularly nostalgia for landscapes lost due to drought or wildfire, can limit proactive and novel approaches to management (R36). The respondent suggested that the desire of managers for preservation of historic ecological conditions, despite the fact that the ability for systems to recover has been in decline, discourages adaptive solutions, such as planting more drought-tolerant or fire-resistant species, in favor of preserving existing landscapes, even if those ecosystems may struggle more in changing climatic conditions. Additionally, there is pressure from the public and local communities to keep existing ecosystems intact, due to personal

attachment to existing ecosystems and species that are considered desirable for that landscape.

Many respondents noted the loss of the pinyon-juniper woodland ecosystem, expressing personal and public feelings of ecosystem-attachment. Two respondents, a vegetation specialist and a plant biologist, discussed the decline of flora which they spent years working on multiple projects in an attempt to recover these species. A restoration specialist for the NPS discussed feeling a strong sense of connection to a species of shrub, the blackbrush *(Coleogyne ramosissima*), as well as loss and frustration related to the population decline despite multiple unsuccessful restoration and seeding efforts.

> **"It's been really, really dry. Those poor little blackbrushes, most of them dried up." - Biologist, Restoration & Vegetation Lead, National Park Service (R22)**

Pessimistic responses were common when discussing personal experiences and management challenges for the landscapes on which they work. There was a shared sense that the impacts of ecological stressors outweighed the respondents' ability to successfully implement management practices.

> **"I don't use the word hope anymore, quite frankly. I use the word possibility, and what [solutions] might be out there. But given what I've seen and where we come from, hope is really not a part of the picture anymore." - Superintendent, National Park Service (R30)**

> **"And I mean, we saw the impact, there was Arizona's fourth largest fire, burning right on the opposite side of a river near us. And that river ultimately protected us from burning again. But just even seeing that so close, was pretty triggering for the superintendent here and for people here." - Fire Ecologist, U.S. Forest Service (R3)**

> **"Even as a professional, I'm very emotional about it. It's so in your face, so obvious and so impactful. It's just been heartbreaking, watching the**

mountain burn off in a place I built a house 20 years ago." - Natural Resource Specialist, National Park Service (R26)

Based on these responses and the emotionally heavy tone found within the interview responses when discussing the personal experiences of witnessing wildfire and drought impacts, it is apparent that psychological wellbeing is impacted by the challenges of management.

V. Perspectives Related to Climate Adaptation and Proactive Management Strategies:

Definitions of Adaptation:

Management emphasis:		
On-the-ground applications (n = 8)	Managing as restoration action (n = 5)	Interpersonal focus (n = 2)
"Adaptation can mean adapting my management practices on the land. Changing my decisions from five years ago, when I was thinking more conservatively" (R1) "It makes me think about human interventions" (R8) "I think of adaptation as management actions that can be taken to support ecosystems, species, communities to respond to change, be more resilient" (R5)	"we're adapting our management strategies and goals, so that we're not just dealing with bare ground and weeds" (R22) "it's really taking adaptation actions, using restoration actions to heal the lands" (R27)	"Adaptation could mean even how I adapt my style as a supervisor. I have to change how I approach things based on what they need" (R28)
Science emphasis:		
Environment & ecology (n = 9)	Climate change (n = 4)	Data-based approach (n = 1)
"for a ponderosa pine forest, adaptation is just restoring natural structure and pattern" (R12) "it all comes down to adaptation by flora and fauna" (R25) "I think of how the environment and wildlife will have a level of adapting but there's also a tipping point" (R9)	"resiliency strategies outlined in the IPCC" (R20) "the idea of adaptation is when we actually make changes in response to climate change" (R6) "I think the word adaptation always triggers climate for me" (R10)	"adaptation is using the most current data and science to address climate related issues" (R14)
Combined Emphases:		
Social-Ecological focus (n =6)	Flexibility for Changes (n = 2)	
"we actually think about it both ecologically and socially…By working on restoration and other activities that make forests more resistant, resilient and adaptable, it also helps the human social system be more adaptable as well" (R29) "Adaptation includes what we're doing on the landscape to ecosystems and human systems…trying to make them work together for the predicted climate future" (R31) "I think of it along two separate lines: one is natural adaptation and the other is social" (R5)	"we use adaptation in the sense of adaptive management instead of having setting goals that are set in stone, understanding that there will be flexibility depending on what climatic conditions are going to exist at the time. As well leaving language in there for revision" (R18)	

Table 2.1 Categorization of responses to the question "How do you define adaptation?"

Definitions of the concept of “adaptation” varied between respondents, showing the complicated nature of using this term and applying it to management strategies. These responses ranged from broad definitions to specific on-the-ground applications of climate adaptation strategies. This table shows the difficulty in categorizing individuals’ definitions of a broad concept, revealing that the interpretations of “adaptation” are complex, diverse, and often a single term represents a multitude of understandings. Respondents frequently used the term in relation to both science and management aspects of adaptation.

Though every respondent was asked the same question: “how do you define adaptation?,” and “When you hear the term adaptation what do you think of or what does it mean to you?,” the responses were varied, with many respondents emphasizing multiple topics within a single definition. As shown in the table, a single respondent, R5, defined adaptation as it relates to on-the-ground application of adaptation strategies, as well as relating the definition to the physical environment and social dimensions. The range of definitions and understandings of the term adaptation between federal agencies, state agencies, and international institutions, and how these may shape respondents’ perspectives and discourse around the concept of adaptation will be examined in a subsequent discussion chapter.

> **“It's just an umbrella term for a lot of things in land management”– Botanist, USFS (R31)**
>
> **“I don't think climate adaptation is always very clearly defined. Even if they don't use the word climate adaptation, county organizations, water providers, the Forest Service, and others, are having to think about communities and people that depend on those resources. I think a lot of what they're focusing on is probably climate adaptation, even if they don't necessarily define it that way, or label it that way. I think it varies across the country.” - Fire Ecologist, NGO (R32)**

Respondents' overall impressions of the concept of adaptation can be characterized as emphasis on the physical and biological science aspects of climate adaptation (n = 14), the management aspects (n = 15), or a definition that incorporated both science and management elements (n = 8). As shown in the table (2.1), respondents defining adaptation in primarily ecological terms focused on environment and ecology when expressing their conception of adaptation, followed by defining it in terms of ecological response to climate change, and finally, one respondent focused on a data-based approach, meaning that their focus when defining the term was related to adaptation in terms of understanding predictive models and best-available science to prepare and respond to future conditions. For the management-based definitions, respondents focused primarily on practical applications, “on-the-ground” approaches to adaptation, having the overall sense that adaptation is related to the use of frameworks to build adaptive capacity on the landscape. Followed by this definition, adaptation was often defined by respondents as being synonymous with ecological restoration efforts. Adaptation was not considered to be something distinct from these other concepts by these respondents. These respondents shared the perspective that restoration actions were the only way to promote effective adaptation, citing concerns related to the impacts that climate induced ecological stressors have had and are projected to have on the landscape, making restoration efforts critical for adaptation.

Two respondents, both in upper-level leadership positions, defined adaptation as adapting their management practices and leadership styles to better support staff as they face increasing challenges in the landscape. Many respondents shared a sense that adaptation should be defined as adapting to changing social-ecological conditions

and offered a combination of a management-focus and an ecological-focus in their responses. Often, in the same sentence, the respondents would mention a management aspect such as on-the-ground applications and refer to basing these applications on a physical science aspect, such as climate models. Two respondents defined adaptation as management practices needing to increase capacity for ecosystems to be able to adapt to changes, using the word “flexibility” within their definitions. These definitions share commonalities with definitions of resilience and building greater resilience, which involves facilitation of greater flexibility in current management practice.

Multiple respondents provided several explanations that spanned across the categorizations for the concept of “adaptation” when asked how they define adaptation (R1, R2, R9, R14, R12, R20, R23, R26, R31, R34). I chose the primary areas of focus for each response in order to categorize their definition, but it must be acknowledged that many respondents often provided multiple responses to the question, and these definitions often merged into personal examples of applications of adaptation, which will be explored in the following subsection, “Understandings of Adaptation.” As an example, one respondent, a silviculturist for the USFS, applied the definition to land management, personnel management, as well as the changing ecology of the landscape itself, using “adaptation” in distinctive ways within each example (R1). An NPS employee discussed adaptation in terms of both the broad implications for environment and society included in the IPCC, as well as a more practical, local scale consideration of how park units should adapt infrastructure and visitation-wise (R20).

Understandings of Adaptation:

Since individual understandings of adaptation varied widely, there was a consensus surrounding the challenges of applying the term adaptation broadly. Across agencies, experience levels, and vocations, respondents struggled with conceptualizing adaptation in a clear and concise manner. What some respondents considered to be adaptive management; other respondents would consider to be business-as-usual management approaches. These divergent understandings and how the term is applied led to a sense of frustration among some respondents, one of which felt that terms such as “adaptation” and “resilience” are essentially buzzwords that do not inspire novel ways of addressing ecological change (R27). One respondent, who defined adaptation in multiple ways herself, felt that: “it's one of those things that means totally different things to different people” (R1). A natural resource manager for USFS felt concerned when their superior told them to include the word “adaptation” in a report, being told to “just throw that word in there, but we're still doing everything the same. It doesn't really mean we're doing anything different, so just say it differently” (R36). A manager with experience in both the USFS and NPS echoed these sentiments, stating how “We're doing the same old stuff that we've done for years and years and years.” (R8).

Multiple respondents were skeptical and expressed that there was a somewhat negative connotation related to the term, with one being initially hesitant to offer a definition: “Adaptation, I hate to use the word and you want me to define it?” (R9). Respondents shared a common sense of confusion, and even frustration, surrounding the term adaptation. Several respondents felt more positively about adaptation as a concept but felt that the word is widely but often falls short of leading to necessary

proactive action. Some respondents questioned the ability of the extent to which preparing for adaptation is possible and how often true adaptation is practiced (R8, R9, R14, R33, R36). Several respondents found that while their understanding of the term is clear, the overall consensus was that people often use the term adaptation in broad, subjective ways, despite the definition of "adaptive management" being mostly understood across agencies. Respondents felt that the concept of adaptation is not understood or used in a uniform way across agencies.

> **"Can humans, can managers adapt to the changing environment? And that, to me, is still debatable. This idea of adaptive management has been around for a long time. And it's a very good strategy with a consensus that this is the best way to manage. But in terms of being applied to the ground, I have seen it *very, very few times.* Even though the strategy and the idea are very, very well documented, very well thought out, it's actually practiced very seldom." - Ecologist, U.S. Forest Service (R33)**

> **"I think there's probably some lack of understanding or knowledge of it. I think for federal land managers we are stuck in the past sometimes. It's kind of like the Park Service's dying infrastructure. We're stuck in our ways sometimes. Maybe people understand climate adaptation, but it's the action that is missing."- Natural Resource Specialist, National Park Service (R10)**

> **"Sometimes I feel like we use that word without really understanding what it means. Climate adaptation means that we just go along, trying to adapt, and then we're not actually ever doing anything." – Superintendent, National Park Service (R21)**

Respondents were also skeptical of there being a clear understanding of the definition of the term. With many respondents offering multiple definitions when asked to define adaptation, the term is clearly used in multiple contexts, which led to a sense of confusion. It is important to point out this confusion, as respondents felt it impacted their ability to apply for "climate adaptation" and "resiliency" focused grants for projects, especially when the grants did not provide definitions of what is encompassed within these terms (R18, R27, R29). One respondent struggled to determine if her project fit

within this category, feeling that the process was more about shaping language to fit existing project ideas that were not planned as being climate adaptive, and did not feel that she was proposing projects that were more proactive and climate adaptive than typical projects (R27). Even within the same agency, there was a sense that the term is applied to projects and understood in different ways that led this respondent to feel confused about what grants her projects could qualify for. The ambiguity surrounding adaptation also negatively influences their ability to communicate about projects effectively with stakeholders that may be less familiar with the term. There was an understanding across agencies and vocations that the term adaptation is extremely broad and is understood and applied in a multitude of ways. Multiple respondents, across agencies, suggested that many on-the-ground applications of adaptive management are really just existing strategies for restoration or risk mitigation, rather than novel approaches to management under climatic change (R18, R27, R29). The lack of clarity or consensus involving a shared understanding of adaptation was a frequent theme addressed by respondents across agencies and vocations, from high level park leadership to on-the-ground practitioners and researchers.

> **“We don’t have a proper definition. It's difficult to even understand properly if you're categorizing a project correctly.” - Manager, Bureau of Land Management (R18)**
>
> **“People are using the term more, but it could be elaborated on. I could say, oh, we're using an adaptation strategy for a restoration and some people would be like: Well, what does that mean? Talking with other colleagues of mine that are within NPS or BLM, they would understand it, but I also have worked closely with private landowners and whatnot, and they might not understand what those terms mean.” Restoration Specialist - National Park Service (R17)**
>
> **“I don't think there are a lot of land managers that really embrace the term adaptation” – Wildlife Manager, USFS (R27)**

“I would say we're not directly doing adaptation-based management; we're doing more risk reduction. So, it [the project] was still the same ecological restoration. But it just had some adaptation type benefits to it” - Watershed Protection Manager, Coconino County (R12)

“Maybe just having a clear definition on what adaptation is, and what that means, maybe from people like you from a higher education institution or other agencies just so we're all kind of on the same page. But I think right now everyone has a different idea of what that means and how they're applying it on the ground. So, I think when you asked that question, I think first of all, you kind of need to define what it is.” - Monument Manager, Bureau of Land Management (R35)

Proactive Versus Reactionary Approaches to Adaptation:

Respondents questioned whether a stronger, shared understanding of adaptation and how it can be applied to adaptive management strategies would lead to more proactive approaches, or if there are other factors leading to more reactive approaches from managers. When asked whether or not respondents were able to take a proactive approach to addressing adaptive management, a conclusion was that respondents were forced to act more retroactively in their responses, due to not being able to adequately predict what changes are coming. Respondents echoed the sentiment that models and projections can only predict future conditions to a certain extent. In particular, respondents in higher level roles of leadership, such as park superintendents and chiefs of natural resources in the National Park Service or district ecologists and natural resource planners for the Forest Service, felt that they struggle to find funding for management strategies unless a disturbance event has already occurred.

NPS employees found that frameworks like RAD (resist-accept-direct) have been helpful in preparing for change and creating adaptive management strategies. The RAD framework was viewed as a helpful management tool that had the possibility to lead to

more proactive strategies, but respondents still felt limited in their ability to take action. One reason for this lack of action despite RAD and adaptation toolkits being viewed as helpful by respondents, include the respondents' understanding of the scale and magnitude of climate change and related impacts leading them to feel discouraged about their ability to implement proactive adaptation strategies. Multiple respondents discussed the scale and the pace of change leading to difficulties in facilitating proactive management, with managers that have worked in this field for decades feeling that the climate change was not adequately addressed in the past, leading managers to attempt to adapt at a quick enough pace to manage current conditions, while also preparing to adapt to projected changes (R21, R28, R30). One manager, a superintendent with the NPS, felt that the rate at which managers and agency leadership can make proactive changes cannot keep up with the rate of ecological change, but felt determined to pursue proactive approaches as much as possible (R30).

One respondent, an NPS physical scientist tasked with applying the RAD framework to address drought and make management recommendations for water resources in the national park, found that "the RAD framework still makes it seem like humans are in control of this whole climate thing and that the climate doesn't destabilize ecosystems preventing adaptation. RAD is still reactive, maybe we're not in control" (R20). Respondents across agencies and vocations felt that their agencies were overall more reactive than proactive in their management strategies.

> **"Drought, and climate change induced wildfire are such insurmountable things at this point. We weren't reacting early enough, today our agency is almost certainly more reactive than proactive." - District Botanist, USFS (R31)**

“We're becoming reactors, rather than planners and managers, I think. A lot of my job is now dealing with reacting to fires reacting to fire events, whether they're small or they're big, rather than focusing on research, consultation and cooperation to prevent these things from happening. And I think across the world, all managers are dealing with that now. Ideally, we'd be putting energy into managing and preventing these things from happening. Now we're working just to save infrastructure. We're working to save what's left.” - Monument Manager, Bureau of Land Management

“**We think about it, maybe on a broad scale, but I don't think individual land managers on the ground are thinking as much about climate adaptation.”- Fire Ecologist, NGO (R32)**

VI. Facilitation and Implementation of Adaptation

Implementation of Adaptive Actions and Examples of Successful Efforts:

A key area of variation between respondents was the extent to which they felt they would be able to effectively facilitate adaptation on the landscapes they work on. A restoration specialist for the NPS discussed the important work of trying to facilitate adaptation to the greatest extent possible while “realizing these changes are gonna happen either way, so how can we help find new strategies to mitigate that impact?” (R7). While discussing these perceived limitations, respondents also discussed successful adaptation efforts. 23 of the 37 respondents discussed restoration efforts as a key approach to climate adaptation and discussed strategies for restoration that they and their agencies have taken part in.

Over a dozen respondents mentioned efforts they described as successful examples of effective implementation of proactive planning and adaptation. When asked whether they or their agencies have implemented any strategies that they would consider to be adaptation on their landscapes, participants responded with success stories which mainly focused on restoration efforts. When asked about current

implementation, several NPS respondents discussed current efforts in progress for increasing renewable energy across their park units (R10, R20, R22).

A fire manager working on the Flagstaff Watershed Protection Plan (FWPP) discussed how there has been an investment of $10 million through citizen's approval of taxes to facilitate ecological restoration within priority watersheds in the city of Flagstaff, and efforts were matched by the U.S. Forest Service who provided an additional $12 million to assist the project's goals (R12). The restoration goals of the FWPP could reduce the threat of catastrophic wildfires in and around the city through proactive fire management. An NPS restoration specialist utilized citizen science by developing a QR code placed on stands that visitors can scan and easily set their phones up to take a photo of the landscape, which allows her to easily document post-wildfire recovery in regions of the park that employees are unable to monitor as frequently (R7). The development and expansion of long-term monitoring efforts of wildlife and vegetation were also highlighted as successful adaptation efforts by respondents across agencies (R4, R8, R21, R18, R26, R31, R37). Two respondents in NPS leadership worked to get additional wildfire and disaster preparedness training for their staff, finding this to be a successful strategy for adaptive management, especially since both had firsthand experience with the challenges of management during wildfire-related crises (R11, R28). Several respondents from the USFS discussed efforts to create a more desirable and resilient state of a mixed conifer forest, so that it will burn with lower severity and better protect a watershed that is directly above a town (R1, R31, R34).

Success stories of collaborative efforts were highlighted by interviewees. One respondent discussed the successful collaboration of the Four Forest Restoration

Initiative (4FRI) and the potential for similar initiatives to develop across the Colorado Plateau. Several respondents referred to 4FRI as a success, with respondents that have been working on the project hoping to collaborate on similar initiatives with a diverse set of stakeholders, including not just USFS, but NPS, BLM, state agencies, ranchers, and private landowners in landscape-scale efforts. Gaining the support of volunteers in on the ground management efforts for restoration, such as native plant reestablishment, tree planting following a disturbance, and introduced species removal, were seen as a successful way to get the community involved and educate the public about the importance of restoration (R21, R24, R29). Collaborative efforts led by the NPS's Water Resources Division, to preserve water resources across public lands across the region, have been successful in creating networks of stakeholders to contribute to the efforts and tie existing restoration efforts together (R10, R13).

A natural resource specialist for the NPS details a successful collaborative effort between managers of several NPS park units, two USFS districts, a family-owned ranching business, and private landowners to promote natural movements for the pronghorn antelope (*Antilocapra americana)*, which involved a task of rewiring fencing to non-barbed wire and raising the height of wiring across 270,000 acres (R26). Another respondent, a district wildlife biologist, discussed a funded plan to establish new wildlife corridors, in the form of infrastructure such as bridges, which will reduce habitat fragmentation, allowing for increased movement of multiple threatened and endangered species in their historic ranges (R1, R24, R27, R31). Respondents discussed the benefits of thinning vegetation and prescribed burning efforts as successful management strategies on their landscapes, leading to outcomes such as open

understories, less piles of woody debris, and wildlife returning to the region due to better browsing opportunities (R1, R4, R23, R24, R26). Several respondents from the USFS discussed the difficulties in conducting thinning treatments to restore fire regimes because there is little demand for small diameter wood, making it hard to remove wood after treatments (R1, R12, R23, R27, R31). The predominant strategies that were considered, discussed, and sometimes disagreed upon by respondents include prescribed fire and thinning efforts, seeding and tree planting, and assisted migration.

Approach to Adaptation - Prescribed Fire:

An increase of prescribed fire efforts was unanimously supported among respondents. Prescribed fire was mentioned as an effective strategy by nearly every respondent, and there were no negative comments about implementing prescribed fire. Several respondents acknowledged the disconnect between the public and scientists/managers in understanding and support of prescribed fire. Respondents frequently mentioned that public perception is currently still more favorable towards suppression rather than prescription burns and education is needed to shift public support for prescribed fire. According to a fire ecologist for the BLM, one of the main challenges that managers face is that they are already dealing with trying to keep ecosystems healthy and resilient in the face of stressors, and the accumulation of fuels that are yet to be removed leads to a much greater likelihood of large-scale catastrophic wildfires (R23). Respondents shared the understanding that wildfires are going to be a serious challenge and areas will be burned whether they choose to proactively manage for fire or to suppress fire. Respondents shared the view that prescribed fire allows for some level of control over when and how fires burn, while continued suppression will

lead to larger-scale, higher-severity fires. The sense that managers need to continue to and expand on their use of prescribed fire as an adaptive action was a commonality between respondents.

Several respondents expressed the challenges of prescribed fire being unable to be implemented at the necessary scale and timeframe needed in order to effectively be a proactive response. One respondent commented that monetary incentives are still present in fire suppression and are more profitable than prescribed fires.

> **“I hate to say it, but we do have a large percentage of the agency that makes a lot of money fighting fires [fire suppression]. So there's an incentive to go and put these fires out, but there's no incentive to do the right fire [prescribed fire]. So, people in our agency are going to do fire, they work 80 hours plus another 100 hours. So, they're getting all that overtime and hazard pay. That's a lot of money in their pockets. If you go to a prescribed fire, they're working 80 hours and they're not getting overtime for that. So, there's no monetary compensation for that, so there's no incentive to do that.” - Ecologist, U.S. Forest Service (R33)**

> **“Being able to maximize taking opportunities when they come with these shrinking windows. I think that's a climate change impact because our usual traditional prescribed fire windows are becoming more variable.” - Firefighter and Watershed Restoration Manager, Coconino County (R12)**

Approach to Adaptation - Assisted Migration:

The use of assisted migration as an adaptive action emerged as a contested issue across respondents. Though never directly asked about assisted migration, the topic was brought up frequently by respondents across agencies. Those with educational backgrounds in management tended to be more supportive of assisted migration efforts, while respondents with backgrounds in science tended to bring up concerns with increasing assisted migration efforts and introducing species.

> **“We as managers in the Forest Service don't like that, because those are not forests, they're grasslands, and it's converted to something other than**

forest. But that doesn't mean that they won’t serve a purpose, right?” - Research Ecologist, U.S. Forest Service

A USFS respondent, with a background in Forest Science, was strongly opposed to assisted migration, arguing that managers must begin changing views and perspectives of managed forests/ecosystems, and allow themselves to see value in different ecosystems that arise, whether that ecosystem was initially present on the landscape or not (R33). Another respondent that previously worked as both a botanist and chief of natural resources argued against assisted migration efforts and felt that overall, the less interventions managers make on the landscape, the better. One respondent from the U.S. Forest Service was strongly in support of the introduction of a tree species that is considered more drought tolerant and fire resistant, after noticing that the spruce trees were not recovering following a large fire, “So you don't want to plant a tree species here to keep this forest as a forest? Only because it came from Mexico, but the research shows it's going to align with the future climate here.” (R36).

Several respondents across agencies acknowledged their concern that without implementing a certain level of planned introduction of species or assisted migration, ecosystems will experience significant amounts of biodiversity loss. These respondents favored planned species introduction efforts despite the possibility of unintended consequences because they felt that the risk of “barren” landscapes would be a worse outcome. These respondents also felt that more research should be conducted regarding such efforts before implementing them.

Approaches to Adaptation - Seeding and Planting:

Another area of contrasting perspectives between respondents involves the adaptation actions of post-wildfire seeding and tree planting. Some respondents expressed optimism towards seeding and planting efforts for rehabilitating the environment following wildfire. A respondent working as a restoration specialist for the NPS expressed optimism that the cacti seedlings were successfully growing across the park and felt that it was important to conserve “iconic” park species, of both ecological importance as well as cultural significance to tribes throughout the region and to the public (R7). During this interview, the respondent showed me areas where she and volunteers had planted cacti seedlings the previous year that were growing successfully, taking the time to create irrigation channels around the cacti with rocks using the same method as the tribal community in this region. This respondent set up citizen science monitoring efforts in the park, where visitors can photograph the cacti regrowth at various stations, allowing her to monitor them over long periods of time. The respondent also showed me seed blankets of native species meant to reduce erosion and possibility for landslides following the wildfire which burned 88% of the park. These blankets were placed only several months prior, but the respondent felt optimistic that they would successfully rehabilitate the area, which appeared barren following the fire (R7).

Respondents discussed how they noticed variation between resource managers when discussing how comfortable they feel obtaining seeds from outside park boundaries and expressed a level of uncertainty about potential for unintended consequences of introducing seeds from other regions (R5, R22, R35). Several

respondents disagreed with this and felt that obtaining seeds from other regions allows for greater genetic diversity and could improve chances for seedlings to survive (R3, R7, R17, R36). A lead fire ecologist with the USFS that is working on a seed bank study found that seeds need to come from regions with similar ecotypes, or ecotypes that allow for more drought and fire tolerant species to grow successfully (R3). A restoration specialist for the NPS implemented a seeding project that failed entirely, which she attributed to having limited seed sources and the seed not taking in her park, but expressed that seeding is still a valuable adaptation tool, noting other projects that have had favorable outcomes, including the BLM Seeds of Success Program and the USGS common gardens projects (R22).

Both respondents that favored and opposed seeding efforts, often discussed their perspectives that the efficacy of seeding and planting is debatable, and more research is still needed to understand the timing of when seeds should be planted, which is especially uncertain in current drought conditions. These respondents did not discount the approach of seeding and tree planting entirely but suggested that more research would be beneficial. A respondent from the USFS felt that a more complete understanding of under what conditions and how many trees need to be planted is an area where more research is needed in order to have more successful results (R33). A BLM vegetation specialist felt that in terms of what kind of seeding works, “some of it is a bit experimental” stating that they are always trying to improve seeding practices, but that the question for managers still remains regarding which species will be the most resilient to ecological changes (R18).

Respondents in both upper-level management and science advising roles expressed negativity about post-fire seeding efforts due to their experiences with seeds and plants not surviving and efforts largely failing. Several respondents tried to seed and plant trees following a wildfire and had little to no success. A science advisor for the NPS stated that they planted across 10,000 acres several times following a high severity fire, with 90% of seedlings dying each time (R14). One respondent that did not favor seeding felt that the USFS and other agencies practice tree planting following wildfire events largely to benefit their image with the public, rather than based on scientific evidence, but acknowledged that more research is needed to understand the potential for successful efforts (R33). Multiple respondents stated that they do not see seeding as a long-term viable restoration practice, feeling that these efforts often are costly and ultimately unsuccessful (R6, R8, R34, R35, R35).

> **"Trying to rehab those areas with seed would just require a huge amount of investment to cross those thresholds back into its historic community, I had a professor tell us you'd be better off throwing money out of a plane instead of seeding" - Monument Manager, Bureau of Land Management (R35)**

The variation that emerged in perspectives between natural resource managers and those with job duties that include implementing efforts on the ground, such as restoration specialists and ecologists, reveals that vocational experience may influence perspectives regarding adaptation efforts.

Advice & Insights for Managers Yet to Experience Large-Scale Ecological Change:

Respondents recognized that a combination of both wildfire and drought conditions contributed significantly to the ecosystem transformation. Respondents

provided numerous insights regarding what they would do differently if faced with similar challenges, as well as what they have found works well and what they would like to continue to do in the future. Respondents shared these insights they gained in retrospect, with the hope of helping prepare others working in land management that have yet to experience large-scale change. The following section highlights the responses received when asked what advice they would like to share with natural resource managers that have yet to experience large-scale changes. The respondents have experienced large-scale changes; they wish to convey the following advice to managers that have yet to face large-scale changes. These insights range broadly from practical, on-the-ground management and implementation strategies, to planning and increasing proactive approaches, to offering encouragement for other leaders in the face of current and projected changes.

The insights given by respondents can be broadly categorized as focused on the following: fire, drought, and/or vegetation management, science-informed decision-making, proactive leadership and planning, proactive training and preparedness, communication and collaboration, and support and encouragement. Often, these insights coincide in terms of management applications. The fire, drought, and vegetation management insights are related to on-the-ground proactive management efforts that can help better prepare landscapes for ecological changes related to these stressors. The science-informed decision-making insights are focused on research insights that respondents found helpful to consider when creating management plans. Proactive leadership and planning insights refers to insights related to better planning and preparing proactive adaptation strategies and actions. Needs for proactive training and

preparedness was discussed less frequently than other insights but is worth mentioning because respondents that experienced large wildfires on the lands, they manage felt that staff would have benefited from increased wildfire and disaster preparedness. Communication and collaboration insights are related to the consistent theme of needing to improve in both these areas. Support and encouragement related insights emphasize promoting the psychological well-being of managers that have yet to experience large-scale change through encouragement and expressions of solidarity, reminding others that many are going through similar challenges.

Insights from Respondents That Have Experienced Large-Scale Ecological Change: Fire Management

- Break the fire return interval through green stripping, brown stripping, or treating invasives along roads to compartmentalize potential fires, so ecosystems have time to recover. (R3)
- Continue to create defensible spaces (R12)
- “Attack the most vulnerable sectors of your park that border infrastructures and buildings. It's important to estimate tonnage, dead and down, and bark infested fuels. It takes a brave manager to be able to find the funding to go in and remove those fuels, so that when a catastrophic wildland fire goes through it, it isn't severe, it becomes low or mosaic or low intensity.” (R11)
- Start planning before the next wildfire happens and start with identifying areas where you can do fuel reduction projects (R22)
- Encourage a better public understanding of the necessity for prescribed burns and the important role fire plays in ecosystems, especially through outreach and education (R17, R22)

- Embracing fire rather than suppressing it because mechanical thinning alone will not solve current challenges. Fire suppression is ultimately going to lead to more loss of forests. (R32)
- Using natural fiber mats to stabilize slopes, prevent erosion, and preserve the soil, allowing for increased ability for restoration following large wildfires (R17)
- "As a scientist, I think we have the solution. The solution is more fire. It's as easy as that." (R33)
-

Drought Management

- Prioritize addressing and focusing management actions in the most severely drought stressed ecosystems because they become more fire prone as drought worsens (R10, R25)
- Understand that grazing and water permits are going to decrease in availability and help permit holders prepare for these declines and inevitable shifts in water access (R19)
- Advocate for protection of water resources over increased recreation, development, and grazing and finding ways to shift toward increased water conservation (R29)
- Update Park infrastructure to conserve water and plan for water shortages and how these will impact visitors and staff (R20)

Vegetation Management and Restoration

- Focus on managing plants that alter the fire regime, such as annual invasive grasses which thrive on disturbance (R12)
- Follow-up seeding efforts as much as possible because sometimes certain conditions are not met and that leads to seeding being nonviable (R22)
- Create a better, fully comprehensive database and map layers of introduced species invasions. While different organizations have taken on small parts of gathering this data this is a massive undertaking, as the invasion is on such a massive scale and increasing exponentially (R37)
- Allow traditional knowledge to inform restoration decisions and approaches. For instance, use traditional water irrigation and channel diversion methods to protect

seedlings from erosion and flooding, especially when implementing post-wildfire restoration (R7)

- Reconsider the planting of solely commercial species as a strategy and instead focus on increasing biodiversity and resilience through planting (R3)

Science Informed Decision-Making

- Continue to work sound ecology and science into management and follow the advice of scientists not politicians (R2)

- Advocate for funding long-term studies to document landscape scale changes and impacts on species over time (R16, R20, R21, R22)

Maintain Ecosystem Function

- Promote species diversity, don't eradicate entire tree species from a stand (R1)

- Be cautious when making choices to help ecosystems recover, rely as much as possible on natural processes. Interventions should focus on ensuring natural processes take place and ecosystems remain intact to the greatest extent possible (R8, R30)

- Place management emphasis on conservation of biodiversity and preservation of system integrity, shifting away from the focus on conservation of "iconic" and "charismatic" species (R4)

- Focus on carbon storage as a management priority. (R12, R24)

- "There needs to be a paradigm shift towards more conservation of system function, the actual components of the systems are going to be changing, and we just need to maximize the function. By function, I mean fixing carbon, pulling nitrogen out of the ground, supporting a robust assemblage of native wild plant and wildlife communities, providing an ecosystem service we rely upon, storing carbon and turning out oxygen. We still want to have these vibrant and robust systems, but the components are going to be changing, and they're going to start changing quickly." (R24)

Proactive Leadership and Planning

- Advocate for a transition from a seasonal workforce to a larger year-round workforce in order to extend the timeframe for conduct prescribed fire and management efforts (R12)

- Advocate for a shift to a year-round workforce to increase knowledge and understanding of the ecology, history, and current challenges in the region, rather than having seasonal employees shifting across many regions (R14, R26)

- Hire employees with strong first-hand education and experience of the landscapes and an understanding of the region (R26)

- Getting project plans approved proactively, increasing the ability to respond ahead of time (R35)

Proactive Training and Preparedness

- Become a “student of fire,” meaning to take the time and training needed to learn more about fire ecology and encourage your colleagues to do the same. A better understanding of fire science will allow you to develop more tools to better protect the ecosystems we work in. (R19, R26, R30)

- Personnel training for improved methods of presenting ideas to one another that facilitate effective communication and allow for more open discussion of novel ideas and strategies that may not be part of the status quo (R15)

- Implement disaster preparedness training and require staff to participate and understand what to do in the event of a major wildfire or disaster and ensure the entire team is prepared(R28)
- “The way we've managed in the past, it's not working. It doesn't mean it hasn't taught us things. Sometimes those lessons are bad lessons, or the lessons we should have done differently and now we know.” (R19)

- “Use every tool in the toolbox. Send experts into the field and tell them to come back with whatever options they have, and find something that’s doable and implementable” (R24)

Communication and Collaboration

- Managers need to communicate and increase their planning efforts with scientists, their fire management teams, and cultural resource employees. Plan as a team and prepare historic structures and infrastructure for wildfire. (R11)

- Greater education and outreach related to drought, wildfire, and climate change in order to encourage public support and greater funding (R27)

- Continuing current and expanding interagency and stakeholder partnerships (R31, R34)

- Increasing actual collaboration instead of just using the term (R11)

- Sharing resources, data, ideas, and proactively planning as a team as much as possible, and more holistic approaches to management (R34, R21, R9)
- Prepare through information gathering, through working with others, and reaching out to other managers, really examining modeling, understand what transformations may be possible in the future so that managers can make proactive decisions (R8)

- For researchers, share how your findings can be used now, or a year from now, so managers can apply it on the ground, including actionable steps would be extremely beneficial (R13)

- "Maintaining consistency in approach and breaking the problem down into components that identify what changes are needed and then trying to implement those in our on-the-ground efforts has been really successful" (R32)

- "Let's learn together, let's do research, let's fund these projects, let's get the background data. And working towards action. Remind yourself that it is all about action in the end. We could spend years researching and getting baseline conditions, but climate change is urgent and, in the end, you should be taking action" (R26)

Support and Encouragement

- "Don't be afraid to try new approaches" (R35) and "stay open minded and be willing to consider new approaches, and learn new restoration techniques and strategies" (R17)

- "Find your purpose or relocate if you lost it, as far as why you do the work you do. Find the passion in it, because that's what's going to keep you going. If you do have hope, keep that hope alive, know that what you're doing makes a difference." (R30)

- "Don't forget to breathe. Take a deep breath. I really think it comes down to letting the data drive the discussion. We must allow ourselves a little bit of grace to be human because these things are going to be hard. Yes, most places that you loved and cared

about, and that you knew like the back of your hand will experience changes. But we can help determine what happens next" (R36)

Table 2.2 *Examples of Advice and Insights Provided by Respondents*

VII.Supporting Effective Management Under Drought, Wildfire, and Climate Adaptation:

Necessity for Effective Science Communication and Outreach:

The benefits of effective science communication were a common theme when discussing opportunities and advice for how to gain support for adaptive management decisions and facilitate action on landscapes. Primarily, respondents discussed the need for science communication in the context of the outreach to the public, noting that the public has the ability to influence what actions agencies are, or are not, able to implement (R1, R3, R5, R8, R10, R11, R12, R14, R15, R17, R22, R25, R29, R34, R35). Specifically, at the policy decision-making level, respondents felt that public support could provide opportunities and resources for increased support for adaptation efforts. Respondents across agencies felt that the National Park Service has been the most successful in interpretive outreach to the public, and respondents from the USFS expressed the hope and desire to see more interpretive positions in the USFS (R8, R23, R25). A respondent from the BLM felt that there is a strong need for more interpretive positions in the BLM, but that the remote nature of many of the lands managed by BLM has been a limiting factor (R19).

Respondents discussed the challenges of the diversity of values and perspectives of the public influencing their ability to effectively communicate scientific ideas. This was brought up most frequently when discussing the need for increasing prescribed fire application across landscapes, with multiple respondents citing that

efforts are often restricted due to public perception. As discussed in the public perception subsection, the attitude of the public toward prescribed fire can either limit or allow for increased efforts. Respondents felt that increasing the public's scientific understanding of wildfire would present greater opportunities for needed policy shifts at the state and federal level, and support for agencies to implement the widespread prescribed fire efforts needed to restore historic fire regimes. Two respondents that were leaders on the 4FRI project found that prioritizing community engagement and understanding of wildfire and the need for restoration efforts, not only built lasting connections between agencies and the public but shifted views in favor of large-scale restoration efforts (R9, R12). 4FRI (The Four Forests Restoration Initiative), used a combined thinning and burning approach as treatment for four natural forests in Arizona (McCauley et al., 2019). This single large-scale restoration of ~400,000 ha provides climate benefits equal to removing the emissions of between 55,000 to 110,000 vehicles each year through 2100 (McCauley et al., 2019). The 4FRI project would not have been approved by the public if it was not for taking small steps such as going into the community and educating about fire safety and promoting tree thinning in people's backyards, and incrementally building the social license necessary to treat over 2 million acres of forest (R12). Respondents also felt that the 4FRI project was successful in getting support due to its collaborative nature, where the public may be distrusting of a given federal or state agency, they found that the community was supportive and encouraged that multiple agencies and stakeholders were advocating for the project (R3, R9, R12). This speaks to a potential need for increased collaboration between agencies in science communication and outreach efforts with the public. Across

agencies, there was a focus on the need for communication efforts to be focused on how the community prefers to receive information. An NGO leader, who frequently collaborates on projects with federal agencies and ranching stakeholders, mentioned how social media outlets, such as Twitter, were often an ineffective way to communicate with the key audiences she works with, and that it is important to focus communication efforts and resources on outreach that is applicable to the target audience (R15).

Multiple respondents felt that the charismatic and namesake species that are managed on the Colorado Plateau, from ponderosa pines to pronghorn antelope, should be focal points for outreach in order to convey the impacts that stressors such as climate, drought, and wildfire will have on the landscapes. While overall respondents felt positively about science communication efforts with the public, there were suggestions for improvements and opportunities that have yet to be taken. One respondent stated the necessity for greater incorporation of education focused on climate change within park visitor centers in order to facilitate effective science communication (R26). This respondent cited Glacier National Park as being a leader in effective science communication through their visitor centers and interpretive signs that highlight climate change and the impacts it is having on the park's glaciers to a large audience. The respondent felt that many managers have not incorporated climate change-related messaging in their interpretation and outreach due to concerns of making the public feel guilty, leading to loss of popularity and public disapproval. Several respondents expressed interest in increasing interpretive signs at heavily trafficked locations on the lands they manage, with the hope of better educating the public while they are visiting and connecting to the landscape (R5, R7, R26). There were no respondents who

expressed that greater science communication efforts were not necessary, though not all respondents brought up science communication as needed to facilitate effective adaptive management.

Necessity for Increased Resources, Support, and Leadership:

When asked to describe the greatest barriers to implementing climate adaptation projects, respondents primarily discussed needing resources in the form of funding and staff, greater support and direction from agency leadership and government administrations. Without addressing these needs, multiple respondents felt that they would continue to be unable to effectively implement projects. Respondents specified needs for increased resources, support, and leadership necessary to shift toward more proactive management. Increased resources in the form of funding and staffing are needed to effectively facilitate adaptive actions. Respondents frequently discussed planned projects they would implement if they had the necessary resources. Several respondents discussed ideas for new job positions they would like to create to assist with adaptive efforts. Other respondents discussed the need for greater numbers of employees in all aspects of fire, from more firefighters on the ground to more fire scientists and GIS experts to support them (R3, R34). A few respondents also discussed the need for additional training for staff to better prepare and respond to future wildfires (R11, R30).

Respondents discussed the need for a greater expansion of scientific understanding related to the changes occurring on their landscapes, as well as current and projected trends throughout the region, in order to better determine which management approaches to take. The main needs for information identified in order to

create stronger scientific understanding and facilitate decision-making are in actuality more related to needs for resources, as respondents discussed the need for greater funding and easier abilities to hire staff to conduct research. Four respondents held somewhat contrasting views, finding that the amount of available scientific information is overwhelming, and cited lack of time to review existing research on top of all of their other job duties, as a significantly greater obstacle than the lack of information itself (R2, R23, R24, R36). Respondents found it helpful when organizations actively share new research briefs and newsletters, and when scientists publish research findings in a clear, concise manner that managers can implement from.

Many respondents across agencies felt overwhelmed by the number of duties they have, stating that their job should be divided into the work of multiple individuals. Because of this, the respondents felt they have been unable to manage and oversee all of their planned projects, let alone keep up with the latest research findings.

> **“I think in the public land management realm, no matter what agency you're talking about, generally speaking, we don't have the resources and for a long time haven't been able to do enough on the landscape, whether it's staffing limitations or project funding limitations. We’re always being asked to do more with less which doesn't work, period. It's not how I want to approach the management of these lands. We do the best we can with what we have and most of the time, it's not enough, but it is what it is.” - Superintendent, National Park Service (R28)**

When looking at needs from agency leadership, several respondents discussed the need for more processes, directions, and support developed at the national or regional level in order to better understand how to implement adaptive action, with a superintendent from the NPS citing how difficult it is to feel as though each park unit is left to navigate these decisions alone (R21). A resource management technician for the NPS felt that park units are often isolated from one another and “decentralized” from the

larger agency, and a great deal of power is given to park superintendent to make major decisions, which sometimes does not leave room for novel ideas or strategies for management (R5). Several respondents described management directions given by those in agency leadership as often conflicting, confusing, and/or unclear (R5, R11, R21). Other respondents disagreed, feeling that management directions and strategies are clear, mentioning that many adaptation toolkits and resources are widely available, but efforts have been lacking due to funding and staff issues. One USFS respondent felt that financial resources should be available but are dependent on U.S. government administrations which have the ability to allocate resources to federal agencies, more than the agencies themselves. He argued that financial resources are available in the U.S. and agencies just need to be given them, stating "there is no richer country in the world and these lands are managed by the federal government. I have worked a lot in Mexico and managers wish they had the resources we have" (R33). Over the course of this project, the discussion on resource related limitations shifted to a more optimistic outlook from multiple respondents due to the passing of Biden's IIJA, which will be discussed in the next section.

Recent Legislation to Support Management Actions - The Infrastructure Investment and Jobs Act of 2022:

Beginning in August 2022, respondents from multiple agencies discussed the Biden Administration's Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Law (BIL), which has led to increased funding for projects and increased ability to hire new staff, including $5.5 billion allocated to the U.S. Forest Service (USDA). The IIJA also provided $103 million specifically for wildfire

management, including $80.9 million for prescribed fire and fuels management, and $19.4 million for Burned Area Rehabilitation projects, as well as funding for the creation of an interagency firefighter health and mental wellbeing program (U.S. Department of Interior). The respondents expressed mostly positive opinions and optimism related to the IIJA about being able to implement projects that had been placed on hold due to budgetary limitations and looked forward to hiring staff for increased on the ground management efforts, including monitoring, surveying, and fire management efforts, such as prescribed fire and thinning treatments. A fire ecologist for The Nature Conservancy, expressed optimism that the IIJA would allow greater collaboration on proactive projects between organizations and that the IIJA was a major step forward in the right direction to address the climate crisis, particularly that it provides significantly greater funding for wildfire management at a much larger scale (R32). A monument manager for the BLM noted that funding had already been received to increase prescribed fire efforts and several projects that had been on hold were able to resume (R35). The consensus of the respondents was an optimism and sense that the IIJA provides a great deal of monetary support to federal agencies and this legislation will help managers enact adaptive strategies and hire new staff to gain a better understanding of what changes are occurring on their landscape.

However, the IIJA does not solve all existing limitations and several respondents provided more critical perspectives related to the IIJA. A manager from the BLM expressed that while the IIJA provided much needed funding, with economic inflation, the funding has not been enough, and resources are still spread thin (R18). The BLM works with contractors to have environmental and cultural assessments done, as they

tend to manage large amounts of acres and do not have the internal staffing to do all of the monitoring needed (R18). This respondent experienced how management contracts take a great deal of time to be approved and processed, and following approval, there is a new obstacle of rising fuel costs that are prohibitive to hiring contractors and getting them to remote locations, leaving many projects on hold (R18). Multiple respondents across the three federal agencies noted how the remote locations of many public lands managed by these agencies leads to the need for more competitive salaries and opportunities for affordable housing.

While the IIJA provides funding to hire more staff, there is still the challenge of being able to offer higher salaries to compete with job opportunities in less remote locations. A fire ecologist for the USFS felt that the IIJA did not resolve the problem of it being “very, very challenging” to draw people into the career field of fire, even when pay increases were offered (R3). This respondent mentioned that there are vacancies across multiple areas, from positions such working on engines, in aviation, Helivac, and hot shot crews, but also in supporting roles (R3). An NPS superintendent expressed a sense of frustration that while major influx in resources will be helpful for him to implement projects and improve park infrastructure, the funding will ultimately be ineffective at addressing large-scale ecological problems, “it's not going to solve the problem because the scale of the problem is too large, it's a global situation, it's not just localized anywhere” (R30). The IIJA is unable to solve the problem at a global level, but managers are looking forward to increased support for projects that have been awaiting funding.

Necessity for Increased Collaboration Between Agencies, Managers, and Scientists:

The need for increased collaboration between agencies, and/or between managers and scientists was discussed by 28 of the 37 respondents. Collaboration between agencies, especially inclusion of tribal agencies, was seen as an important way toward improved successes of planned efforts. There were no respondents that expressed opposition related to additional collaboration between agencies and stakeholders, or managers and scientists. Respondents discussed how planned projects could be made more successful through greater collaboration. Though beyond the scope of this project, numerous respondents discussed the crucial need to include tribal leaders in collaborative efforts when the lands they manage border tribal lands, and multiple respondents discussed the need for tribal perspectives to be included in all decisions involving their ancestral lands that rightfully belong to them (R11, R14, R26, R32, R33, R34, R36). It is important to note that such collaboration would need to allow the tribal leaders to have equal power in making decisions.

Increased collaboration addresses issues of spatial scale, because respondents managing smaller landscapes are better able to express how decisions made on adjacent lands impact their park (R5, R21). Collaboration can not only lead to more effective management, but also cultivates empowerment, involving managers of smaller public lands in the decision-making process. Several respondents expressed frustration with the difficulty in accessing funding that could be used for projects that extend outside of the boundaries of the lands they manage.

> **“We need to be able to work together. I have a great relationship with the National Forest which surrounds me around [park unit], but it's difficult to**

co-manage projects. It's difficult to co-manage funding." - Superintendent, National Park Service (R21)

As discussed in the previous section, respondents discussed examples of facilitation successes with cross-boundary and cross-agency projects. Many of the adaptation successes described by respondents were a result of effective stakeholder collaboration and increased involvement between agencies. Several respondents expressed the need for federal and state agencies, especially in regions where lands managed are adjacent to each other, to come together and create proactive management strategies. One respondent, an NPS archaeologist with over two decades of experience in crisis response, discussed how training for crises would benefit greatly from including participants from multiple agencies, as well as nearby community leaders, determining plans of action and what resources can be shared and how to best go about this, for instance sharing a helicopter when a large wildfire occurs (R11). Multiple respondents echoed this sentiment, expressing that wildfire, drought, and climate impacts extend outside the boundaries they manage, and that collaboration on proactive strategies would be mutually beneficial.

One challenge identified by respondents (R14, R28) for long-term and larger-scale collaborative efforts is how people tend to move from location to location frequently in federal agencies. Establishing greater numbers of permanent positions and encouraging individuals to advance in their careers within the same region, preferably the same park unit or national forest, would allow for greater collaboration between agencies, as well as building trust with communities (R14). Both NGO leaders interviewed discussed how much of their work is related to facilitating collaboration

between stakeholders particularly identifying needs and how these needs overlap in order to enact important on the ground research and stewardship projects (R29, R32).

In addition to increasing collaboration between stakeholders, creating more collaboration between managers and scientists was a common theme. A manager from the BLM found that collaboration with USGS researchers allowed her team to have a better understanding of soil science, allowing her to make more informed decisions (R19). Multiple NPS and USFS respondents discussed the importance of their collaborative efforts to build and share knowledge with other agencies and researchers from the USGS, the Rocky Mountain Research Station, and a wide number of universities. Overall, promoting collaboration was seen to better address the spatial and temporal issues that adaptive management under uncertainty poses, giving stakeholders means to address, prepare for, and mitigate ecological stressors on their landscapes while also building a sense of community when addressing large-scale changes.

VIII. Demographics of Interview Respondents:

Table 1.1 *Current Agency Affiliation of Interview Respondents*

National Park Service	U.S. Forest Service	State Agencies	Bureau of Land Management	NGOs
18	10	4	3	2

Table 1.2 *Interview Respondents' Current Region of Employment*

Arizona	Colorado	Utah	New Mexico
21	6	5	5

Table 1.3 *Total Years of Experience of Interview Respondents*

1-5 years	6-10 years	11-19 years	20-29 years	30+ years
4	10	11	9	3

Table 1.4 *Vocations of Interview Respondents*

Vocation Type:

Natural Resource Manager	Superintendent, Monument Manager, Program Manager/Director	Physical Scientist, Ecologist, Science Advisor	Fire Management, Fire Ecology	Vegetation and/or Restoration Specialist, Botanist	Wildlife Biologist, Wildlife Program Director
10	9	6	6	4	2

Table 1.5 *Education of Interview Respondents*

Educational Background:

Bachelor's Degree	**Master's Degree**	**Doctoral Degree**
14	16	7

CHAPTER FIVE

SURVEY RESULTS

Introduction:

The principal takeaways and themes that emerged from the interviews in chapter four of the results were expanded upon to develop questions for a survey that was distributed to a larger network of natural resource managers, and those in related fields or organizations who are currently employed in the Southwestern U.S. The survey expanded the geographic scope from the Colorado Plateau region to include the larger Southwest region of the U.S. The survey questions were directly influenced by the results obtained from the interviews with land managers that have experienced large-scale ecosystem changes. The online survey included 36 questions in total, with the overall focus of the questions related to personal perspectives related to landscape scale change, wildfire, drought and climate adaptation. The survey was designed and hosted at NAU with a mixed-methods approach which included a combination of open-ended, fill-in questions, as well as close-ended questions, ranking questions and 3-point, 5-point, and 11-point, Likert-scale questions.

A weblink to the NAU survey was distributed through listservs and newsletters of the Southwest Fire Science Consortium, Arizona Game and Fish, and the Southwest Climate Adaptation Center. The link to the NAU survey was also shared with federal land managers, and further shared by interview participants via email and a clickable link to individuals they identified as working in the field of natural resource management in the Southwest. One hundred fifty-three responses were collected through these

listservs and through an anonymous link. The final way in which the survey was distributed was through a QR code I printed on business cards and distributed at the Biennial Conference of Science and Management on the Colorado Plateau, which accounted for 15 of the responses. Two hundred fourteen individuals opened the survey, and of those 214, 153 participants answered at least 50% of the questions.

Not every survey participant answered every question, and as long as survey participants answered over 50% of the questions, their answers were accounted for in the survey results. Survey participants sometimes chose to skip questions that required a short answer or fill-in-the-blank response, which is a common occurrence for online surveys and one of the reasons the majority of the questions were not created in this format. This chapter is structured around the key themes and takeaways determined over the course of the interviews.

I. Demographics of Survey Participants:

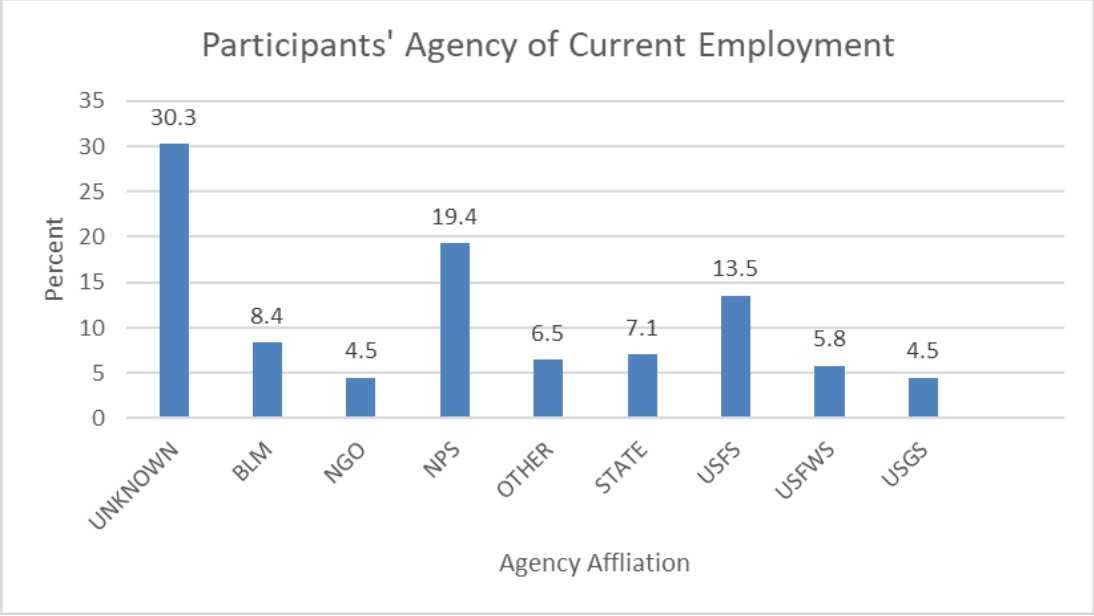

Figure 7.1 *Participants' Agency Affiliation for Current Position*

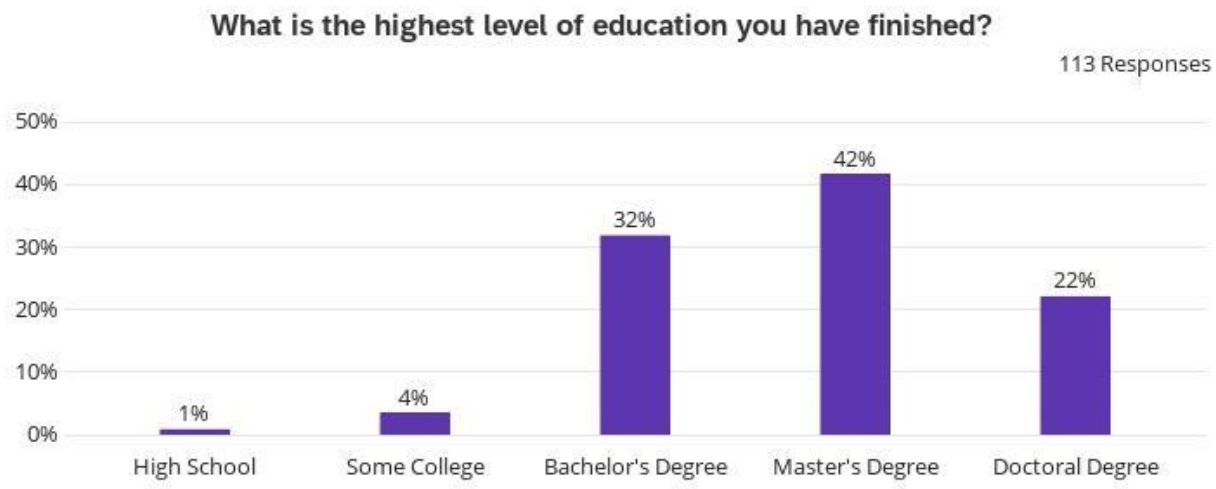

Figure 7.2 *Participants' education levels*

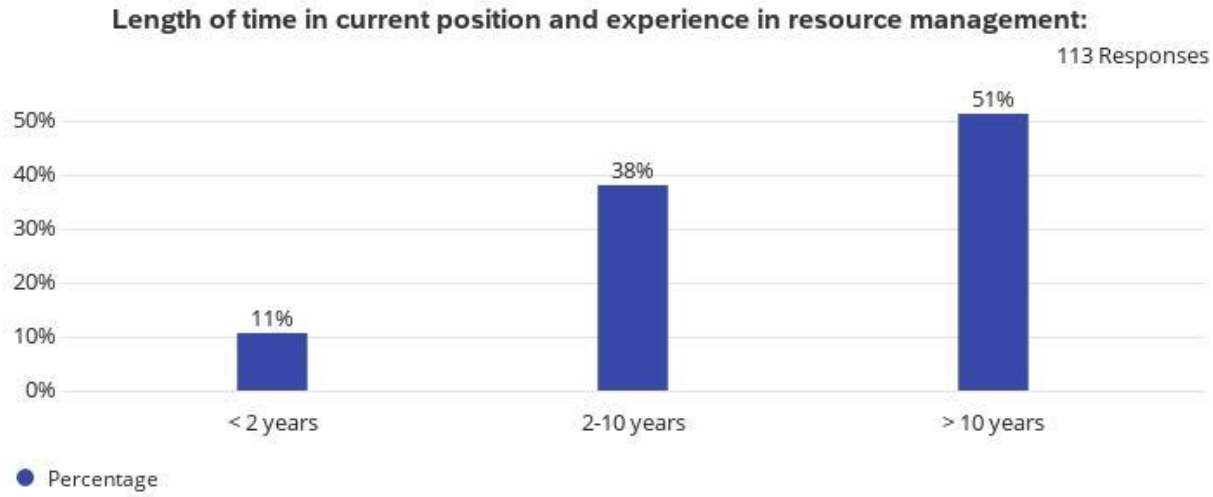

Figure 7.3 *Years of experience of participants in current position/similar positions*

II. Stressors:

Participants were first asked to consider the extent to which they have experienced stressors on the landscapes in which they work. While the interviews targeted decision-makers on public lands that identified themselves as having experienced large-scale ecological transformation and change, survey questions were

developed to better understand the degree to which ecological stress and/or transformation is being experienced by managers more broadly across the Southwest. Participants were not required to have experienced a significant degree of ecological change on their landscapes in order to complete the survey. Participants were asked to characterize the degree, spatial scale, and temporal scale to which they have experienced drought and/or wildfire, as well as to characterize the overall extent these stressors have impacted the ecosystem(s) they manage. When asked to characterize the degree to which ecosystems in which they work have experienced the stressors of drought and wildfire, participants were given five options, ranging from not at all, slightly, moderately, substantially, to completely.

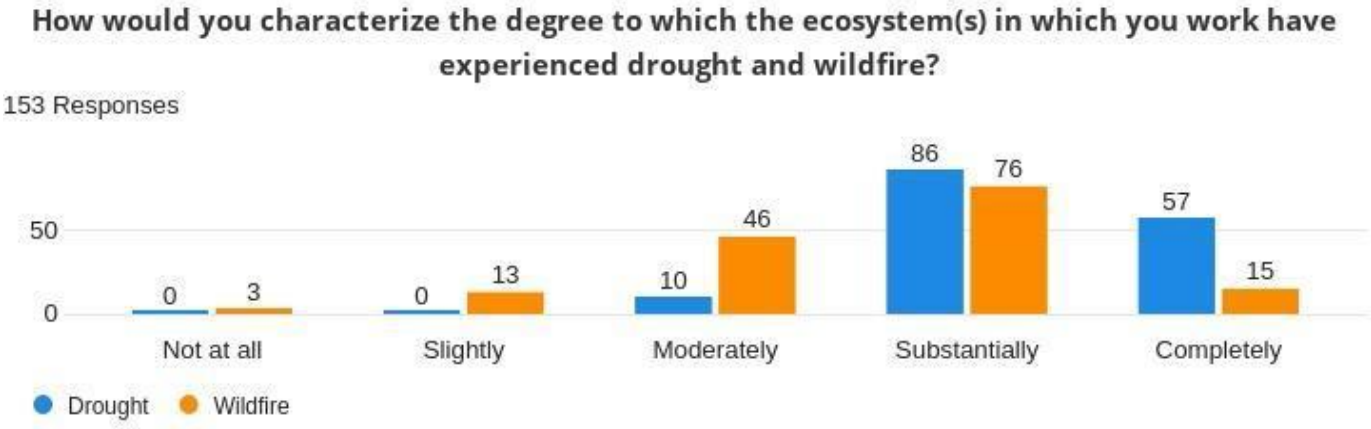

Figure 1.1 *Degree of ecological stressors drought and wildfire experienced in Southwest ecosystems* (χ2: 20.87, *p*-value: 0.007)

Survey participants responded that drought was frequently experienced more substantially and completely than wildfire across ecosystems. Primarily moderate and substantial wildfires impacted the landscapes (Figure 1.1, Figure 1.3). The chi-square test was used for comparison of drought and fire distributions of responses (Figure 1.1). Both drought and wildfire primarily have been experienced to a substantial extent in

ecosystems (Figure 1.1). The large number of participants who stated that drought had impacted the landscape “completely,” indicates that drought is being experienced to a widespread degree throughout ecosystems in the Southwest (Figure 1.2). There were no respondents who felt that drought had not been experienced in the ecosystems in which they work (Figure 1.2). The questions of drought-induced stress and wildfire-induced stressors were answered by an equal number of participants.

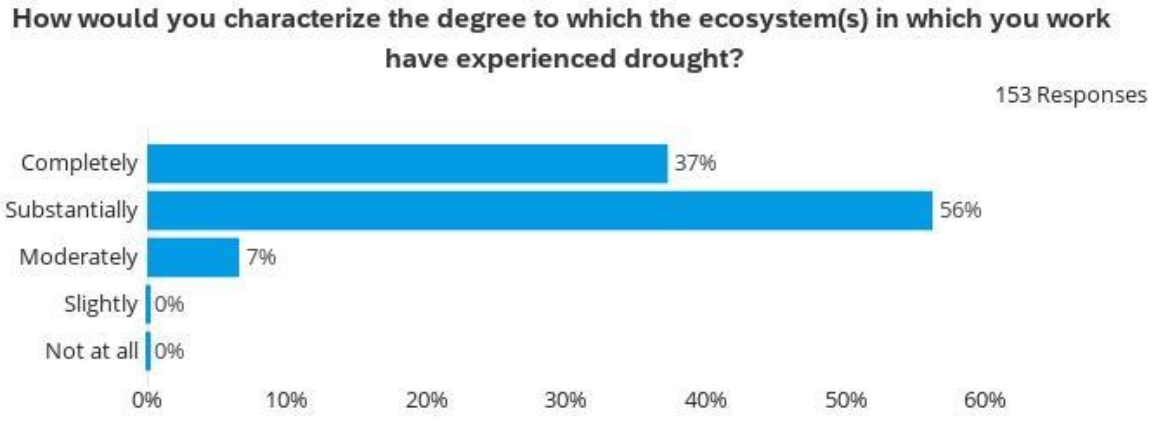

Figure 1.2 *Extent of Drought Experienced in Southwestern Ecosystem(s)*

Most frequently, participants responded “substantially” (56%), followed by “completely” (37%), followed by a small percentage reporting moderate (7%) levels of drought experienced, with 0% of participants responding “slightly” or “not at all.” Drought is being experienced to a significant extent across ecosystems in the Colorado Plateau region.

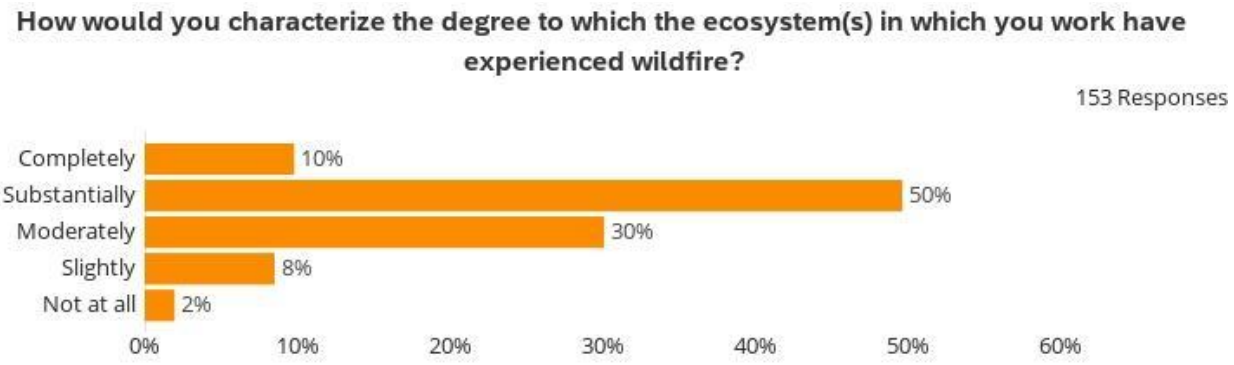

Figure 1.3 *Extent of Drought Experienced in Southwestern Ecosystem(s) Experienced by Managers*

When asked the degree to which wildfire has been experienced in the ecosystems in which they work, half of participants responded “substantially” (50%), followed by moderately (30%), “completely” (10%), “slightly” (8%), and “not at all” (2%) (Figure 1.3). The majority (60%) of participants found that wildfire has been experienced to a significant degree. It is important to note that fire is a natural and important component of healthy ecosystem function (Hurteau et al., 2014, Roos et al., 2022). A consideration should be that these results are not inherently negative for the Colorado Plateau region and dependent on the connotation of “substantially.”

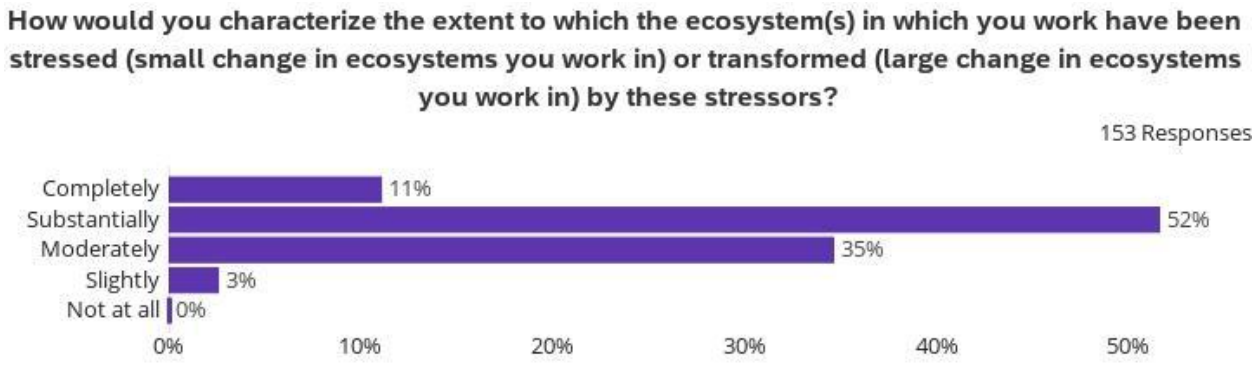

Figure 1.4 *Extent of Ecological Stress and/or Transformation Experienced by Managers*

The majority of participants (63%) reported that the ecosystems in which they work had been “substantially” or “completely” stressed and/or transformed (Figure 1.4). There were few (3%) participants who did not feel that ecosystems are experiencing a great deal of change, reporting ecosystems have been stressed “slightly.” There were no participants (0%) that reported lack of ecological stress impacting ecosystems in which they work (Q3).

The overwhelming majority of participants (93%) reported that drought had been experienced either “substantially” or “completely” in the ecosystem(s) they manage (Figure 1.2) and 80% of participants reported that wildfire had either been experienced “substantially” or “completely” (Figure 1.3). Responses to questions related to participants’ characterization of ecological stressors indicate that natural resource managers are often experiencing substantial levels of stress (63%, Figure 1.4) across ecosystems due to the stressors of drought and wildfire.

III. Ecosystem Response:

Participants answered a series of questions regarding their views of the ability for stressed and/or transformed ecosystems to respond to changes brought on by increased frequency and/or intensity of ecological disturbance and change. Ecological disturbances cause changes to a landscape, which can sometimes be beneficial for ecosystem health but also can cause lasting damage and harm to the ecosystem.

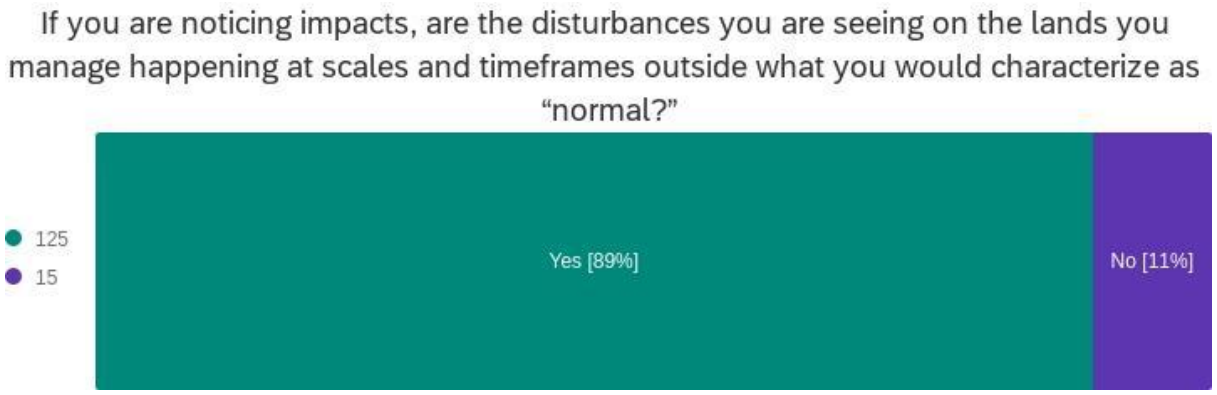

Figure 2.1 *Perception of disturbances occurring outside of "normal"*

The majority of participants (89%) reported that the disturbances seen on the lands they manage are happening at scales and timeframes outside what they would consider to be "normal," with only a small proportion of participants (11%) reporting that disturbances are outside of what they would normally expect to experience on the lands they manage.

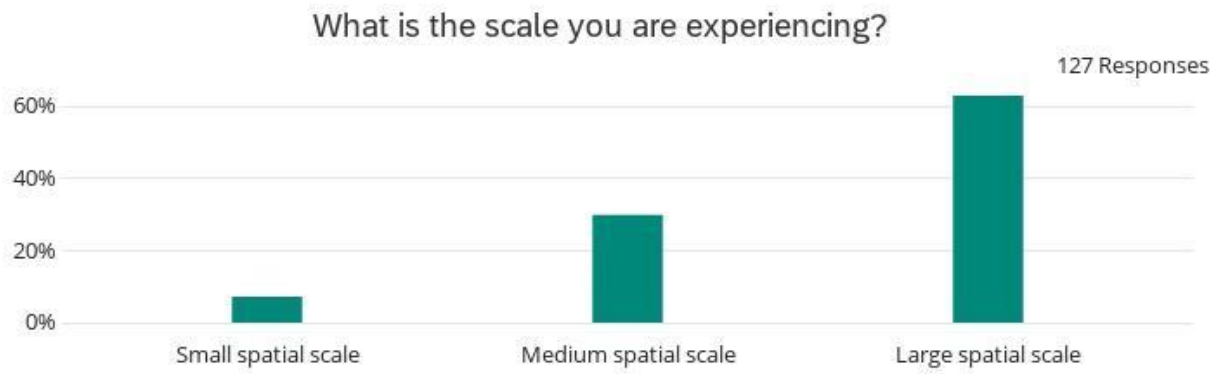

Figure 2.2 *Managers' views of spatial scale of disturbances occurring outside of "normal"*

The majority of participants reported disturbances occurring at a large spatial scale (63%), followed by a medium spatial scale (30%), and least often occurring at a small spatial scale (7%) (Q6).

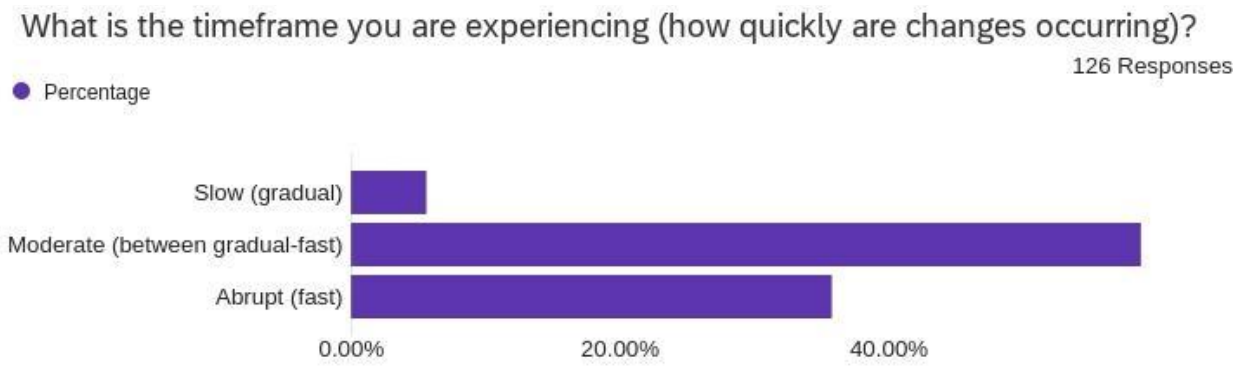

Figure 2.3 *Managers' views of temporal scale of disturbances occurring outside of "normal"*

Most frequently, participants reported that the pace of disturbances occurring on the lands they manage is occurring at a "moderate" timeframe (59%), followed by "abrupt (fast)" timeframe (36%), with the fewest (6%) participants reporting a "slow (gradual)" timeframe for observed changes (Q7). The spatio-temporal scale of ecological disturbances presents important considerations and challenges for present and future management. Participants (89%) observed the spatio-temporal scales of disturbances occurring outside of "normal," as well as happening primarily at large spatial scales (63%) and at a moderate pace (59%). Through utilizing the chi-square test to determine whether the results deviated from an even distribution among possible answer categories, survey participants' experiences of the spatial and temporal scales of landscape changes was determined to be statistically significant ($\chi 2$: 29.08, *p*-value: < 0.001).

Ecological disturbances occurring at larger spatial scales and in shorter time frames can reduce the ability for an ecosystem to return to equilibrium following a disturbance, and thus require a more extensive management response (Zelnik et al., 2018). As discussed in the interview results, managing ecological stressors at large

spatial scales becomes more difficult when combined with changes occurring at a moderate to abrupt pace (Chapter 4, p. 15-17). As shown in the interview results, this leads to increased challenges for managers to respond to ecological changes effectively (Chapter 4, p. 15-17)

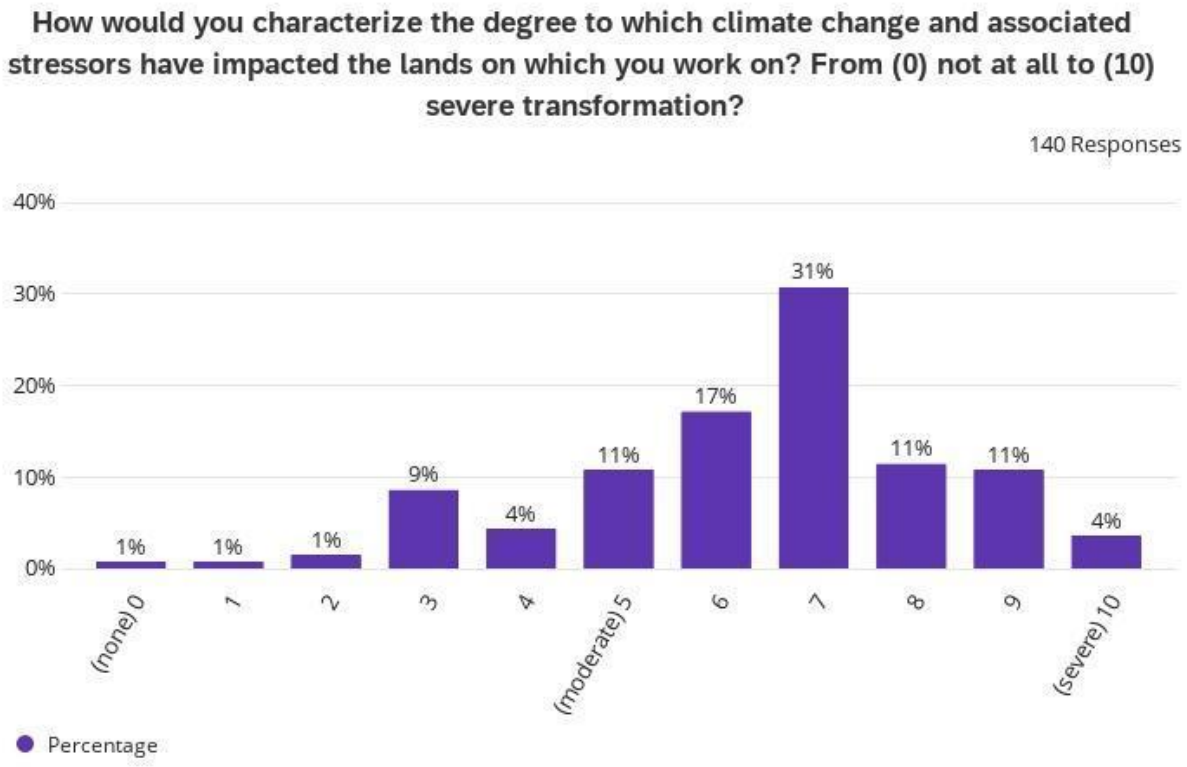

Figure 2.4 *Perceived degree to which climate change and associated stressors* ***have impacted*** *ecosystems in the Southwest U.S., when asked to select one choice on a scale of 0-10.*

Participants largely (89%) reported that climate change and associated stressors have contributed moderate to severe levels of impacts (5-10 on the scale), whereas only 16% reported minimal or medium levels of impacts (0-4 on the scale). (Q8). The majority of participants (31%) selected 7 out of 10 on the stressor impact scale, indicating that managers working in the Southwest region largely viewed climate change and associated stressors as contributing slightly over moderate levels (7 out of 10) to

current ecological transformation and change, with few results that showed disturbances viewed as causing minimal ecological stress (16%).

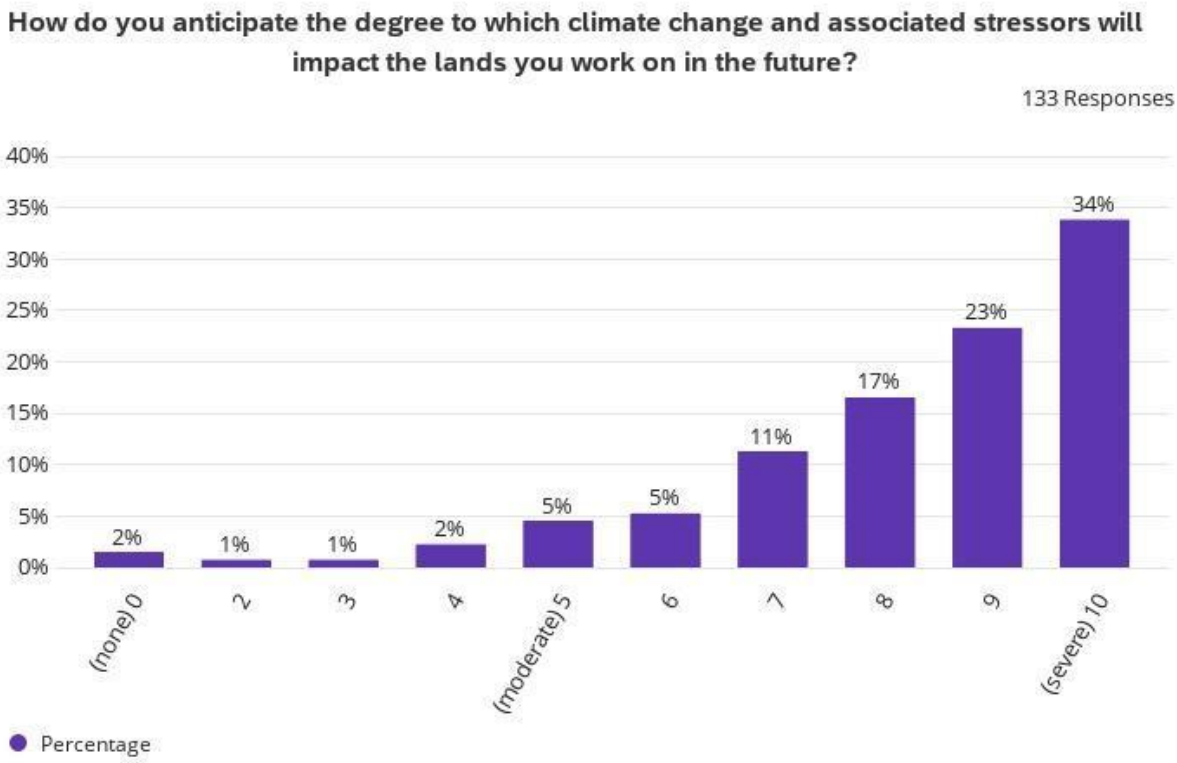

Figure 2.5 *Perceived degree to which climate change and associated stressors* ***will impact*** *ecosystems in the future in the Southwest U.S., when asked to select a choice on a scale from 0-10.*

High levels of future ecological stress were predicted by 74% of participants (choices 8-10), and of this 74%, 34% viewed anticipated future ecological stressors as having the potential to lead to the most severe ecological transformation.

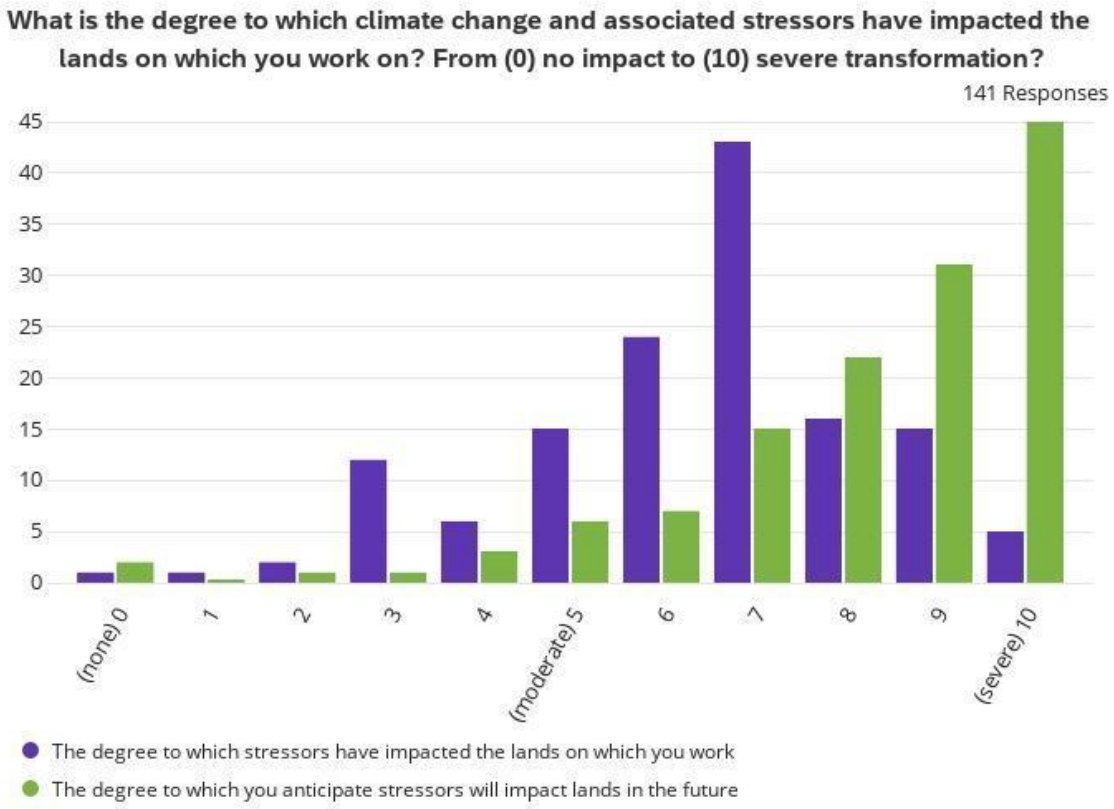

Figure 2.6 *Comparison of managers' perspectives on the degree to which climate change and associated stressors* ***have*** *and* ***will impact*** *ecosystems in the future in the Southwest U.S., on a scale from 0-10.*
(*n*: 132, χ2: 305.52 , *p*-value:<0.001)

As shown in the frequencies cross tabulated in Figures 2.4 and 2.5, there is a significant difference between participants' views on the degree to which stressors have impacted the lands they work and their views on the degree to which stressors are anticipated to impact public lands in the future. There was no difference observed between participants' agency and how they view the impacts of the past (p-value: 0.89) and future impacts of stressors (p-value: 0.75). Agency affiliation may in fact shape how the respondents view ecological stressors, but this study was limited by the fact that

multiple survey respondents opted out of including their agency affiliation, which limited the comparative analysis of results and ability to make comparisons of expected and observed results through chi-square testing.

While fewer participants (26%) reported that climate change and associated stressors have contributed to severe levels (choices 8-10) of ecological impacts into the present-day, the anticipated future impacts of stressors leaned heavily toward contributing to drastic levels of ecological change, with 74% of participants finding that they predict severe (choices 8-10) levels of stress (Figure 2.6). When comparing perspectives on both current and anticipated impacts, very few participants found there to be no impacts, with 1% reporting no impacts to this day, and 2% reporting no anticipated impacts (Figure 2.5). “Slight to minimal” ecological impacts (choices 1-4) were reported the least frequently in the present day (15%) as well as for anticipated future conditions (4%). Impacts viewed as just above moderate levels (31%) were the most common assessment of the current level of impacts by participants, while the most severe level of transformation (34%) was the most frequently anticipated level of future ecological impacts (Figure 2.6).

Survey responses related to ecosystem response suggest that in addition to “substantial” ecological changes being brought on by drought and/or wildfire (Figure 1.4), in combination with other stressors, there are challenges posed by changes occurring primarily at a medium to large spatial scale (Figure 2.2) and at a moderate to abrupt timeframe (Figure 2.3).

IV. Management Strategies and Decision-Making Under Drought and Wildfire:

Participants were asked to consider the extent to which they and their agencies are able to prepare and respond to ecological change from a management perspective. These questions address whether decision-making tends to occur more proactively, in anticipation of ecological stress and change, or more reactively, in response to changes that have already taken place. Participants were asked about their views on how resilient the ecosystems they manage are without human interference (Figure 3.1), how they describe their organizations' responses to ecosystem changes (Figure 3.2) and to characterize the amount of control they feel they have over shaped ecological response to stressors (Figure 3.3). These questions were meant to better understand how decision-making processes take place for managers faced with conditions of increased ecological stress and change.

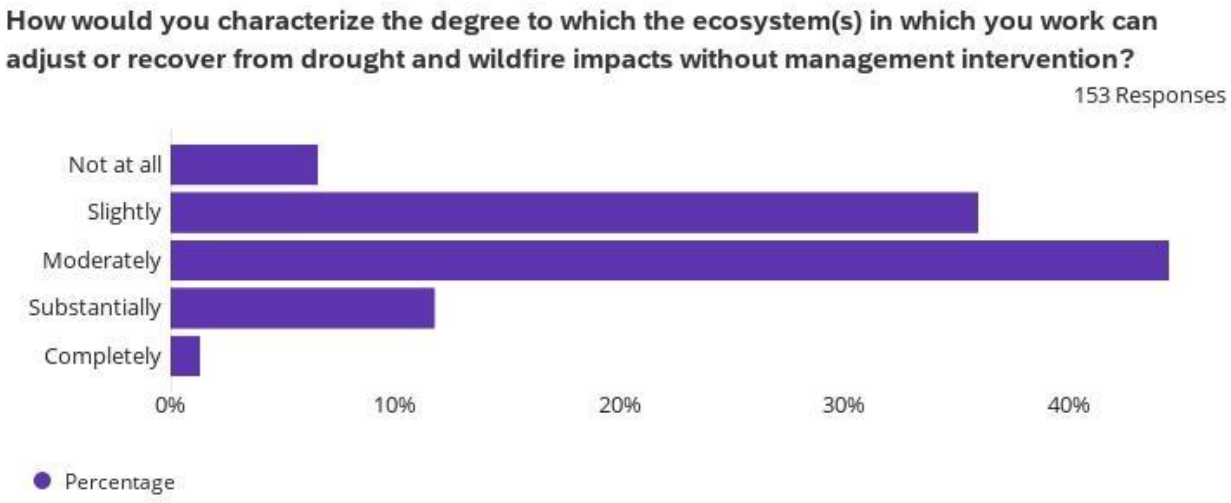

Figure 3.1 *Managers' views on degree to which ecosystems can recover without intervention*

Only 1% of participants reported that ecosystems would be able to recover "completely" from drought and/or wildfire impacts without management intervention. A small percentage (12%) reported that ecosystems could recover "substantially," 44%

reported “moderately,” 36% reported “slightly,” and 7% reported “not at all” (Q4). Through analysis of cross tabulations, it was determined that there was no statistically significant difference between expected and observed distributions of results for participants in different land management agencies regarding their views on ecological recovery without intervention (p-value: 0.93). As discussed above, there may exist differences among participants related to their agency affiliation, but this was limited by participants opting out of reporting their agency in the survey.

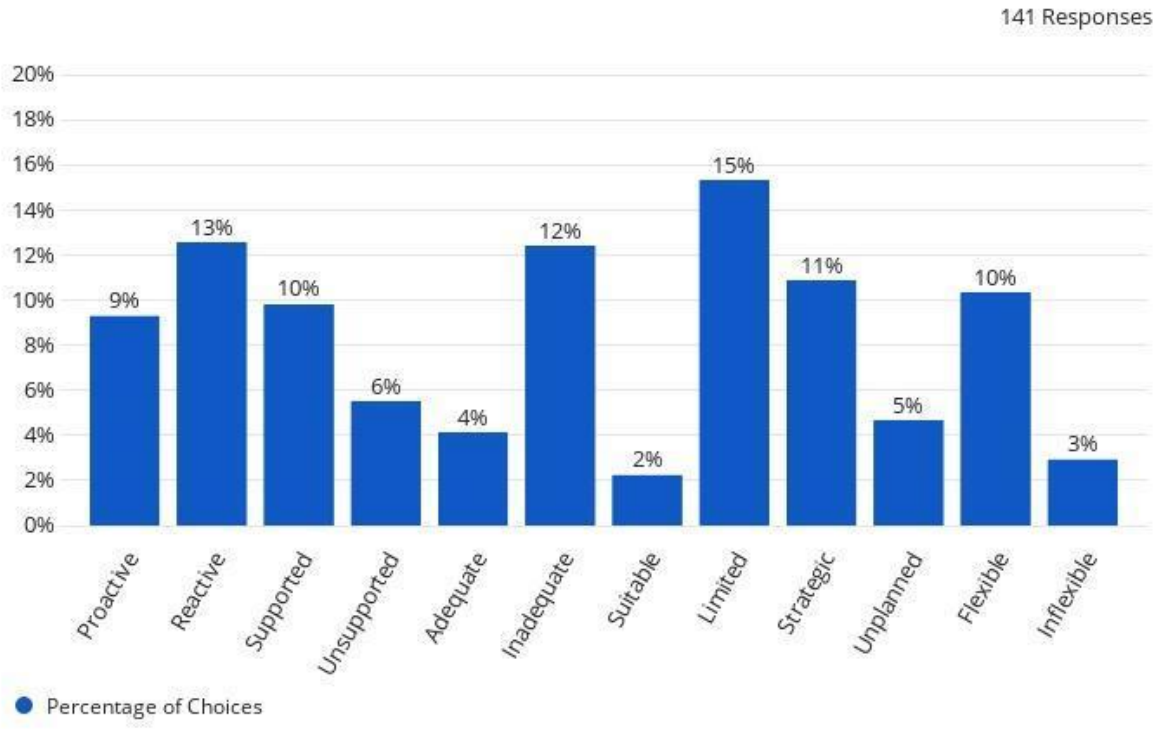

Figure 3.2 *Participants’ selected descriptions of their organization’s response to stressors*

Participants were given the ability to select as many descriptions as they would like and were asked to characterize their organization’s responses to ecological stressors including drought, wildfire, and climate change. The most frequently selected

choice was a view that their organization's response to stressors was limited (15%, 89 selections), followed by reactive (13%, 73 selections), and inadequate (12%, 72 selections). The top three selections (limited, reactive, and inadequate) were followed by strategic (11%) and flexible/supportive (10%). Responses were most often characterized in negative terms, being viewed as limited (selected by 63% of participants), reactive (52%), and inadequate (51%). This was despite organizations also being viewed in more positive terms, as having strategic responses (45% of participants), as well as flexible and supportive responses (43% of participants). Participants selected that their organizations had responses that were supported (10%, 57 selections) more frequently than unsupported (6%, 32 selections) and were more likely to be viewed as strategic (11%, 63 selections) than unplanned (5%, 27 selections) in their responses. Inflexible responses were noted less frequently (3%, 17 selections) than flexible ones (10%, 60 selections). The description "suitable" for organization responses to stressors was chosen the least frequently (2%, 13 selections).

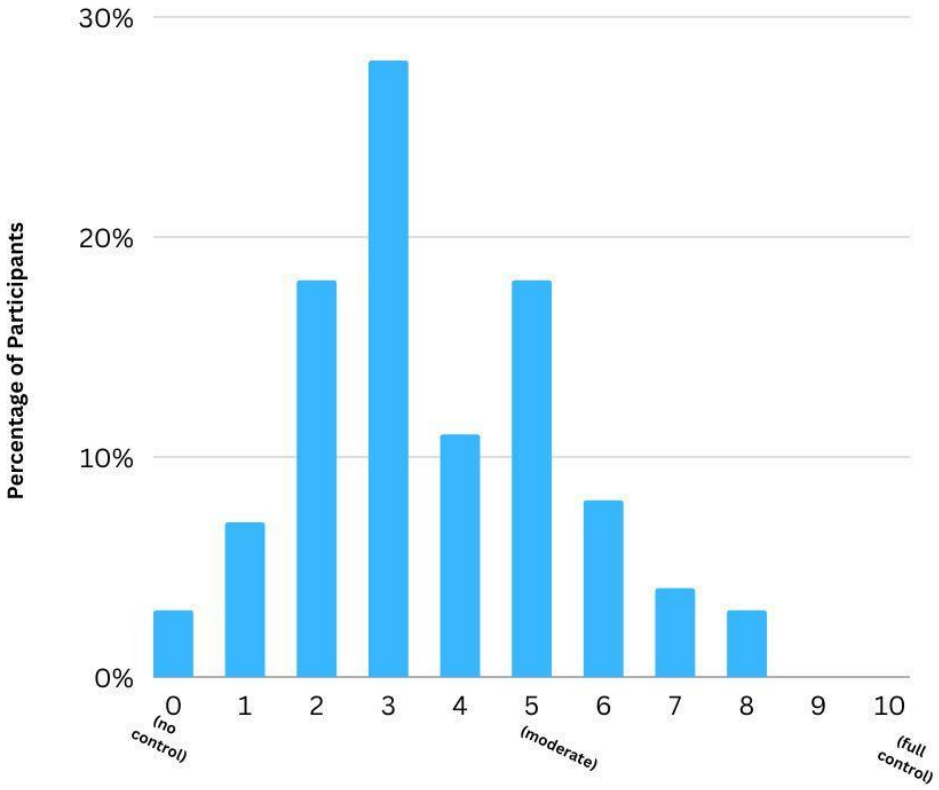

Figure 3.3 *Perspectives of personal control over shaping direction of ecosystem responses*

There were no participants stating that they had nearly full or total control (choices 9 and 10) over shaping the direction of ecosystem/natural resource response (Figure 3.3). Only 3% of participants felt that they have no control over ecosystem response. Over half of participants (53%) reported their control as low (1-3) overall. Only 15% participants reported having above a medium amount of control in shaping ecosystem response (choices 6-8) revealing that managers feel limited to their ability to control ecological responses (Q20). There was no statistically significant difference found between agencies in their perspectives on their control over shaping ecosystem response (p-value: 0.159).

The majority of participants found that ecosystems had a moderate ability to recover without any management interventions. Organizational responses were most frequently being described as limited, reactive, and inadequate. Over half of participants reported that they have a low amount of personal control over shaping ecological responses, which suggests that there are management barriers that extend beyond an individual manager's willingness to adopt adaptation strategies and actions.

V. Primary Barriers and Potential Limitations:

The following questions were included to understand participants' views on the primary drivers that create barriers to effective facilitation of climate adaptive actions. These survey questions were included in order to gain broad insights following the interviews in which some of the key themes that arose surrounded the potential limiting factors that prevent managers' abilities to take more proactive management approaches. Interview discussions frequently came back to resource and/or information needs, so both quantitative and qualitative survey questions were asked related to whether these needs are being met (Figures 4.1 and 4.2) and asked participants to identify what specific resources and kinds of information they find the most important to allow them to better prepare and respond to ecological stressors. The majority of participants (86%) expressed that they do not have sufficient resources to prepare for/respond to climate induced changes, including drought and wildfire, with only 14% reporting they do have sufficient resources (Q28).

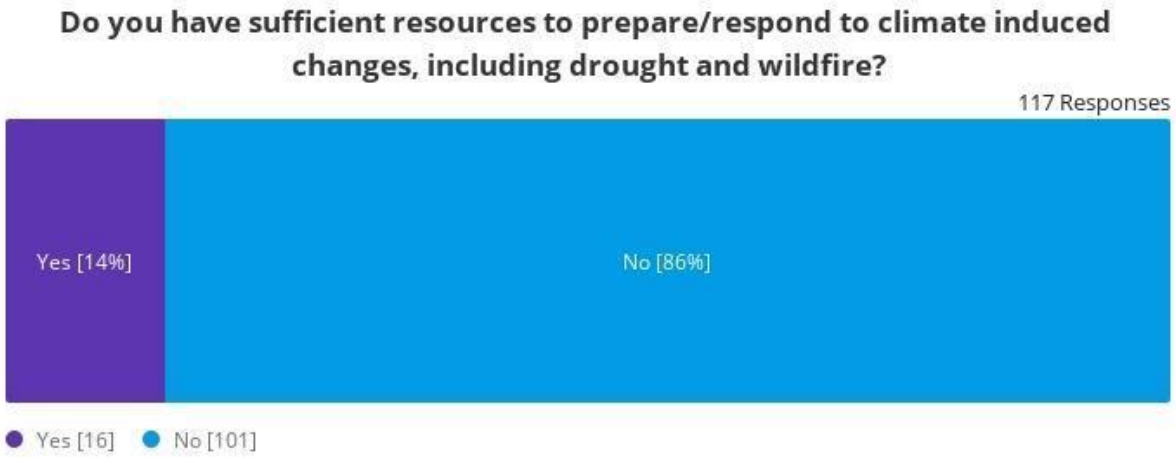

Figure 4.1 *Resource availability for effective preparation and response to changes*

Of all the open-ended, qualitative questions provided in the survey, the question related to resource needs (Table 4.1) was the most frequently answered by participants, with 78% of the total participants responding to this question. Financial resources, in combination with staffing resources, were the most reported needs (27.5%) followed by solely financial resources (15%). The least frequently reported resource needs were agency support (9%), followed by science and information needs (10%). In the “other” category, the “resource” of time (5%) emerged as a need, with insightful observations from managers including how additional time needs to be allocated to accommodate the efforts required to identify adaptation approaches and plan implementations. While this closely relates to the resource need of additional staffing to plan proactively and implement actions, it was notable that time was identified as a distinct resource need. Another participant identified that “time and a reasonable workload” was the most needed resource, which echoes themes of the interviews in which managers expressed

that they have too many business-as-usual tasks and job duties to adequately research, plan, and implement adaptive actions.

Resource Type and Description:	**Examples:**
Financial Resources *(n = 18, 15%)* Money and funding opportunities	Additional funding is needed to support research, planning, and implementation of actions
Staffing Resources *(n = 16, 13%)* Increased numbers in workforce	Increasing science staff and staff on the ground More people to engage in proactive, science-based adaptation planning and implementation. Novel idea: civilian climate corps
Both Financial and Staffing *(n = 33, 27.5%)* Participants identified both resources as their top needs	More funding to hire and expand workforce. Novel idea: fully functional climate adaptation program with continuity and accountability at each level of organization

Collaboration and Training *(n = 15, 13%)* Needs for interagency collaboration and engagement and/or additional staff training	Increased collaboration and communication between scientists and managers, other managers, stakeholders, and the public, cohesive efforts Communication training for agency staff Novel idea: Training for natural resource professionals to understand adaptive management and how to apply it to various projects
Science and Information *(n = 12, 10%)* Needs for addressing gaps in scientific knowledge and/or information gaps	Needs for better data on ecological relationships and responses to climate change, science-based decisions and information, more science developed directly with management agencies to direct responses
Agency Leadership Support *(n = 11, 9%)* Support and flexibility from agency leaders to implement actions	More support from agency leadership for proactive planning, clearer agency processes
Other *(n = 15, 12.5%)*	Time *(n= 6)* having the time necessary to research, plan, and implement actions in top of regular job duties Legal *(n =3)* more NEPA finished early and correctly so that actions can be more easily implemented Federal-level *(n= 3)* support from Congress Unclear/not relevant *(n = 3)*

Table 4.1: *Responses to the survey question "What resources would you need most to prepare/respond/adapt?" (n = 120)*

Participants identified specific job positions that would better allow them to prepare and adapt, including: “climate adaptation specialists on the ground,” significantly increasing science staff for monitoring efforts and gaining a better understanding of what implementations work and how to modify them for more successful results, and a separate job position for a climate adaptation specialist, who has expertise and knowledge about adaptation strategies and how to successfully implement them. The latter suggestion would also address the interview and survey participants’ concerns raised around time constraints and the overwhelming number of existing duties that managers often have.

Finally, two insightful suggestions for additional resources involve changes at the agency administrative and policy levels, one of which includes the creation of a national “civilian climate corps” to expand job opportunities and address the need for on the ground staff to implement adaptive actions at a larger scale. Another novel suggestion identified by a participant is the need for an agency-wide climate adaptation program with continuity and accountability at each level of organization. The results suggest that the focus should be placed on improving the ability of managers to receive funding for projects, as well as increasing staffing to implement adaptation efforts, with over half (55.5%) of responses directly related to funding and/or staffing resource needs.

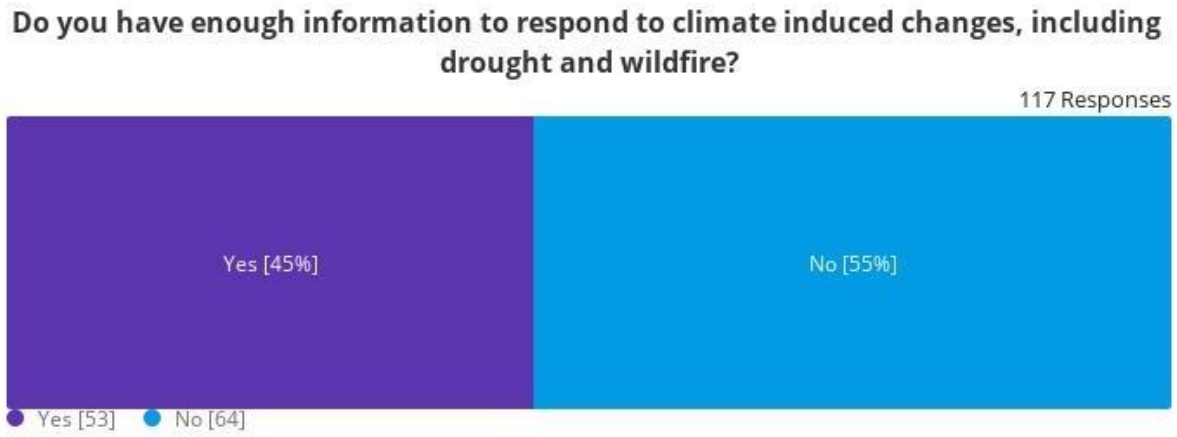

Figure 4.2 *Information availability for effective preparation and response to changes*

With lack of resources being reported by 86% of surveyed participants, and lack of information being reported by 55% of respondents, lack of resources is perceived as the most critical barrier for effective proactive management. Slightly over half of participants (55%) reported that they do not have enough available information to address and respond to these changes, while 45% of participants reported that they feel they have enough information (Q25). This yes/no question contradicts interview responses that there is enough, or in some cases, an overwhelming amount of information. It also seems to contradict the finding that clearer, more precise, and applicable existing information is more imperative at this time than generation of new information, as discussed in interview results as well as in the following open-ended qualitative question (Table 4.2).

Type of Information Need:	**Examples of Information:**

Clearer Existing Data and Information and/or Expansion of Existing Data and Information (n = 24, 27%) Response expresses need for refinement of existing information and data, greater clarity and precision	Existing models and projections made more precise and refined (especially at various spatial and temporal scales), more specific case studies that have successfully (or not) implemented adaptive management strategies, better hydrology data, better data on native plant species characteristics and propagation practices that would be most adaptable to climate change, better understandings of how specific resources will be impacted (plants, animals, cultural, etc.) "improved quality of information is more important than different/additional information"
New Adaptation-Focused Data and Information (n = 16, 18%) Response expresses need for forward-thinking, novel data with a strong focus on climate adaptation	State and transition models designed with the next one hundred years in mind, species modeling with emphasis on future climate change projections, rapidly developed sound peer reviewed science, greater research on ecological stressors to specific ecosystem types (ex: pinyon-juniper woodlands) and medium-scale adaptation strategies that allow for a nuanced approach
Funding Related *(n = 4, 5%)* Funding needs seen as a first step to acquiring necessary information	Access to funding specific to implementation, More funding opportunities for landscape scale projects and studies for collaborating agencies
Proposed Research Directions *(n = 16, 18%)* Specific areas for further research needs are identified	Better research on strategies to improve soil moisture retention, forest aquifer recharge, regionally specific reforestation guidelines research on where on a large landscape to focus efforts for best results
Planning and Policy Information *(n = 14, 16%)* Information needs related to decision-making, planning, or shifting current policies	Additional training/seminars on adaptive management, building partnerships and planned coordination of efforts across agencies with clear guidance, information on how to establish climate adaptation partnerships, step-by-step guidelines on how to implement actions

Unsure, or No Information Needed *(n = 14, 16%)* Uncertain what information is needed or argues that enough information is available	No idea, there is nothing we can do, more information creates little action in today's processes "we have the information, but do not have the resources to respond to anything other than the most simple fixes"

Table 4.2: *Categorization of responses to the survey question: "What information would you need most to better prepare/respond/adapt?" (n = 89)*

Over half (58%) of the total survey participants responded to the open-ended question related to information needs, though this was the least answered of the qualitative questions. The largest percentage of participants (27%) expressed the need for more clear and precise existing data and information and/or the need for existing information to be expanded upon and provide more nuance and better understanding of how to apply existing information. Within this category, there was a consistent theme that the data and information needs are well-known, but that there is room for improving the quality, precision, and applicability of this information. The need for new adaptation focused data (18%) and specific suggestions for research directions to address information needs (18%) were the second most frequently reported needs. Participants expressing a need for new adaptation focused data responded that current data and information often fail to have a strong focus and connection to climate adaptation and emphasized a forward-thinking approach to information and data acquisition. Research directions focused on examples of targeted research and needs for better information related to particular ecosystems and ecological responses to stressors. In the planning and policy information needs response category (16%), several participants highlighted their interest in better implementable guidance, more training and seminars that address

adaptation provided by agency leadership, as well as step-by-step guides to approaches for land managers to prepare, respond, and adapt. Participants discussed limitations of increased information, sharing the perspectives that funding is a barrier to acquiring necessary information (5%), or the viewpoint(s) that current information is adequate but not being utilized due to lack of resources or support for implementation (16%). Responses falling under the category of no information needed highlighted the view that a wealth of information is currently available, but limitations may include funding issues, agency culture issues, or an overwhelm of information leading to difficulties in choosing the most appropriate management approach.

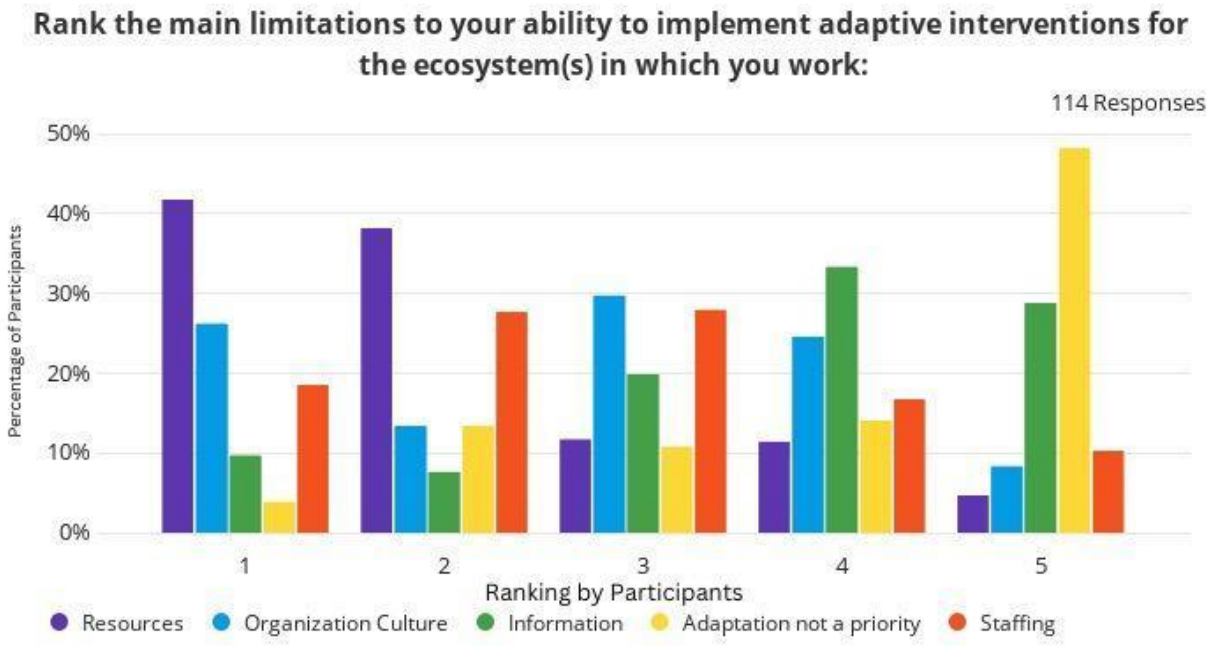

Figure 4.3 *Ranking (1-5) of the most significant barriers for implementation of adaptive actions*

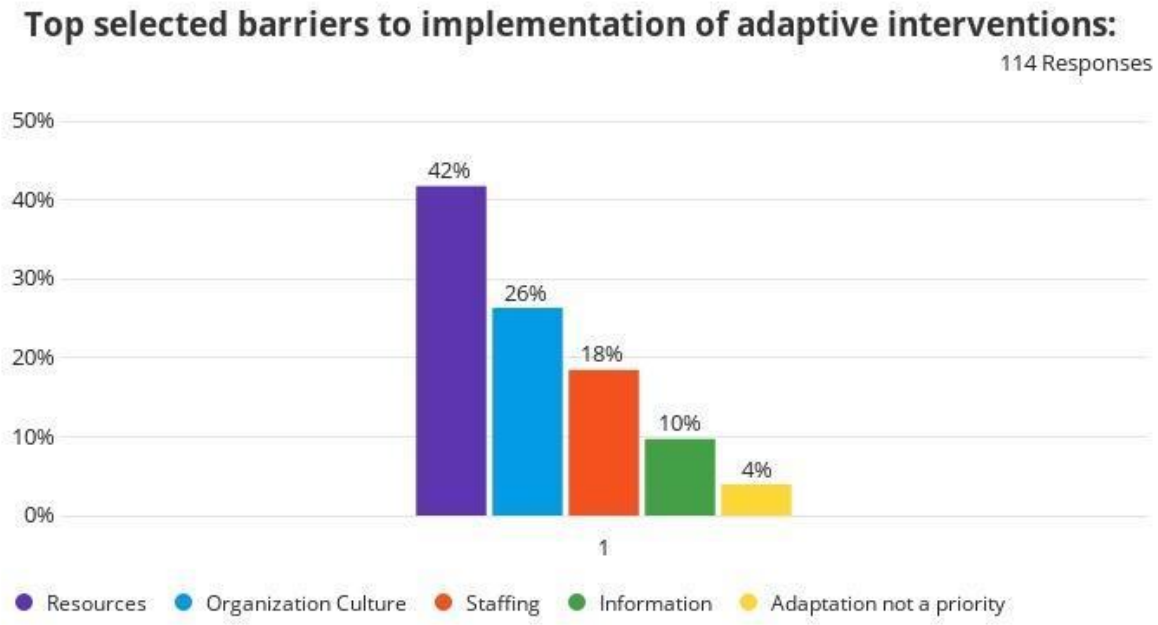

Figure 4.3.1 *Limitations ranked as the primary (#1) barrier for adaptive action implementation*

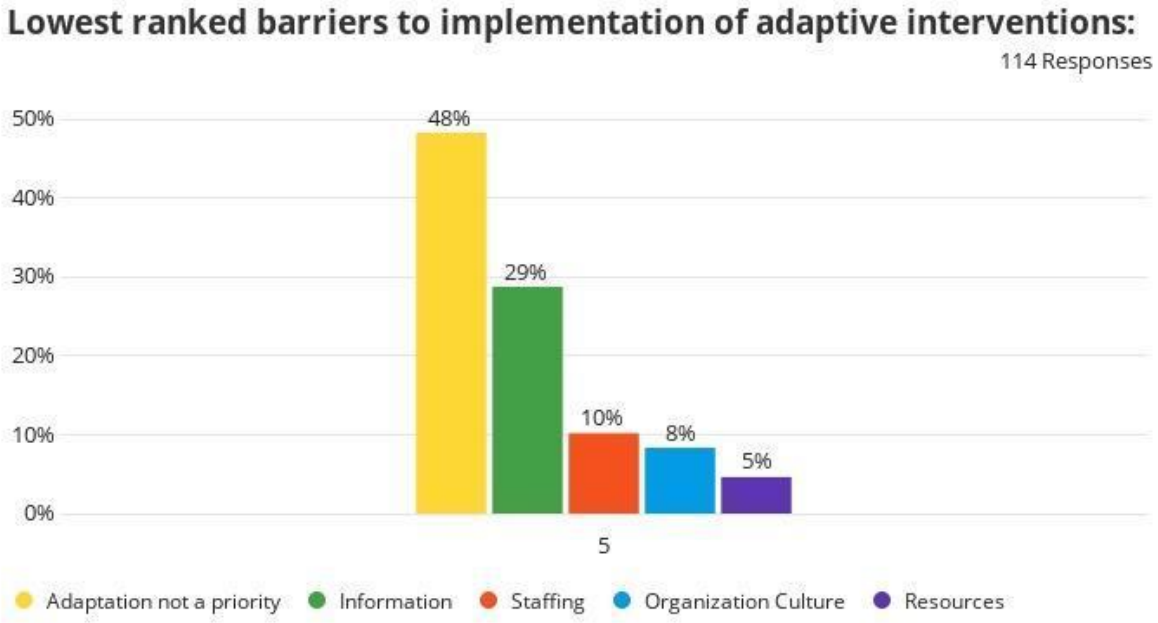

Figure 4.3.2 *Limitations ranked as the least significant barrier (#5) for adaptive action implementation*

When asked to rank the main limiting factors for managers' abilities to implement adaptive interventions with five choices, respondents ranked resources (42%) as the top limiting factor, followed by organization culture (26%), staffing (18%), information (10%), and lastly, adaptation not being a priority (4%). Resources were considered to be the second main limiting factor (38%) followed by staffing (28%) The lowest ranked barrier, identified by nearly half of participants (48%) was that adaptation is not a priority for agencies, followed by information barriers (29%). This suggests that participants perceive their agencies as finding adaptation important, but that other limitations create barriers to implement adaptive actions. Nearly 30% of participants ranked information barriers as the least significant barrier.

When surveyed about the most significant barriers for action, information was the fourth choice out of five, with only 10% of participants identifying information as the top barrier, falling behind resources (42%), organization culture (26%), and staffing (18%) (Figure 4.3). This echoes the interview respondents' views and the open-ended survey question results findings that existing information needs to be expanded on, more than lack of enough information being the primary barrier to action. In table 4.2, the greatest type of information needed identified was "clearer existing data and information and/or expansion of existing data," with 27% of participants responding that existing data and information needs to be refined and/or expanded upon. Also shown in table 4.2, the need for novel adaptation focused data and information was cited as a need by only 2% more participants (18%) than participants who stated uncertainty as to what information

is needed and/or that enough information is readily available (16%). Interview and survey findings related to the information barrier seem to conclude that information is not the primary barrier to action, which undermines the approach most commonly pursued in adaptation efforts of providing managers with more information.

VI. Perspectives on Climate Adaptation and Proactive Management Strategies:

This section of survey responses emphasizes how the diverse array of individual perspectives of participants related to climate adaptation, both what it means and how it should be applied. These questions seek to understand how managers apply their understanding of climate adaptation to the management strategies and approaches they take. The ability to plan management strategies to adapt to ecological stressors and a changing climate proactively (anticipatorily) versus having to plan reactively is important to consider in relation to personal perspectives on what is meant by climate adaptation. Adaptation can be applied in many ways and survey participants had the tendency to associate adaptation with specific management applications, policies, and/or frameworks. The following questions were chosen to strengthen the understanding of how managers perceive the concept of climate adaptation within the context of managing for stressors.

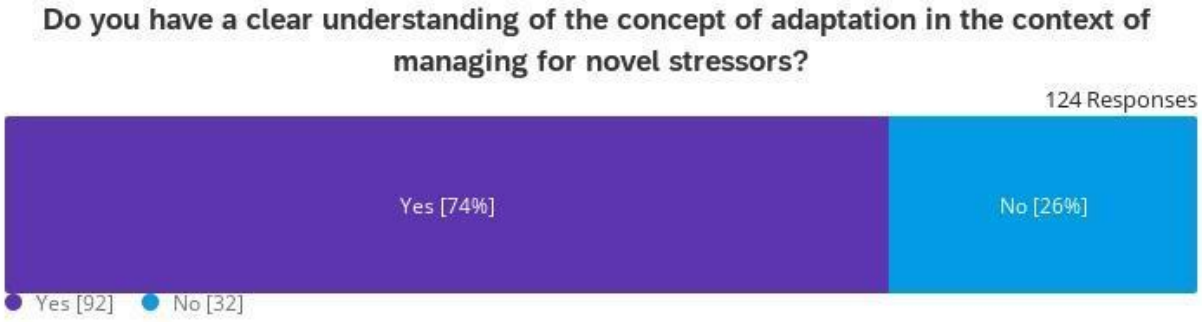

Figure 5.1 *Understanding of the adaptation according to participants*

Survey participants primarily (74%) reported that they do have a clear understanding of the concept of adaptation in the context of managing novel ecological stressors, while 26% reported that they do not have a clear understanding of adaptation (Q11).

Definition and Description:	**Examples of Definition:**
Adaptation (general) *(n = 32, 30%)* Definition restates and elaborates on main themes of the IPCC Fifth Assessment (2014) definition of climate change adaptation Does not include specific examples of adaptation	Emphasize the importance of anticipating and adjusting to current and projected changes rather than relying on historic conditions, adoption of novel practices to prepare for changes proactively and/or responding to changes with more flexibility and new approaches May discuss building resilience, flexibility, proactive actions, strengthening natural systems, and/or adaptive capacity

Adaptation (specific) *(n = 35, 32%)* Applications of adaptive actions and/or examples of what such actions entail are included within the definition Does not include broader definitions of adaptation	Definitions include a science and/or management focus, and incorporate examples of particular applications including restoration, modeling, assisted migration, monitoring efforts using new techniques, native plant seeding and recovery, planting, prescribed fire May include an emphasis on implementing a specific policy or framework (Resist-Accept-Direct) in management strategies *(n = 7)*
Adaptation (comprehensive) *(n = 15, 14%)* Definition includes both general and specific definitions of adaptation within a single participants' response	Broader understanding of adaptation (evaluating and monitoring vulnerability of ecosystems under different scenarios of climate change) used in combination with specific applications and/or examples (to promote relocation of species to more suitable habitats)
Somewhat Adaptation *(n = 7, 6%)* Definition provided may include the word adaptation but includes some elements that do not fall under the definition of adaptation	Some characteristics of adaptation but are vague/unclear or may incorrectly refer to adaptation as synonymous with mitigation efforts
Not Adaptation *(n = 19, 18%)* Definition provided is incorrect, incomplete, or misunderstanding of adaptation	Definitions may refer to specific strategies that could be business-as-usual or adaptation but fails to connect them to adaptation (eg. "fuels treatment" with no further explanation) May be unclear, characterize adaptation as not possible, or places an emphasis on limitations/ineffectiveness instead of providing definition

Table 5.1: *Responses to the survey question "How do you define adaptation in the context of the work you do?" (n = 108)*

Of the total participants, 70% responded to the open-ended question asking them to define adaptation in the context of their work. The provided definitions were compared with the formal IPCC Fifth Assessment (2014) definition of climate adaptation: "The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects." The majority of the responses (76%) were characterized as defining some central aspect of adaptation, whether generally, specifically, or a comprehensive definition, which included a combination of the two. General definitions restated or elaborated on the IPCC definition, while specific definitions pointed out applications or examples of adaptation in the form of management actions. Comprehensive definitions revealed the strongest understanding of the definition of adaptation because they included a broad understanding in combination with a specific adaptive approach. Nearly one-quarter (24%) of responses were either somewhat a definition of adaptation (6%) or not adaptation (18%), revealing that there are still misinterpretations and/or incorrect understandings surrounding the concept of adaptation. Within adaptation definitions, there were discussions of both specific adaptive actions and adaptation frameworks, and how these are not being utilized to promote adaptive actions. One response that fell under the "not adaptation" category was particularly interesting, despite not being an accurate definition of adaptation: "I work in wildlife for the state. Our agency still won't even publicly use the term "climate change" and only uses the term "drought". We have a "drought team" but

it doesn't have the right people on it and it is almost exclusively focused on wildlife drinking water augmentation. The state is almost in total denial about the coming ecosystem shifts."

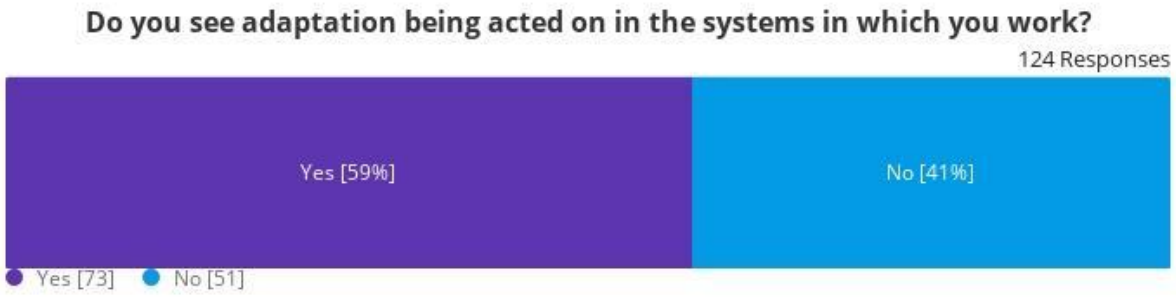

Figure 5.2 *Managers' perception of whether adaptive actions are taking place*

A larger percentage of participants (59%) felt that adaptive actions are being implemented in the ecosystems they manage, with 41% finding that adaptive actions are not being acted on in the systems they work in (Q12).

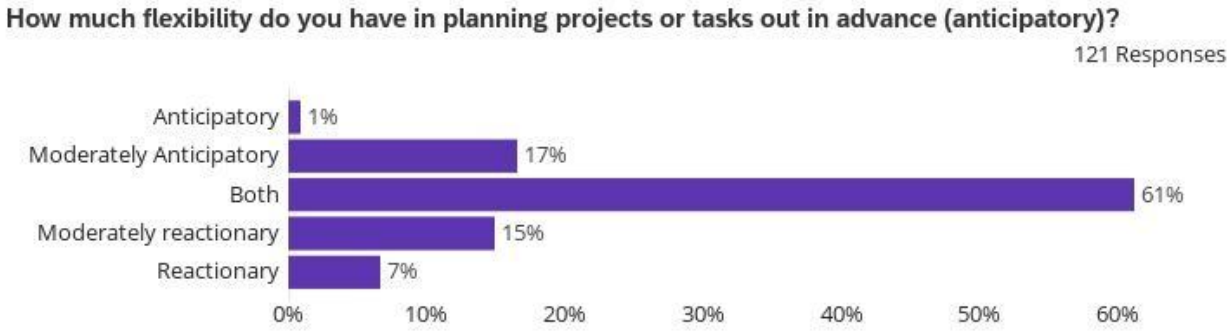

Figure 5.3 *Flexibility to plan projects in advance versus in reaction to what has already happened*

In natural resource management, anticipatory planning involves carrying out projects and tasks in advance of ecological change, which gives greater opportunities for proactive adaptation strategies to be implemented, in comparison with reactionary

planning, which focuses on responses to what has already happened and needs the most urgent attention. The majority of participants (61%) felt that their personal flexibility with projects and tasks was a combination of both anticipatory and reactionary planning. The flexibility to be fully engaged in anticipatory planning was the lowest selection (1%). Reactionary (7%) and moderately reactionary (17%) planning were reported as more common than anticipatory (1%) and moderately anticipatory (17%) flexibility in planning efforts (Q22). Management decisions made in reaction to what has already happened do not always provide opportunities to address what is currently happening, or what is projected to happen in the future. While most participants (74%) felt that they understood the meaning of the concept of adaptation, they gave a wide diversity of responses which suggest there is not a singular understanding of the concept.

VII. Facilitation and Implementation of Adaptive Actions:

The following survey questions are centered around participants' perceptions of their abilities, as well as the abilities of their organizations, for the effective facilitation of adaptive actions. These questions were also designed to address how participants view agencies' responses outside of their own (Figure 6.1) and reflect on their organizations' abilities to proactively implement adaptation actions. Through an open-ended question (Table 6.1), participants identified specific adaptive actions they would like to take next on the lands they manage and then considered the likelihood of being able to facilitate those actions (Figure 6.6). Participants were also asked to consider their levels of

confidence (Figure 6.2) and optimism about their ability as decision-makers to shape ecological outcomes (Figure 6.6).

Figure 6.1 *Managers' personal flexibility to proactively plan projects.*

Overall, participants felt that their organization is implementing the same amount (44%) or more (40%) adaptation actions in comparison with other organizations (Q14). Only 15% of participants felt that their organization is doing less compared to other organizations.

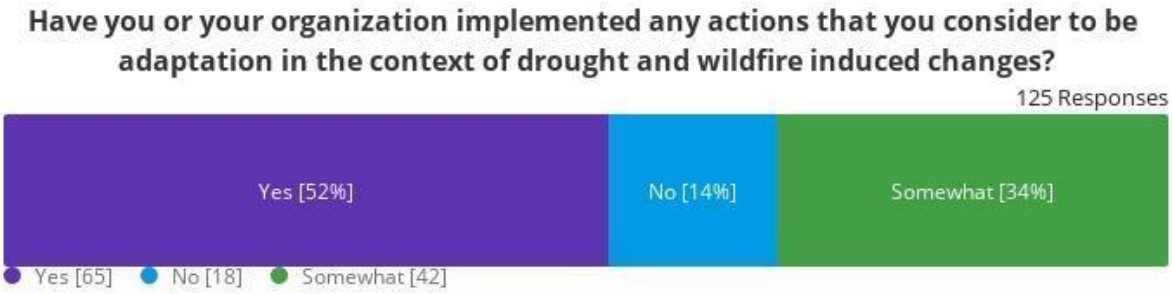

Figure 6.2 *Managers' views on whether agencies have implemented adaptive actions*

Over half of participants (52%) reported that they have implemented actions which they consider to be adaptation in order to prepare and respond to drought and wildfire induced changes. Just over one-third of participants (34%) reported that they

have “somewhat” implemented adaptive actions, and only 15% reported that they have not implemented adaptive actions (Q15).

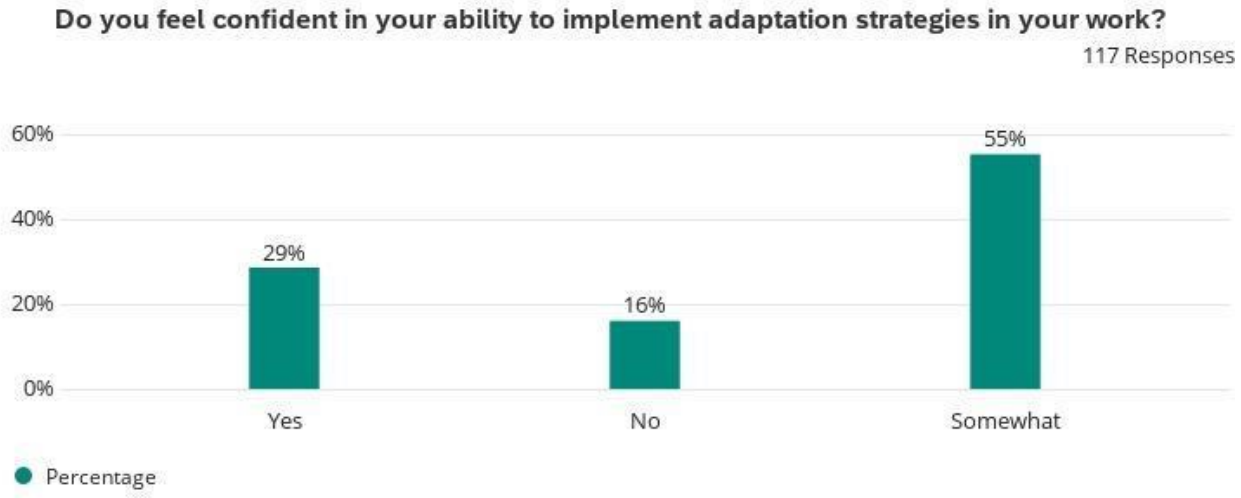

Figure 6.3 *Managers’ level of confidence for ability to implement adaptive actions*

Over half of participants (55%) responded that they feel “somewhat” confident in their ability to implement actions considered to adaptation in the work they do, followed by 29% of participants reporting that they feel confident, and 16% of respondents stating that they do not feel confident in their ability to implement adaptation strategies (Q17).

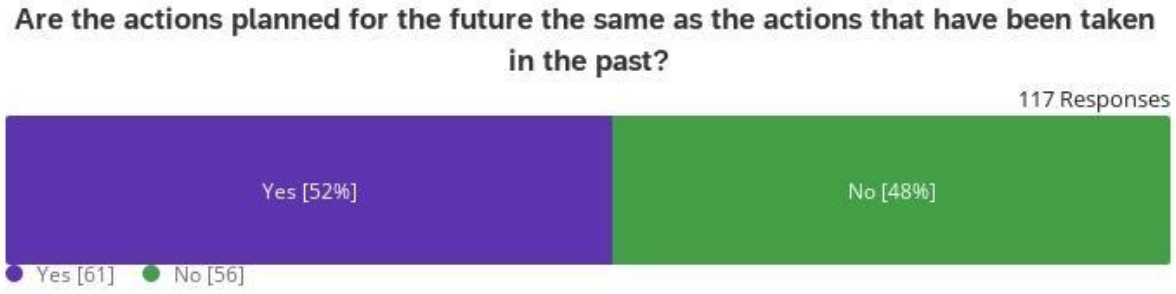

Figure 6.4 *Managers’ perspectives on novelty of planned actions being implemented as adaptation*

Over half of participants (52%) felt that planned implementation of adaptation actions are the same as actions that have already been taken in the past, while 48% felt that planned actions are different from past actions (Q17).

Action Type and Description:	**Example of Action:**
Adaptation, Proactive (general) *(n = 26, 26%)* Adaptive action described is a proactive approach, but definition is general and does not give specifics or examples of how it will be implemented.	Responses encourage land management focused on climate change rather than business as usual, with no examples of specific actions emphasizing adaptation Building flexibility and adaptive management into all planning efforts, climate informed intentional decision-making, institutionalize considerations of likely future conditions when we consider site-specific actions
Adaptation, Proactive (specific) *(n = 33, 33%)* Adaptive action described is both specific and proactive, often providing details of how and why action should be taken	Increase acreage of prescribed fire and cultural burning, partner with other organizations to fund thinning projects, common garden and restoration experiments to assess genetic viability under new climate conditions, develop a statewide climate adaptation plan, combining wildfire funding with water planning interests in the budget process to help minimize aridification of the soil and reduce wildfire impacts on water flows, management aimed at enhancing soil moisture capture and (natural) aquifer recharge, interorganizational/ intergovernmental programmatic state or regional climate change adaptation program and framework for at-risk, threatened, and endangered species

Adaptation, Reactive *(n = 14, 14%)* Adaptive action described is reactive (acting in response to observed ecological changes)	Invasive species management, post-wildfire rehabilitation, addressing past agency plans and actions that have contributed to stressors, change grazing timing and livestock breed, water tables are diminishing, and streams need to be built up to hold water longer, restoring and reconnecting fragmented habitats
Somewhat Adaptation *(n = 15, 15%)* Action described has some aspects that fit the definition of climate adaptation, but may have non-adaptive descriptions included within it, definition may be a generalization or unclear/vague	More assertive proactive adaptation, which will require additional resources and funding sources that allow such an approach Increased education to the public about the importance of watersheds to them and their future (adaptation), and why getting out and walking is better than jumping on an ATV (not adaptation) Let fires burn and conserve water supply (adaptation) and take actions that reduce carbon emissions (mitigation, not adaptation)
Not Adaptation *(n = 12, 12%)* Includes actions that are "business-as-usual" or mitigation, actions that are unclear/view adaptive action as not possible	Address non-climate stressors (not an adaptive action), continued brush management (business as usual) Cloud seeding (mitigation, not adaptation) I don't know what can be done (view that adaptation is not possible)

Table 6.1 *Categorization of responses to the survey question: "What specific adaptive actions would you like to take next?" (n =100)*

Of the total survey participants, 65% identified actions they would like to implement which they consider to be adaptive (Table 6.1). The greatest percentage of responses included specific, proactive actions (33%) that fall under the definition of climate adaptation, followed by responses that included general proactive approaches

without emphasizing specific actions they would like to take (26%), with a total of 59% of actions described being at least generally proactive adaptation, with 73% of actions described being either proactive or reactive forms of adaptation. Next, actions fell under the category of adaptation but were reactive, rather than proactive (14%) and reactive actions provided all happened to be specific, rather than general. This was closely followed by responses that were somewhat adaptation, but also included some combination of non-adaptive, vague, and/or unclear elements within the adaptive action (15%). The smallest percentage of responses were not adaptation (12%), incorrectly characterized business-as-usual approaches as adaptation, viewed adaptation as not possible, or expressed uncertainty in ability to take action.

One participant identified a novel, reactive approach that argues for the need for increased accountability and/or review of managers' decisions and their impacts, possibly by an independent third-party, when business-as-usual decisions are chosen instead of proactive ones or when both proactive and business-as-usual decisions would be feasible. This may be an area for further research to better understand why managers may decide to opt for the business-as-usual approach instead of a proactive one, when limitations such as funding or staffing are not determined to be restricting factors.

Interestingly, when asked to provide specific actions that the participants would like to take next, over one-quarter (26%) provided general proactive approaches yet did not identify specific actions within those approaches. Responses included "encourage land management that is actually focused on climate change rather than business-as-usual" and "we need to increase the scale and pace of management treatments to help

natural systems adapt both pre- and post-disturbance," both of which suggest the need for climate adaptation actions but fail to describe what actions they would like to take. However, despite some vagueness and lack of clarity found in the category of general adaptive actions, nearly half of participants (47%) described specific actions that would be considered to be adaptive, based on the IPCC definition of adaptation.

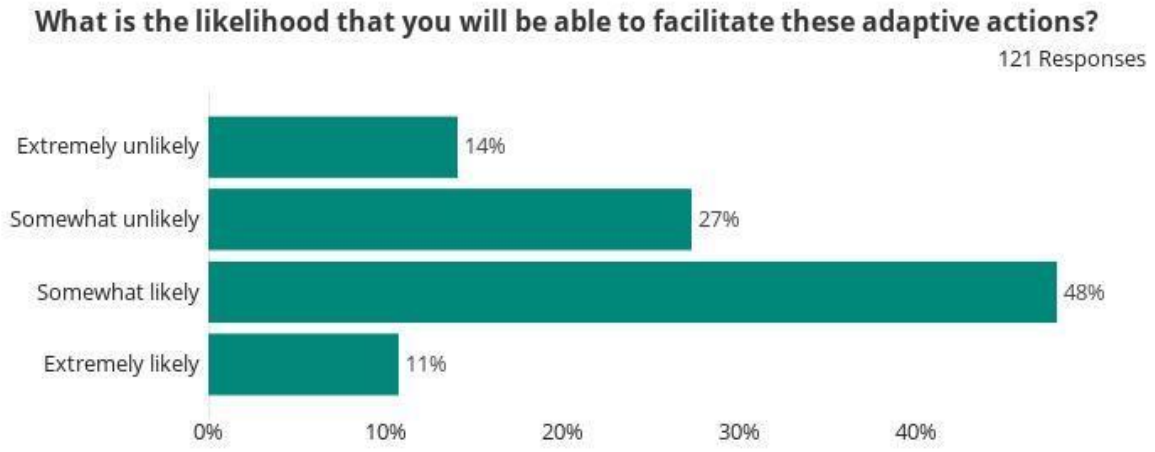

Figure 6.5 *Likelihood of ability to facilitate desired adaptive actions*

After reporting which specific adaptive action they would like to take, participants answered a follow-up question related to their perceived ability of being able to implement their stated action. Nearly half of the participants (48%) felt that it was "somewhat likely" that they will be able to facilitate their desired adaptive actions, compared to only 11% of participants who felt it would be "extremely likely." (Q19). To a lesser degree, over a quarter of participants (27%) felt that it would be "somewhat unlikely" and 14% felt it would be "extremely unlikely" to facilitate their preferred adaptation actions (Q19). Over half (59%) of participants reported that they felt either somewhat or extremely likely to implement adaptive actions.

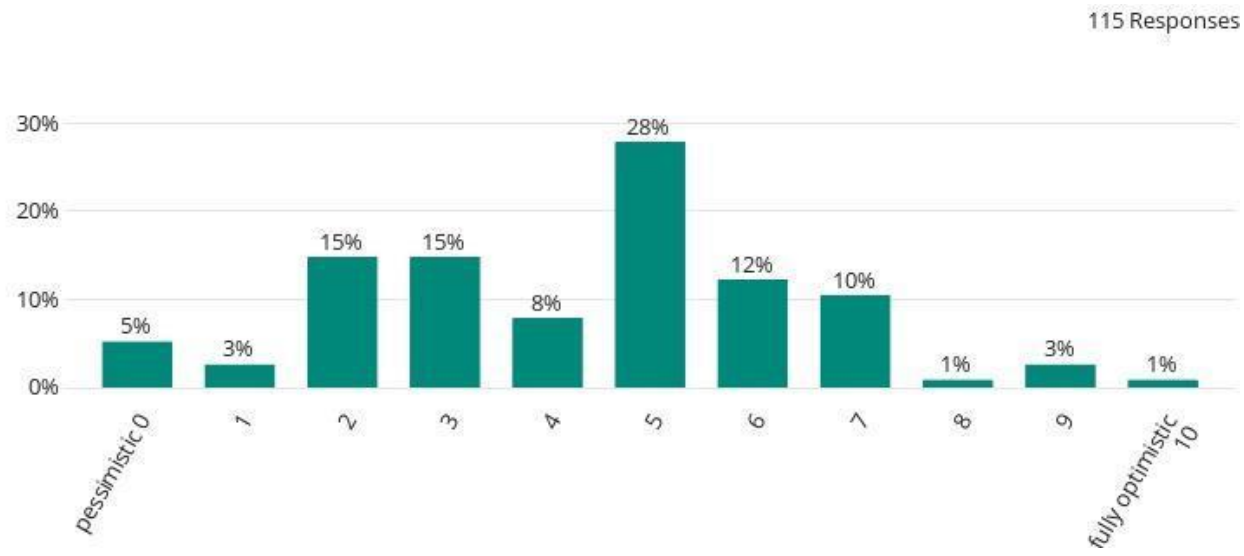

Figure 6.6 *Levels of optimism felt toward agency's abilities to address conservation challenges*

The largest portion of respondents fell in the median range when asked to rank their optimism regarding their agency's ability to address forthcoming conservation challenges, related to wildfire and drought, on an 11-point Likert scale from 0-10, with 0 being fully pessimistic and 10 being fully optimistic. Participants most frequently (28%) fell directly in the median between very pessimistic and very optimistic. Only 5% of participants responded with high levels of optimism (8, 9, or 10), indicating a view that their agency will be able to address current and future conservation challenges. (Q24). While 1% reported feeling completely optimistic, 5% reported feeling completely pessimistic. Responses indicating pessimistic outlooks (23%) indicate that there are higher levels of pessimistic outlooks towards their agencies' ability to address forthcoming challenges than there are very optimistic ones (5%). This trend toward pessimistic outlooks suggests that managers feel limited in their confidence levels to address future conservation challenges, especially when combined with the findings that over half of participants feel that planned interventions are the same as those taken

in the past and less than one-third of participants reported the view that they can successfully implement adaptive actions.

CHAPTER SIX

DISCUSSION

The following chapter expands upon the interview and survey results providing an in-depth analysis of the original research questions through a political ecological framework. Results provided significant insights into the perceptions and experiences of natural resource managers on their approaches to planning climate adaptation strategies and transitioning these strategies into on the ground actions. Barriers and limitations to implementation were emphasized by participants frequently, which illuminated the necessity for consideration and analysis through the political ecological framework. Political ecology provides explanations of the causes for socio-ecological issues through the examination of spatial scale (regional/local to national and global) and institutional structures and barriers, while accounting for and prioritizing the perspectives and experiences of actors living through environmental challenges (McCarthy, 2005). The political ecological approach can be utilized to examine the power dynamics between managers, scientists, and leaders at the agency institution level, identify and provide insights as to the barriers to effective land management, and better understand the driving political, economic, and societal forces behind ecological changes and transformations. A political ecological approach also provides natural resource managers with greater clarity as to how these driving forces challenge managers' abilities to prepare and respond to ecological change.

Political ecology places an emphasis on an extensive understanding of root causes and political, economic, and social drivers behind environmental issues,

including climate change, as well as examining the human dimensions (Goldman et al., 2018). The political ecology approach is crucial to examining issues surrounding management in times of worsening climate change because this approach centers around normative goals, meaning it allows for the identification of causes that need to be fully addressed in order to reach solutions (Robbins, 2012). This chapter explores the complexities of individuals' understandings and applications of climate adaptation, in conjunction with the management challenges experienced under increasing conditions of uncertainty and ecological changes.

Through the following discussion, I will address the three research questions which guided this project. Research question 1 will be addressed in the sections "I" and "II," research question 2 will be addressed in sections "III" and "IV," and research question 3 will be addressed in section "V." These research questions will be examined through an application of a political ecological theoretical framework to better understand and explain challenges for natural resource managers when implementing climate adaptation, as well as using these theoretical lenses to begin to identify areas of possibilities for alternatives and institutional changes.

I. Perceptions related to ecological change: ***"The reality is, it's getting warmer and it's getting drier."***

The following section provides a response to the first component of research question 1: "*What are natural resource manager perceptions related to ecological change, including climate change*?" Perceptions related to climate change were relatively straightforward, with both interview and survey respondents viewing climate change as a primary driver of the ecological changes experienced across their

landscapes. The overwhelming majority of participants (93%) reported that drought had been experienced either “substantially” or “completely” in the ecosystem(s) they manage while 80% of participants reported that wildfire had either been experienced “substantially” or “completely,” showing that drought has been perceived as transforming ecosystems more than wildfire. The main points of divergence between respondents were related to synergistic impacts, mainly to what extent climate change is contributing to ecological changes in combination with other ecological stressors, and to what degree climate change will accelerate the pace and scale of ecological transformation. Respondents frequently discussed ecological stressors having a strong influence on one another, creating positive feedback loops and an intensification of existing ecological stressors, as well as leading to the potential for new ecological stressors to arise. There was a consensus among managers that there is not a full understanding of how the synergistic impacts of ecological stressors of drought, wildfire, and climate change will interact with, and influence one another, referring to synergistic impacts of stressors as potential “tipping points” at which the influences of these stressors lead to ecosystem transformation. These tipping points were discussed by interview respondents in the context of synergistic impacts of ecological stressors having the potential to lead to tipping points. Tipping points are often discussed on the global climate scale, with tipping points being the point where “the forces that create stability are overcome by the forces that create instability… [where the] system tips over into disequilibrium” (Cairns, 2004). Respondents identified the primary synergistic ecological stressors that could lead to systems falling into a “disequilibrium” as being drought and wildfire, both of which are worsening in scale and magnitude in

combination with warming temperatures due to climate change. Even once a new equilibrium is reached, the ecological integrity of the system may be severely degraded and unable to sustain the natural and/or social systems that relied on the supports of the previous system prior to the state change (Groffman et al., 2006). Many climate tipping points have been identified and are in danger of being crossed and have been noted as having consequences being experienced to different degrees depending on the region of the world (Lenton et al., 2019). Climate tipping points can occur when a change leads to a nonlinear response within a system, with this change being either a series of small changes, or a large abrupt change to the properties of the system (Lenton, 2011). Tipping points in relation to anthropogenic climate change have often been considered widely at the international scale, however, it seems as if there is a need to draw greater attention to what I call “regional tipping points,” which emphasize a management focus on smaller spatio-temporal scales when identifying socio-ecological drivers of ecological changes. While tipping points are often discussed as impacting the planet on a global scale, consideration of synergistic interactions of stressors and the potential to lead to regional tipping points is imperative to assist managers in their ability to proactively prepare and respond to changes. These stressors, as well as the feedback loops they create, are intensifying due to climate change leading to larger impacts and have the potential to contribute to regional tipping points.

Some of these stressors, which could lead to regional tipping points being crossed, were identified by respondents as: increased drought stress, more frequent high-severity wildfires introduced species, soil moisture balance, increased aridity, higher winds, increased evaporation, continued fire suppression, resource

mismanagement, human land-use and production, biodiversity loss, and increased sublimation leading to snowpack decline. Many respondents reported that ecosystems they managed had experienced drought (93%) and/or wildfire (80%) to a substantial degree. A major concern with regional tipping points is like that of global scale climate tipping points, as positive feedback loops of synergistic ecological stressors have the potential to cause both a series of small changes and abrupt changes to the system, both of which could cause regional tipping points. One reason why it is important to examine ecological stressors at the regional scale, as opposed to the national and/or global scale, is that it is easier to identify and address potential tipping points and the feedback loops that could contribute to them at smaller scales. This is especially true for challenges in creating effective management actions despite the complex uncertainties of the spatio-temporal scales at which stressors will impact these landscapes.

Addressing tipping points at the regional scale provides justification to agency leaders and/or government institutions for the need to create abilities within agency policy for increased collaborative efforts between stakeholders within that region. Examination into regional tipping points allows for the understanding of potential for ecological transformation and gives managers a scale at which to work collaboratively to better prepare for them. Results showed that over half of participants (53%) felt they had low control ecosystem response to change, and only 15% felt reported having a moderate amount of control over ecological response. Addressing the potential for "regional tipping points," to occur allows for the possibility of empowering managers through collaboration at a reasonable, actionable scale, so they feel that they have

greater control over shaping the direction of ecosystem responses, or at least better prepare for possible impacts from regional tipping points.

Identifying the spatio-temporal scales at which stressors are contributing to ecological change is crucial for research and adaptive management efforts because it allows for specific actions to be defined, planned, and implemented within a specific region and for the creation of implementation and meeting objectives within a specific timeframe (Nash, 2014). A common consensus among interview and survey participants is that ecological stressors are being experienced at larger scales and more widespread across landscapes than has been typical of this region historically. As management interventions frequently occur at a small spatial scale, this suggests greater challenges. This finding is interesting because this was echoed in the survey responses, which were expanded to allow managers across the Southwest region to express their perceptions related to experiences of ecological change.

While unsurprisingly, interview respondents expressed that ecological change and transformation was being experienced to a large-scale as this was a condition of being interviewed, this result also was quite apparent in survey results as well. An overwhelming majority (89%) of participants felt that disturbances are happening at scales and timeframes outside of what they consider “normal” for ecosystems (Figure 2.1) at predominantly large spatial scales (63%), followed by medium (30%), and at largely moderate (59%) followed by abrupt (36%) timeframes (Figure 2.3). Ecological disturbances which occur at larger spatial scales and over shorter time periods can reduce the ability for an ecosystem to return to equilibrium following a disturbance, and thus require a more extensive management response (Zelnik et al., 2018). The spatio-

temporal scales of ecological disturbances experienced by participants presents important considerations and challenges for present and future management.

Additionally, interviewees and survey participants shared the perspective that ecological resilience is being challenged due to human influences, both mismanagement and climate change, with vegetation not returning post-disturbance in some ecological systems and die-off becoming more common and widespread, as certain ecosystems are less able to respond to synergistic stressors of drought, introduced species, and wildfire disturbances. It was still recognized by interviewees that there is variability in ability to recover post-disturbance. In this region, a consistent perspective among respondents, that both have (interviewees) and sometimes have yet (survey participants) to experience large-scale changes, was that landscape-scale changes due to ecological stressors are inevitable. In the survey results, most participants (63%) found the ecosystems in which they have been “substantially” or “completely” stressed or transformed by ecological changes, with no participants reporting landscapes not experiencing ecological stress (Figure 1.4). One interview respondent characterized the overall view of ecological change well, stating how ecosystems and individual species which were previously thought of as “resilient” and “adaptable” have been experiencing noticeable stress and not recovering post-disturbance as they had in the past.

The consideration of spatial scales has been central to the political ecological approach; emphasis is placed on how social-ecological issues are both local and global in nature, with small- and large- scale factors influencing challenges and outcomes (Sayre, 2015). Interview and survey participants both felt that the spatio-temporal scales

of ecological impacts are outpacing current management efforts, with policy-making at the federal level and management decisions at the individual park unit and/or regional level often being discussed as occurring at a slow temporal pace and failing to occur at a widespread scale across ecosystems, regions, and park boundaries. There are many considerations to be made when understanding the challenges posed by spatio-temporal scales of ecological change, such as mismatches in temporal scales challenging predictability of outcomes, such as tipping points being an area of uncertainty, as well as how understandings of ecological and climatic phenomena are dependent on spatial scale, meaning that observed responses in one ecosystem may present different outcomes in larger ecosystems (Meinke & Hochman, 2000).

Interview respondents, particularly from the National Park Service, felt limited both by the small spatial scales of their park units, as well as the fact that certain, larger and/or more “iconic” park units were often given more financial and staffing resources for implementation. One contrasting issue related to spatial scale was presented by the Bureau of Land Management and U.S. Forest Service respondents, who found that the vast acreage of lands they were tasked with managing led to an inability to implement adaptive actions across such widespread landscapes. Respondents felt they were often limited to addressing ecological challenges in small portions of the lands they manage and expressed a sense of inability to implement adaptation actions at the necessary levels to result in effective outcomes. The respondents’ perception of the large spatial scale of change found in the survey results is further challenged by the constraints of the physical land boundaries reported by interviewees. Through a political ecological lens, spatial scale is often understood within the “politics of scale” which defines scale

as socially constructed, relational, contingent, and contested and incorporates them in a way that emphasizes the role of power relations (Neumann, 2009). The “politics of scale” lead to complications and challenges for effective management. Three key themes theorized as “a political ecology of scale” include socio-ecological processes and scale, scaled networks, and the interactions of agency, power, and scale (Neumann, 2009). The interactions of agency, power, and scale are especially important for consideration in relation to the findings of this project due to the limitations they create for managers to effectively address the previously mentioned challenges related to spatio-temporal scales.

In ecological analyses and management, spatio-temporal scales are recommended to be based upon ecological features and phenomena rather than spatial boundaries, due to the fact that ecosystems are not restricted to political boundaries or arbitrary timelines (Nash, 2014). An additional spatial limitation that emerged is the difficulty for adjacent park units to share funding and resources to enact larger scale adaptive actions, or disagreements between adjacent units on the best management approaches ultimately leading to zero actions being taken. Yet another spatial limitation was presented by managers working on larger landscapes who found difficulty in addressing the scale of changes across a wide diversity of multiple ecosystems across a single park unit, and how climate change and associated ecological stressors will have uneven impacts across ecosystems, with some being more vulnerable to disturbance than others, but also the uncertainty of how threshold-level changes to certain ecosystems may trigger changes throughout other ecosystems within the park, often to an unpredictable extent.

The social construction of scale is an especially important consideration, as it provides greater understanding of the role of the state in the production of scale, emphasizing the spatial implications of political and economic development and influences (Marsten, 2000). This is evident in the federal government's creation of boundaries and borders of public lands, as well as what landscapes and ecosystems are deemed valuable by agency leaders to be protected as public lands, and which are excluded.

One of the most significant challenges expressed by both interviewees and survey participants was the inability to enact effective adaptation planning and action at the spatial and temporal scales necessary to have an impact. However, this is not often how research, planning, and management are conducted, as shown by the interview and survey results in which participants expressed feeling restricted and confined to management within their individual units' boundaries, despite wishing for greater cross-agency collaboration. Agencies have different objectives when it comes to land management, and this contributes to the inability for effective collaboration and management to happen on a larger spatial scale. The intent of the state is to maintain control over natural resources and the physical environment and maintaining control necessitates the creation of spatial boundaries (Neumann, 2009). The development of spatial boundaries for park units were not based on the physical ecological conditions of the landscape or what would allow managers to have the greatest ability to effectively manage at that given spatial scale, instead they were determined and defined based on the priorities and values of the federal government, in a process of "producing scale" (Swyngedouw, 2007). Despite ecological stressors contributing to respondents'

observations of large-scale impacts, managers reported finding it difficult to increase collaborative management efforts across arbitrarily defined spatial boundaries, such as park borders, which were not created based on the ecology of the region or facilitating effective management of systems. Instead, the spatial scale and boundaries of landscapes are produced by leaders in the U.S. federal government agencies and state agencies, with the primary objective of maintaining control over natural resources. Often agencies emphasize differing management strategies and approaches based on divergent agency objectives, which are determined by individuals that hold power within the agency at the federal level, as opposed to scientists and managers experiencing ecological changes on the ground.

Even agency leaders at the federal level are constrained in their actions and decision-making abilities due to the power of the federal government that alone has the ability to distribute or withhold funding and resources to agencies. Climate change continues to lead to ecological impacts, but management decisions and planning often fall outside the physical land unit boundaries. Natural resource managers are currently facing the insurmountably difficult task of effectively preparing for and responding to ecological changes. This is due to the contrast between the large scale at which climate change is acting on ecosystems and the much smaller scale at which managers are able to perform actions on the ground. In addition to the large spatial scale at which climate change impacts ecosystems, both interview and survey respondents expressed their perspectives that stressors in the future will lead to greater impacts than they have historically. This was expressed by interview respondents in relation to how they face

the challenges of managing under uncertainty of how severe the impacts will be, as well as the high levels of future ecological stress predicted by 74% of survey participants.

II. Definitions and Perceptions of Adaptation: **"[Adaptation is] one of those things that means totally different things to different people."**

This section provides a response to the second component of research question 1: "*What are natural resource manager perceptions related to adaptation, what is their definition of adaptation?*" Though every interview respondent was asked the same questions -"how do you define adaptation?" and "When you hear the term adaptation what do you think of or what does it mean to you?" - responses varied. Respondents often emphasized multiple aspects of climate adaptation in their definitions. Respondents also emphasized some aspects within their definition of adaptation that fall under the general categorization of adaptation, as well as emphasizing strategies or actions that are not considered adaptation or presented a mischaracterization of adaptation. There was also an emphasis placed heavily on science or heavily on management, which was largely dependent on educational background, and illustrates that individual experiences of managers has an influence on how the concept of adaptation is both interpreted and applied on the ground.

Survey participants' responses were similarly multifaceted, with adaptation strategies and mischaracterizations often all encompassed within a single definition, despite largely reporting (74%) that they have a clear understanding of the concept of adaptation in a management context (Figure 5.1). Diverse understandings of such a widely used term in natural resource management means that the term can be applied in multiple ways, depending on the respondents' personal definition. This leads to

management and communication challenges, especially if managers do not have a shared understanding of the term and are often applying it differently from one another. As shown in both Table 2.1 and Table 5.1 of the open-ended survey questions related to adaptation, there were a wide range of definitions, understandings, and desired applications for the term adaptation. This finding suggests that such varied understandings shapes respondents' perspectives as well as agency discourse around adaptation, both conceptually and as a strategy for implementation of action. Interview respondents often defined adaptation as it relates to on-the-ground application of adaptation strategies, but also attributed the definition to the physical environment, specifically an emphasis on ecological adaptation to climate change, and social dimensions of adaptation. For interview respondents, adaptation was perceived both positively and negatively, with respondents expressing frustration with the concept, and others viewing adaptation as crucial, but expressing doubts related to the term being used often in planning without it leading to the necessary actions.

Presently, natural resource managers and decision-makers do not have a shared understanding of the term and are often applying it to management in different ways from one another. Managers themselves even report a sense of skepticism regarding shared understandings of not only the definition, but the applications of the term in proactive management approaches. Another issue is that management approaches are often "business-as-usual," meaning that approaches are current common strategies in resource management that would take place with or without worsening ecological stressors but are being portrayed by agencies as if they are climate adaptive management. One USFS respondent that is responsible for climate planning for the

lands they manage, reported that their supervisor told them to include the word “adaptation” in their report in order to increase the likelihood of receiving project funding. This respondent was told by their superior to “just throw that word in there, it doesn't really mean we're doing anything different, so just say it differently.” This interviewee acknowledged concerns that despite the emphasis on the use of a word that is meant to encourage adaptive actions, “we're still doing everything the same.” This insight reveals that in this instance, the term adaptation was used to carry out business-as-usual management tactics and as a buzzword that allowed managers to receive funding for approaches that were not considered adaptation. Also, 52% of survey participants reported that actions that are planned for the future are the same as actions taken in the past, which contradicts the survey result of 59% of participants reporting adaptation being acted on in the systems in which they work. These findings, paired with 74% of participants reporting a clear understanding of the concept of adaptation in the context of managing novel stressors, suggest that the adaptation may not be acted on as frequently as reported.

Interview respondents across agencies viewed applications of adaptive management suggested by agencies as being existing, business-as-usual approaches to restoration and risk mitigation, as opposed to novel approaches to address climate change. Interestingly, it was also reported by fifty-two percent of survey participants that planned implementations of adaptive actions are the same as actions that have already been taken in the past. This perspective was highlighted well by a respondent who viewed adaptation as being infrequently applied on the ground: “Even though the strategy and the idea is very, very well documented, very well thought out, it's actually

practiced very seldom." This take-away from the interviews contrasts with the survey findings in which a larger percentage of participants felt that adaptive actions are being implemented in ecosystems they manage (59%) than those who felt that adaptation is not being acted on in the systems they work (41%). As the interview was more open-ended than the survey, this result may suggest that it was easier for managers to give an on-the-ground perspective. The survey may have led respondents to feel constrained and encouraged to respond as representatives of their agency. This finding also contrasts with the survey findings that the least significant barrier to implementation is that "adaptation is not a priority" to agencies, which was chosen by nearly half of survey participants (48%). This may be due to the fact that this choice may have been too subjective, where the participants may have interpreted the meaning as their personal view that adaptation is a priority or that adaptation is not viewed as a priority for agencies.

An additional finding was that understandings of the concept of adaptation varied depending on the vocation and job duties of respondents. For example, when asked to define adaptation, interviewees in upper-level management positions, focused solely on the idea of adapting their management practices and leadership styles to better support staff members as they face increasing challenges on the landscape. These definitions focus on adapting leadership styles but without specifics on how these leadership styles would be more "adaptive" in terms of preparing and responding to climate change. Responses ranged from vague, unclear general definitions of adaptation to highly specific applications of adaptation strategies, revealing a wide array of usages for the concept. When asked in an open-ended question to provide specific actions that the

participants would like to take next, over one-quarter (26%) of participants provided generalizations, failing to identify specific actions, which suggests that there may be a lack of clarity and/or consensus around what is considered adaptive action, as well as on-the-ground examples of what adaptation entails. Nearly one-quarter (24%) of responses were not adaptation, revealing that there are still misinterpretations and/or incorrect understandings surrounding the concept of adaptation. These definitions were categorized as being vague/unclear, incorrect, confusing adaptation with mitigation, business-as-usual approaches confused with adaptation, or described how adaptation is not possible, placing emphasis on limitations and ineffectiveness as their "definition" of adaptation (Table 5.1). Nearly half of the participants (48%) felt that it was "somewhat likely" that they will be able to facilitate adaptive actions, with an additional 11% reporting that it would be "extremely likely," yet the interview takeaways and survey responses highlight how managers' definitions of adaptation are not clear, often lack consensus, and that participants frequently failed to give specific, actionable examples.

Often, both survey and interview respondents mentioned specific management actions and gave a broader definition of adaptation, reflective of the IPCC definition, showing an understanding of the broader concept and its application. However, other participants also attempted this approach and resulted in confusing, unclear definitions; some identified strategies that would not be considered climate adaptation, or gave a broad definition of mitigation, which is focused on reducing emissions and impacts, as opposed to adaptation, which focuses on preparing ecological systems for projected changes. Followed by this definition, adaptation was often defined by respondents as being primarily focused on ecological restoration efforts that address past impacts but

also are viewed as contributing to greater ecological health and better resistance to ecological stressors. These respondents shared the perspective that direct, widespread restoration actions are the primary way to promote effective adaptation, citing concerns related to the impacts that climate induced ecological stressors have had and are projected to have on the landscape. This was an interesting way for managers to perceive restoration, as restoration efforts across a given landscape can often be limited by large-scale ecological changes (Gilby, et al., 2018). Other responses seemed to be in support of adaptive action but lacked specificity, such as adaptation defined as "encourage land management that is actually focused on climate change rather than business-as-usual." This quote suggests the respondent's desire for implementing climate adaptation actions but does not describe what actions they would like to take or that they have an understanding of what adaptation actually is outside of a very general definition that adaptation focuses on climate change.

For individuals who focused on management-based definitions of adaptation, respondents focused primarily on practical applications, "on-the-ground" approaches to adaptation, presenting the overall sense that adaptation is related to the use of strategic frameworks to build adaptive capacity on the landscape. The wide variety of responses shows that there may be a disconnect between managers' perceptions on what adaptation entails, with 74% claiming they understand the concept, yet when asked to define adaptation, survey and interview responses both suggest that the term is being understood and applied in disparate ways. Without a stronger, more cohesive understanding of the term adaptation and what adaptive actions actually entail, climate adaptation cannot be applied effectively. Actions that respondents discussed that could

allow for adaptation to be more widely understood include the development of additional adaptation menus and increasing interagency collaboration on adaptive actions.

III. Knowledge, Attitudes and Practices Related to Adaptation: ***"We're doing the same old stuff that we've done for years and years and years"***

This section responds to the sub-question 1(a): "What are the knowledge, attitudes, and practices of land managers related to adaptation strategies?" There is a gap in the existing literature surrounding the knowledge, attitudes, and practices (KAPs) of natural resource managers in relation to the understanding, development, and implementation of adaptation strategies. KAP studies are focused on developing insights and understandings of how differences between individual perceptions shape actions (Saxena et al., 2018). KAP studies examine how perceptions can create obstacles and challenges that prevent implementation of actions (Saxena et al., 2018). In addition to better understanding obstacles, KAP studies can elucidate how to better bridge existing knowledge-action gaps and how to create a greater connection between individuals' knowledge/attitudes and their practices.

Since individual knowledge and understandings of the concept of adaptation varied widely between respondents, there was often a disconnect found between managers' understanding of the concept generally and their abilities to distinguish between business-as-usual approaches, mitigation strategies, and climate adaptation strategies. There was a consensus surrounding the difficulties of applying the term adaptation to strategies and actions, whether managers had a strong understanding of the concept. Across agencies, experience levels, and vocations, respondents struggled with conceptualizing adaptation strategies in a clear and concise manner. What some

respondents considered to be adaptive management; other respondents would consider to be business-as-usual management approaches. These divergent understandings and differences in how the term is applied led to attitudes of frustration among some respondents; one felt that terms such as “adaptation” and “resilience” are essentially buzzwords that do not inspire novel ways of addressing ecological change. These respondents discussed their view that adaptation needs greater clarity and specificity in instructions for implementation. An area of consensus in attitudes surrounding adaptation was the view that organizations use the term frequently and emphasize the importance of adaptive planning, but agencies often fail to provide more direct, step-by-step guidelines.

The assessment that existing knowledge is enough to get started on adaptation actions is known as the “knowledge-action gap,” which is a significant issue that occurs when “research outputs do not result in actions to protect or restore biodiversity” (Roche et al., 2021). The gap between existing research and adaptive actions was determined to be a management issue by both survey and interview respondents. The knowledge-action gap was determined to be an area of primary concern in both interview and survey participants, where information is available, but action is limited. Interview respondents varied in their perspectives on whether there is suitable information to comprehensively understand which actions are the most appropriate for their landscapes, often expressing a sense of “information overload,” feeling that the amount of available research and information can be “exceedingly overwhelming.” The overwhelm of information may also contribute to the knowledge. A prevalent theme that arose when discussing primary barriers to implementing climate adaptation actions with

interviewees, in which respondents felt that they have adequate levels of knowledge and understanding of strategies they would like to implement or expand upon in order to have increased preparation/response for climate change on their landscapes. Interview respondents reported that they have enough information, but evidence suggests that the information is not translating to on the ground actions. Knowledge, attitudes and practices surrounding adaptation are not cohesive, and there is a problem of a gap between scientists' and managers' knowledge and adaptive practices. Attitudes surrounding adaptation were found to be as complex and varied as managers' definitions of adaptation, with some managers speaking optimistically about taking adaptive action and others having largely negative viewpoints, as well as many perspectives in between.

While a high percentage (86%) of survey participants found that they do not have enough resources to prepare/respond effectively, a smaller percentage, though still over half of participants (55%) found that they do not have enough information to respond. In an open-ended survey question asking what resources are needed the most to adapt, the least frequently reported resource needs were agency support (9%), followed by science and information needs (10%). An open-ended question related to information needs was the least answered of the qualitative survey questions with 58% of participants responding, compared to 78% of participants responding to the open-ended resource needs question. The largest percentage of participants (27%) who responded to this open-ended information needs question expressed the need for more clear and precise existing data and information and/or the need for existing information to be expanded upon and provide more nuance and better understanding of how to apply

existing information. Within this category, there was a consistent theme that the data and information needs are well-known, but that there is room for improving the quality, precision, and management applicability of this information. In a quantitative, ranked choice question, 29% of participants ranked information as their least significant barrier, followed only by adaptation not being a priority.

Attention has been called for the need to understand why such gaps exist (Giurca et al., 2022) as well as bridging the gaps between existing scientific knowledge and implementation of necessary actions (O' Brien, 2011). A possible explanation for the gap between scientific knowledge and on-the-ground action is that institutions tend to incorporate science-informed actions slowly, and decision-making of political leadership is often based on short-term solutions (Giurca et al., 2022). Lack of resources was cited by 86% of survey participants as the primary barrier for adaptation, which suggests that scientific knowledge exists in terms of adaptation strategies and actions, but the institutions are not providing the funding necessary to create actions. The knowledge-action gap was discussed in relation to several barriers to adaptation including the lack of resources, staffing, and/or agency and government policy. The amount of information related to adaptation planning and suggested strategies were described by interviewees as often "conflicting" and toolkits with adaptation strategies were seen as neither intuitive, nor straightforward by managers who felt that more clear, step-by-step guidelines and/or step by step examples would allow for more effective implementation.

IV. Management Influences and Decision-Making Across Agencies: **"Everybody's making decisions in their own little kingdom."**

This section provides a response to the first component of research question 2: *"How does decision-making occur with respect to drought and wildfire ecosystem stressors?"* Management priorities are not simply shaped by individual KAPs as discussed previously but are also shaped by agency mission and objectives developed at the federal government level. Contrasting viewpoints related to management approaches between respondents from different agencies and vocations emerged over the course of the interviews. Vocational differences were as expected; those with science educational backgrounds and vocations focused their interview responses on ecological discussions based on their areas of expertise (fire, forestry, plant ecology, etc.), and respondents with educational backgrounds in natural resource management and vocational experience in management positions tended to discuss their perspectives on management approaches. Overall, respondents across vocations focused on applying best-available science and research to their on-the-ground management decisions, and this did not vary significantly between vocational experience.

When asked how they viewed other agencies' adaptive responses, interviewees frequently shared the positive aspects of their own agency's management approaches and addressed the shortcomings they observed within other agencies. Survey participants also shared positive findings related to their organization implementing the same amount (44%) or more (40%) adaptation actions in comparison with other organizations, with only 15% of participants felt that their organization is doing less

relative to other organizations. The criticisms being skewed toward other organizations as opposed to their own agency is most likely due to the reluctance to share openly negative perspectives on one's own employer. Several interviewees discussed shortcomings across agencies. Respondents often characterized other agencies by existing common stereotypes, and often shared critical perspectives about agencies outside of their own more often than critiquing their own employment agency. There was a consistent understanding that management approaches were variable due to different agency missions and objectives.

Tensions between agencies were revealed when respondents were asked to compare management strategies and agency objectives. Multiple respondents from the NPS felt that there was a tendency for other agencies to have a more reactionary approach to management, in comparison with proactive methods, which was attributed to other agencies being constrained due to the size of their landscapes and the lack of staffing relative to this size. Interviewees from the NPS, as well as from other federal agencies, felt that the NPS agency's mission of preservation for the benefit of future generations was a major factor in the NPS actively prioritizing proactive adaptive management. This was being viewed as an explanation as to why NPS is seen as implementing more adaptive actions, in comparison with other agencies. The National Park Service was often characterized by interviewees as being focused primarily on promotion of recreation and tourism (often, with this focus holding a negative connotation for respondents outside of the National Park Service), and more positively, on interpretation and preservation. Respondents also discussed NPS's emphasis on visitation and recreation may deter greater investment into ecological

research and planning efforts. Respondents outside of the NPS felt that NPS has a greater focus on visitor experience and tourism than effective land management, which leads to management for the public's approval even if decisions are not what is best ecologically. The Bureau of Land Management was often described as serving mining and extractive interests, which was viewed negatively. The Bureau of Land Management was also associated with ranching interests, which was discussed with less of a strong criticism and respondents frequently discussed ranchers as additional stakeholders that could participate in collaborative efforts for climate adaptation. The U.S. Forest Service was infrequently discussed with criticism from respondents of other agencies, though several respondents discussed how the USFS is still multi-use and promotes the harvesting of timber and forest products. In other regions of the U.S., the USFS has been critiqued regarding logging and production, but there may have been less discussion of this aspect of the agency on the Colorado Plateau due to ponderosa pine being considered a less valuable wood source, and thus a less significant motivating factor behind management decisions. In comparison to other agencies, USFS interviewees most frequently discussed the management challenges of "playing catch up" and using reactionary management approaches. Respondents across agencies discussed the importance of keeping intact systems intact, but U.S. Forest Service respondents discussed this idea at the greatest lengths. Respondents across agencies and experience levels promoted prescribed burning as a way to both restore ecosystems and adapt to changing conditions.

Differences between agencies became most apparent when discussing contested management approaches. This controversy was especially noticeable in the

variation between actions and approaches taken to manage pinyon-juniper woodlands. USFS and NPS respondents felt that preservation of pinyon-juniper woodlands is important, while BLM respondents focused on pinyon-juniper encroachment causing changes to grasslands and shrublands. NPS and USFS respondents expressed concerns with the BLM's position on pinyon-juniper, with a silviculturist for the USFS stating their concerns with how the BLM approaches pinyon-juniper management: "there are truly people out there that believe that juniper is just a weed." BLM respondents discussed the pinyon-juniper in a context of it needing to be thinned, prevented from expanding in order to preserve critical habitat for the sage grouse and restore historic conditions. A BLM manager discussed how managing pinyon-juniper through thinning also helps decrease wildfire risk, as it is more difficult for fire to spread through open grasslands than in pinyon-juniper systems. NGO leaders who have collaborated with BLM officials felt that the concerns related to pinyon-juniper may be related to the preservation of grazing lands for cattle, in addition to concerns for the sage grouse, but BLM respondents did not discuss this aspect of their management decisions.

Application of political ecology allows for a critical examination of the state's role in creating contradictory goals in land management efforts. Under our current political and economic system, "the state's very legitimacy rests on providing economic development, even if that growth erodes ecological conditions" (O'Connor, 1988). The top-down structure of federal agencies often leads to research and management largely serving and reproducing the priorities and objectives of the state (Collard et al., 2019). This occurs despite the fact that there are clear ecological consequences to failing to

prioritize conservation of biodiversity and adapt to ecological changes. Within our current political-economic system, federal agencies operate under a contradictory notion that development and ecological protection can be achieved simultaneously (Collard et al., 2019). The state's contradictory values of economic development and environmental conservation is illuminated within the differences in priorities and objectives of land management agencies. For instance, the Bureau of Land Management and the National Park Service are branches of the same parent department, the U.S. Department of the Interior, yet they operate with different primary objectives, which can explain the divergent perspectives regarding perspectives on pinyon-juniper woodlands management. The Bureau of Land Management has historically managed with the mission of promoting use from multiple stakeholders, including ranching and mining interests, while the National Park Service centers its management mission around preservation of natural and cultural resources. Despite both being overseen by DOI, respondents from these agencies had significantly different perspectives on the ecological value of pinyon-juniper woodlands ecosystems. The mission of the agency and the primary stakeholders agency leaders include, or exclude, when making management decisions leads to different outcomes in management approaches and perspectives. The political and economic priorities of the state, shape scientific approaches, planning efforts, and management actions (Collard et al., 2019). The multi-use priorities of federal agencies, especially surrounding economic incentives, contribute to additional challenges for implementation of climate adaptation.

Within the survey results, a particularly compelling response related to the ability to make decisions was discussed as an inability to enact adaptive actions. One respondent stated: “I work in wildlife for the state. Our agency still won't even publicly use the term climate change and only uses the term drought. We have a ‘drought team’ but it doesn't have the right people on it and it is almost exclusively focused on wildlife drinking water augmentation. The state is almost in total denial about the coming ecosystem shifts.” Other responses echoed this limitation to decision-making efforts related to climate change, with interviewees discussing how priorities shift depending on which political administration is currently in power. For example, it was noted that during the Trump Administration, the concept of climate change was not allowed to be discussed, which led to the stalling of current projects and research - as well as a loss of funding for research - and implementation of strategies. Moreover, it created a period of time where new research could not be conducted. These results reveal significant limitations placed on adaptation decision-making when ability to make decisions are entirely dependent on continually shifting government administrations that have the power to modify policies, and reshape narratives around environmental challenges, according to their values and objectives.

A political ecological framework is well situated to offer an explanation for how continual shifts in institutional power influence natural resource managers’ decision-making and research abilities in several key ways. Political ecology examines the underlying political, economic, and social forces driving social-ecological issues - in this case the ability to make decisions rests heavily on those who have political and economic power to do so (Robbins, 2012). In the current political economic system,

attempts to implement effective adaptation actions will continuously depend on the interests of those currently holding political office, as agencies with interests in promotion of climate change skepticism and denialism are able to shape the policies of federal agencies. Political ecology helps to explain the limitations of individual resource managers and ecologists to strategize and implement climate adaptive actions, when a given administration denies the existence of climate change. As land management agencies are under the jurisdiction of the elected administration currently holding office, management decision-making abilities are continually threatened and can be restricted at the discretion of government leadership in the future.

V. Uncertainties and Complexities in Adaptation Planning: **"...Climate change is definitely rapid. The question is, can managers adapt that rapidly? The answer is no."**

This section provides a response to the second aspect of research question 2: "*How do natural resource managers create adaptation plans under conditions of uncertainty*?" Managers that had experienced large-scale ecological transformation on the landscapes they manage expressed the desire to create more proactive management strategies to prepare and respond to worsening ecological conditions but were limited in their ability to plan and felt restricted to taking a more reactive approach. When respondents felt they had been successful in implementing adaptive actions, they still expressed a concern that following disturbances they struggled to restore ecosystems back to their previous condition. There was a sense that even large-scale restoration efforts currently deemed as "successful" cannot fully counteract future projected and uncertain ecological conditions. Over half of interview respondents (62%) shared a similar sentiment that restoration efforts are a key approach to climate

adaptation and discussed strategies and plans for implementation of restoration projects, often identifying successful efforts across the Colorado Plateau.

In natural resource management, anticipatory (proactive) planning involves carrying out projects and tasks in advance, which gives greater opportunities for proactive adaptation strategies to be implemented, in comparison with reactionary (reactive) planning, which focuses on responses to what has already happened and needs the most urgent attention. Anticipation, and anticipatory planning, in the context of social-ecological resilience, is related to having foresight, being prepared and proactive in planning and research approaches (Boyd et al., 2015). Participants' abilities to take part in anticipatory planning as much as possible is critical in order to effectively prepare actions that address short- and long-term changes (Bradford et al., 2018). Anticipatory planning is crucial in building social-ecological resilience as it builds capacity for foresight and helps in managers' determining what solutions may be possible (Boyd et al., 2015). Interview respondents tended to view their own management responses as more reactionary than anticipatory, while the majority of survey participants (61%) felt that their personal flexibility with projects and tasks was a combination of both anticipatory and reactionary. This difference may be due to the fact that interviewees have already experienced large-scale ecological changes leading them to be more reactive in their approaches, while survey participants may have not experienced such large-scale changes. Participants that reported planning flexibility as fully anticipatory was the lowest selection (1%). Both reactionary and moderately reactionary (24%) planning were reported as slightly more common than anticipatory or moderately anticipatory (18%) flexibility in planning efforts.

Anticipatory strategies are often the most successful in the beginning stages of ecological stressor induced changes, once it has been recognized that ecosystem transitions are beginning to occur (Bradford et al., 2018). When asked what specific adaptive actions they would like to take next, 33% of participants identified specific, proactive, anticipatory actions they would like to take, and an additional 17% of strategies identified were reactive, as opposed to proactive. It is imperative for managers to have the ability to plan and enact anticipatory strategies as ecological changes become more widespread, and prior to disturbances as much as possible. This has been limited by institutional barriers, with lack of resources being seen as a larger barrier than lack of information. Management decisions made in reaction to what has already happened ecologically will not always provide opportunities to address what is currently happening, or what is projected to happen in the future.

The anticipatory planning approach, despite being found to be the preferred approach that managers often aim for, is not without limitations. Ecological conservation planning efforts are continuously influenced and constrained by social and ecological changes and uncertainties (Pressey et al., 2007). Similar to the concept of adaptation, the concept of “anticipation” in relation to planning is limited by the lack of a unified definition and understanding, as well as varied, sometimes conflicting understandings of what anticipatory planning entails and how it can alleviate uncertainties. This leads to conflicting predictions of future conditions and how planning efforts will prepare social-ecological systems for these conditions (Poli, 2010). Despite not explicitly asking interview respondents about management challenges under increasing conditions of uncertainty, 17 of 37 respondents (45%) discussed challenges directly related to

uncertain conditions, expressing how the magnitude of actual or potential ecological transformations led to difficulty creating and implementing adaptation strategies.

The numerous social-ecological complexities that emerge when taking part in anticipatory planning are often entangled with the uncertainties surrounding the predicted severity levels of ecological stressors including climate change. Greater levels of complexity within a social-ecological system can lead to barriers in anticipatory planning, as levels of uncertainty increase in more complex systems (Boyd et al., 2015). The inability to reduce the levels of complexity within a given system acts as another barrier to anticipatory planning efforts (Rogers, 2011). The theme of uncertainty revolving around management challenges related to the spatial-temporal scales of climate change impacts arose in relation to the unpredictability and complexity of these impacts.

Across the Western U.S. natural resource managers have found it difficult to plan and enact widespread climate change adaptation due to worsening ecological conditions in combination with socio-political limitations and barriers, as both the scale and magnitude of climate impacts continue to increase (Bierbaum et al., 2013). Discourse around uncertainty also focused on the limits of models and research in accurately predicting the spatial and temporal magnitudes of ecological stressors and how they will most likely impact various ecosystems. The predicted timelines for projected changes were called into question, as was the ability for managers and scientists to completely understand the magnitude of projected and modeled ecological changes. Examples of changes happening more rapidly than anticipated on the landscapes than expected were cited as examples highlighting the nature of uncertainty

in decision-making and planning for future conditions. These examples were particularly frequent in relation to unexpected rates of vegetation change, such as pinyon-juniper die off and/or drought conditions significantly reducing water resources and transforming the ecosystem more quickly than projections predicted.

In addition to interviewees discussing challenges related to uncertainty, over fifty percent of survey participants found that they have low levels of personal control over adaptation planning and management in order to shape ecological responses and build greater ecological adaptive capacity. This suggests that adaptation planning under conditions of uncertainty is complicated by management barriers that extend beyond managers' willingness to enact adaptive actions based on management plans. Survey participants most frequently selected the descriptions of their organizations' responses as limited, reactive, and inadequate, suggesting a consensus that land management agencies are not adequately addressing and implementing plans to solve current challenges. With over half of participants expressing low control in terms of management abilities, and nearly half of interviewees (45%) independently bringing up the subject of uncertainty. As survey participants described it best themselves, adaptation planning and management under conditions of uncertainty is currently "limited," "reactive," and "inadequate."

VI. Primary Barriers to Preparing and Responding to Ecological Changes: **"The reality is that everything depends on money. We have to have the personnel and the funding available to do the things that we know would be beneficial."**

This section provides responses to research question 3: "What are the primary barriers to preparing and responding to ecological change and climate change?" as well as sub question 3(a): "Why are actual adaptation actions on the ground not

happening?," sub question 3(b): "What supports are needed to facilitate responses to ecological change?," and sub question 3(c): What are the structural conditions that allow for good decision-making?" These questions are best answered through a political ecological framework, as it provides explanations for why structural limitations exist at the federal government level. Application of political ecology has increasingly been used to explore resource management issues across the Western U.S. (Martin et al., 2021). Political ecology has also been applied to understanding the critical perspectives of resource users in relation to governance issues in industrialized countries and throughout the U.S (McCarthy, 2002, Schroeder et al., 2006). The political ecological approach emphasizes how practices are often situated within a broader range of relations and contextual pressures (Martin et al., 2021). Apolitical narratives related to adaptation challenges, meaning narratives which exclude the consideration of larger political and economic factors, are common within federal agencies as they are reproductions of historic socio-political relations and the interests of present-day actors and institutions (Martin et al., 2021). These apolitical narratives benefit powerful actors and institutions by drawing attention away from the driving causes of current environmental issues (Robbins, 2012). In contrast to political ecology, an apolitical approach fails to examine underlying political, economic, and social forces behind environmental conflicts (Robbins, 2012). While apolitical suggests the absence of the political, even "apolitical" approaches to environmental issues are often political in nature, but these arguments present themselves as objective, unbiased, and straightforward, with little to no mention of larger systemic forces at work (Robbins, 2012). An understanding of political, economic, and social forces behind environmental

issues, including climate change and ecological stressors, provides greater insights into why adaptation actions are not happening on-the-ground, as opposed to the dominant apolitical narratives of agencies, which often exclude the reality of barriers to effective adaptation, which are created at the government level.

As shown throughout this study, there are many institutional and political factors that create limitations for land managers, such as the federal budget allocations determining how much funding and resources are available to enact management strategies. Political ecology's emphasis on powerful actors creating limitations has historically been applied to resource users but can be utilized to explore the multifaceted experiences and insights of resource managers in relation to environmental issues (Martin et al., 2021). Resource managers frequently experience constraints in their decision-making abilities due to social and political factors. For example, current approaches to land management by individual managers are often largely dependent on the objectives and likelihood of approval by federal and state administrations. Both the interview and survey results suggest that institutional and structural barriers are the most significant obstacles to overcome when enacting adaptive actions, as opposed to lack of support or desire to make adaptation a priority. For interviewees, resources, government and policy, staffing, and agency leadership were the most frequently discussed barriers. Lack of resources leads managers to have reduced options for action, with 86% of survey participants finding that they did not have enough resources to prepare/respond to climate induced changes including drought and wildfire. When asked an open-ended question related to what resources are needed the most, survey participants echoed the sentiments of the interviewees by stating that both financial and

staffing resources (27.5%), mainly financial (15%), or mainly staffing (13%) were needed the most in order to better prepare, respond, and adapt, with 55% of participants finding the need for resources and/or staffing to be the most needed resource (Table 4.1). Of the thirty- seven interviewees, twenty-seven (72% of responses) found financial resources to be one of the primary barriers to having the ability to facilitate more proactive approaches.

One specific, insightful funding-related challenge stands out as illustrative of how the availability of adequate funding for applications does not always lead to effective adaptation practices. A manager from the USFS with a background in silviculture described how there was funding allocated in the budget to treat 900 acres of a specific region within the national forest, yet this area of forest did not need thinning treatments at that time, as it had been treated relatively recently. The respondent identified another area of untreated forest that would benefit from thinning treatments yet was considered to be too large of an area by several hundred acres, despite the fact that treating 900 acres within this identified area would still have benefitted the forest. In order to meet agency objectives on a quota of acreage treated, the respondent's views were dismissed by a superior, and the acres were re-treated, as opposed to treating a portion of the forest area that needed treatment. The respondent felt that the superior primarily wished to meet the acreage objective and to make use of the available funding before it was reallocated elsewhere, suggesting a competitive aspect to the acquisition of limited funding. This example shows how institutional objectives and priorities have more power and influence over agency actions than the insights of managers working on-the-ground. It also reveals the power that agency leadership has in prioritizing meeting

quotas and administrative goals, as opposed to using available resources in ways that promote adaptation.

Ability to hire staff for the implementation of projects, as well as to conduct research to build upon existing knowledge, were cited by nineteen of the interviewees as another primary barrier to action. The issues identified by respondents as staffing related often came back to lack of financial resources to hire new staff and to compete with other agencies, such as city or state, especially when hiring fire management staff. Interviewees discussed how lack of affordable housing in remote, rural, and/or tourist-centric locations was another major obstacle to hiring new staff. Additionally, interviewees discussed how many public lands do not have adequate amounts of housing to provide for staff members, especially when an increase in staffing is desired, making it difficult to create positions that appeal to potential new hires. While respondents in administrative and management roles noted the difficulties of hiring the staff they need due to lack of financial resources to create new positions, several respondents in upper-level administrative positions stated that it is hard to find and keep staff due to housing affordability, lack of park housing, and the remoteness/seasonal nature of many entry and mid-level positions.

In addition to contributing to hiring challenges, seasonality of many public lands management positions leads to the difficulty in establishing a strong knowledge and understanding of the ecology of the landscape and the challenges it faces. Interviewees noted the critical need for development of a strong foundational understanding of the landscapes in which people are working to better identify and address changing impacts and potential solutions. The high turnover rate has contributed to lack of development of

institutional knowledge within a particular park unit. Interview respondents discussed how an increased, permanent science staff would be helpful in managing current and future stressors. This is a problem within agency structure - because many positions are designed to be temporary, seasonal work, and according to interviewees working for the National Park Service, there is currently not a streamlined ability for managers to rehire seasonal staff at the same park unit, leading to many staff members being transferred from park to park, often across different regions, resulting in a loss of area-specific knowledge in the process.

The survey findings related to information needs (Table 4.2 & Figure 4.3) paired with managers discussing how they were already overworked, understaffed and struggling with time constraints, suggests that another critical barrier to effective adaptation is how the lack of time prevents effective management and makes a strong case for the need to hire additional staff. As one survey participant insightfully suggested, hiring processes should prioritize additional staff with an educational background in climate science and/or climate adaptation planning for a specific park unit or region, that is tasked with adaptation research, strategic planning for on the ground implementation, and assisting with monitoring of results of actions.

The next question that arises when discussing barriers to adaptation is why funding is not made available for facilitation of actions and/or to hire new staff to assist natural resource managers with their workload. Closely following the lack of resources as a primary constraint to effective action was the limitations imposed by current government administration and existing federal policies, for interviewees. Government policy was mentioned by 25 of 37 interview respondents as a main challenge, citing the

reality that agency decision-making is limited by the tremendous influence and power of the current federal administration to dictate what actions are or are not allowed to be taken. Policy changes at the federal level is often a slow and tedious process, as is advocating for more access to funding. When “policy can get in the way of action” and limit adaptive actions from being implemented, natural resource managers are unable to adopt new strategies.

While it is important that there are limits placed on what actions managers can take in order to ensure that actions are based on best available scientific knowledge and practices, policy and regulations can discourage novel thinking and push managers towards “business-as-usual” strategies. Building on the lack of federal support, respondents (21 of 27) discussed a common sense of frustration with limitations being placed on implementation of action due to lack of support from agency leadership, which coincides with the survey finding in which 26% of respondents found that “organization culture” was a primary barrier. This suggests that those in leadership positions in the agency may be supportive of following institutional guidelines, and may lead to favorability of business-as-usual approaches as opposed to a flexible agency structure that allows for open dialogue, collaboration, especially with other agencies, and for managers to feel they have the ability to suggest novel approaches. Across agencies, management efforts were often characterized by participants as being restricted to “business-as-usual” or “reactive” adaptation approaches. Due to the top-down organizational structure of federal and state institutions, decisions made by managers of individual park units are subjected to the approval of higher-level agency administrative officials. When decisions are made in a top-down manner, it encourages

a business-as-usual approach to management, as opposed to the consideration and implementation of novel approaches, especially if the approach is outside of standard organizational practices.

Policy level limitations are particularly evident when it comes to the expansion of prescribed burning on public lands as a form of climate adaptation, as well a reactive mitigation to the existing landscape conditions due to over a century of mismanagement by fire suppression. An increase in prescribed fire efforts was unanimously supported by interviewees, with no respondents stating that current efforts are adequate or suggesting the need to scale back. With one of the central areas of focus of the ecological change portion of the interviews being centered on wildfire related stressors, nearly every respondent described prescribed fire as an effective strategy and approach that needs to be implemented more widely and rapidly. State and federal regulations have the authority to restrict prescribed fire efforts, despite such efforts being one of the most widely supported and researched approaches to minimizing the number of high-severity fires experienced in this region. This is primarily due to misconceptions and lack of understanding about the ecological role of fire, as well as unfortunate incidents when prescribed fires have gotten out of control and caused property damage. These misconceptions became pervasive in both the public and in natural resource management, due to historic fire suppression practices by federal agencies. However, it is important to note that political ecology research has shown how natural resource management has been shaped by long-standing misconceptions of wilderness and nature, as well as the historic and ongoing influences of colonialism and capitalism (Cronon, 1996, West, 2006). Western colonizers brought their values of control and

domination over the natural world with them, seeking to suppress natural ecological processes such as fire, despite thousands of years of fire management through burning by indigenous groups throughout the region (Cronon, 1996, West, 2006, Liebman et al., 2016).

With or without increased prescribed fire efforts, large, high-severity fires are becoming more prevalent, and likely to continue in this direction due to climate change and continued suppression efforts. This leads to the question of why certain risks are deemed as acceptable, or at the very least unavoidable, while others are met with more scrutiny and resistance. In relation to wildfire across the west, anthropogenic climate change in combination with fire suppression and mismanagement have and will lead to increased frequencies of “megafires,” and yet there is regulation and resistance from both officials and the public to increasing prescription fire efforts, despite scientists and managers conceding that this is one of the most effective ways to adapt to climate change and to respond to the historic mismanagement of public lands by federal agencies. Business-as-usual approaches to fire management in the form of suppression efforts are often still common, despite a consensus from respondents that they are in favor of more widespread prescribed fire efforts. This disconnect between the knowledge and values of managers and scientists and the public, government officials, and city and state officials lead to an additional barrier to action. Lack of support produces a lack of funding for increased prescribed fires and will inevitably lead to out of control, catastrophic fires that are intended to be prevented.

From a political ecological perspective, it is well understood that the power and control of institutions shape politics and the environment. Dominant institutions and

political economic systems continue to shape and transform the physical environment (Robbins, 2012). A political ecological approach allows researchers to ask questions that help determine underlying power dynamics at work when examining social-ecological issues. When applied to natural resource management, decision-making power and abilities to allocate resources ultimately exist within the federal and state government leadership. It is important to note that agency officials in leadership positions are often changing from individual to individual. This means that those in leadership roles within the institutions responsible for providing the financial tools and decision-making guidance are continually dynamic in nature and influenced by numerous political and economic factors. Several of the political economic factors which influence decision-making and resource allocation from agency leadership include political party affiliation, which political party is in power, and strong influences of corporations over politicians' decisions especially in relation to distribution of financial resources and federal budget allocations. As existing adaptation literature suggests, the driving political forces contributing to climate change, as well as the current and projected impacts of climate change, directly relate to struggles over resources, including how they are governed and accessed at various geographic scales (Mahony, 2014). The barriers described by respondents are primarily those related to monetary limitations, most notably, funding and adequate staffing for planning and on-the-ground adaptive action implementation.

Additional financial constraints include lack of funding for additional scientific research, especially for ecosystem-specific studies of response to changing climatic conditions and monitoring of adaptive actions. Such studies are important to climate

adaptation research because they provide greater context as to what strategies are working on the ground, and where modifications may need to be made. For instance, managers discussed uncertainties in attempting adaptive actions that may lead to unintended consequences, with significantly contrasting perspectives on whether strategies such as assisted migration will lead to more ecological harms than benefits. Information barriers could be addressed through additional research, or expansion of regionally specific studies. Another funding-related concern was the lack of affordable housing for existing employees or to support a larger workforce that would be necessary in order to implement widespread adaptive actions. As many public lands are remote and tend to be viewed as vacation destinations, with surrounding communities often viewed as ideal locations for second homes, there is a combination of lack of available housing and being a tourist destination driving up prices and reducing affordability of housing for employees.

Necessary support for effective decision-making identified by interview participants includes the needs for increased collaboration, needs for effective science communication and outreach to the public, needs for increased resources, leadership, and agency support. Increased collaboration addresses issues of spatial scale, because respondents managing smaller landscapes are better able to express how decisions made on adjacent lands impact their park units. Collaboration can not only lead to more effective management but can also cultivate empowerment when involving managers of smaller public lands in the decision-making process that often feel that their efforts are limited. Multiple respondents discussed how funding and resource issues related to cross-boundary projects can be better resolved with increased collaboration.

As discussed in the interview results chapter section on “successful adaptation efforts,” respondents discussed examples of facilitation successes with cross-boundary and cross-agency projects. A successful example of such an effort is 4FRI (Four Forest Restoration Initiative), which is one of the largest restoration projects in place in the U.S., with 2 million acres approved for treatment. 4FRI was pointed to by participants as a success, and attributing this to the project receiving support largely due to its collaborative nature. Adaptation projects that were viewed as successful by respondents were a result of effective stakeholder collaboration between agencies, community members, and due to increased communication between other managers and scientists working in similar ecosystems, as opposed to being confined to efforts within park boundaries.

CHAPTER SEVEN

CONCLUSION:

Climate change is often framed as an apolitical “environmental” problem, as opposed to a socio-ecological problem that is the outcome of political, economic, and societal interactions. However, many environmental problems and management challenges will continue to persist, even if society mitigates the impacts of climate change due to existing political, economic, and social conditions. Political ecology was applied to this research project to provide more comprehensive answers to the research questions and to provide natural resource managers with greater clarity as to how these driving forces contribute to ecological stressors and challenge management abilities to prepare and respond to ecological change. It is through a critical examination of the causes behind management barriers that can provide explanations for why barriers are difficult to overcome, that possibilities and alternative pathways allowing for effective ecological conservation may begin to be envisioned.

This research project gained numerous insights related to perceptions surrounding ecological change, including climate change, involving discussions surrounding themes of concern related to crossing tipping points, positive feedback loops, and synergistic impacts of ecological stressors. Survey results provided several key findings surrounding managers’ experiences of ecological change in the Southwestern U.S. This includes findings indicative of ecological disturbances occurring outside of normal spatio-temporal scales, leading to challenges of managing landscapes dealing with more abrupt, widespread changes. Managers working on small

landscapes find that they cannot enact effective climate adaptation to deal within the limits of their park boundaries, as they are influenced by decisions made on the surrounding environments. In contrast, managers working on large landscapes feel that the spatial scale is too large, and therefore costly and staffing intensive, to implement effective adaptive actions.

Many interview respondents across agencies viewed applications of adaptive management suggested by agencies as being existing, business-as-usual approaches to restoration and risk mitigation, as opposed to novel approaches to address climate change. Natural resource perceptions related to adaptation can be characterized as managers feeling limited in their abilities to enact adaptive actions. Definitions of adaptation were multifaceted and varied widely across interview and survey respondents. This contradicts the survey findings that the majority of participants felt they understand the concept of adaptation. This contradiction suggests that managers may perceive themselves as understanding the meaning of adaptation, but that the actual meaning may not reflect their subjective definitions. This finding related to the confusion and complexities around adaptation suggests that agency discourse around adaptation may influence, and be influenced, by these (mis)understandings.

When asked in an open-ended question to provide specific adaptation actions that the participants would like to take next, participants frequently failed to identify specific actions, which suggests that there may be a lack of clarity and/or consensus around what is considered to be adaptive action. Respondents suggested that adaptation is often used as a buzzword to receive funding but is often not leading to actual on the ground adaptive actions. Knowledge, attitudes and practices surrounding

adaptation are not cohesive, and there is a problem of a gap between scientists' and managers' knowledge and adaptive practices. Attitudes surrounding adaptation were found to be as complex and varied as managers' definitions of adaptation. Variations across agencies in decision-making approaches can largely be attributed to the mission and objectives of the agency at the institutional level. At the regional level of this project, managers were in support of increased adaptive actions, but limitations to their decision-making abilities was a recurrent theme. Adaptation planning is complicated by socio-ecological uncertainties and nearly half of survey participants reported low levels of abilities to shape ecological responses to change.

Concerning the greatest barriers to implementing climate adaptation projects, respondents primarily discussed needing resources in the forms of funding and staff, greater support and direction from agency leadership and government administrations. Without addressing these needs, multiple respondents felt that they would continue to be unable to effectively implement projects. Federal agency institutional structure and decision-making is primarily top-down in nature, reducing the ability for bottom-up decisions to be made that often better reflect the socio-ecological needs of the park unit or the region. Institutional rigidity limits managers to implementation of business-as-usual approaches and discourages novel, proactive approaches to climate adaptation. Respondents specified needs for increased resources, support, and leadership necessary to shift toward more proactive management. There is a critical need for increased resources in the form of funding and staffing to effectively facilitate adaptive actions. Respondents frequently discussed planned projects they would implement if they had the necessary resources. The political ecological theoretical framework was

utilized to gain additional insights related to power relations within agencies, barriers to effective land management, and differences in agency missions shaping discourse and actions. Through understanding the driving political, economic, and societal causes behind ecological changes and transformations, possibilities for institutional and societal changes begin to emerge.

I. Main Research Contributions:

This study builds upon existing climate adaptation and natural resource management research in several important ways. While natural resource management decision-making in relation to climate adaptation has been studied in the past, the political ecological theoretical approach provided novel insights and considerations that are often missed without application of this framework. This approach allowed for the research to explore considerations of how power dynamics unfold between resource managers and the larger agency institutions which have control over allocation of funding and the power to make policy decisions which impact the resource managers' ability to implement climate adaptation. The political ecological approach builds on existing climate adaptation and natural resource management literature in a distinctive way that has not been previously done in a study of adaptive management in the Colorado Plateau region. Through a political ecological approach, limits and barriers were examined in order to provide critical explanations of the underlying causes behind the climate crisis and government inaction. Political ecology provided a crucial lens through which this research project was able to examine the underlying political, economic, and societal causal forces behind climate adaptation limitations and barriers. Importantly, understanding how power relations shape institutions and limit

management actions, shifts the burden of responsibility from managers to federal agencies and government institutions, acknowledging their inaction and failure to enact a widespread, proactive response to climate change.

In addition to the distinctive use of a theoretical framework to investigate the complexities acting as barriers to effective climate adaptation, this research was unique in having a mixed methods research approach used to better characterize a wide range of insights and approaches, which can be shared between managers that have and have yet to experience large-scale ecological changes. This research approach combined qualitative interview results with quantitative and qualitative survey results, allowing for this research to draw out perspectives that may not have been fully characterized within interview data or survey data alone.

Based on results finding that managers feel constrained by spatio-temporal scale and review of the literature, I noticed that climate tipping points have been discussed extensively at the global scale, however, are not as frequently examined at small spatial scales, such as geographic region, ecoregions, or across large public lands. I proposed a novel approach to identifying socio-ecological drivers of ecological change, in which tipping points are examined and projected at a significantly smaller spatial scale, known as “regional tipping points,” which can contribute to abrupt ecological changes and transformation. Approaching the potential of tipping points occurring at the regional scale allows managers to regain a sense of control over shaping ecological response to change, especially when acting collaboratively across agencies and stakeholder groups at the geographic regional level and/or ecoregion level.

II. Study Limitations:

The primary limitation in this study is the focus on federal and state agency management, despite the Colorado Plateau region being home to the largest percentage of indigenous lands in the continental U.S. Despite wanting to incorporate the insights of tribal managers into this project, my committee and I determined that addressing both federal, state, and tribal perspectives comprehensively is beyond the scope of a two-year research project, especially due to the sometimes lengthy process of obtaining a Tribal IRB. These considerations were the basis of our decision to focus on federal and state land management agencies, however it is necessary to acknowledge that this is a significant missing component, and the project would benefit from an understanding of the perspectives of tribal managers. The findings of this project would have been enriched by the ability to compare and contrast the perspectives and insights of managers from U.S. government agencies and tribal land managers. This is an important area for future research, which will be discussed in a subsection of the conclusion chapter.

An additional limitation of this study is challenges presented in interviewing and surveying a highly specific group of managers and scientists, working for the federal government, which may have contributed to reluctance from some participants to be fully honest and critical in their views related to their employer. This presents the limitation of a smaller sample size and the results of survey questions that may be perceived as sensitive topics being left unanswered. If I were to do this project again, I would include additional survey questions that more explicitly questioned perceptions of agency differences in management, as this was discussed more openly by

interviewees, but did not arise as frequently in the survey results. Another unexpected limitation was that multiple survey respondents opted out of including their agency affiliation, which limited the analysis of results and comparison through chi-square tests. If I were to do this project again, I would have placed a greater emphasis on phrasing questions to encourage responses, and I would have made demographic questions selectable, rather than allowing respondents to fill-in-the-blank, because open ended questions sometimes discourage responses. There may also have been reluctance to report agency affiliation due to respondents' fields being in the federal government and the sensitive nature of many of the questions, especially as individuals had different perspectives than official agency narratives around climate adaptation.

III. Recommended Directions for Future Research:

The most critical area for future research would be to expand on this project by conducting a similar study with the incorporation of indigenous environmental leaders across the Colorado Plateau. The southwest region is home to the largest area of indigenous lands in the U.S. and tribal lands border numerous public lands that were the subject of this research. There is a gap in the understanding of how tribal leaders understand climate adaptation and what the most significant barriers are for effective adaptive management on tribal lands, particularly the role of power dynamics between leaders of tribal lands and public lands, as the historical oppression of indigenous groups has created a situation in which they are limited in decision-making and under-resourced. A deeper consideration of how tribal leaders view ecological stressors on their lands, climate adaptation, decision-making, and barriers to adaptation would be

helpful to compare to the perspectives of managers of federal and state lands in this region. Such a study could have the potential to benefit collaborative efforts through identifying shared objectives and tribal perspectives on what actual collaboration entails. This research could help provide steps away from merely including tribal leaders at workshops to giving them decision-making powers, allowing for the true collaboration across agencies and stakeholders, which managers have discussed in this study and others as crucial to enacting adaptation under uncertainty and a changing climate.

IV. Recommendations for Natural Resource Managers:

Recommendations are based on the identification of supports needed to facilitate effective adaptation. These recommendations are related to increasing collaboration and facilitating adaptive management across larger spatial scales. Collaboration increases the knowledge surrounding what adaptive approaches should be taken, with greater amounts of knowledge and various expertises being shared across agencies and stakeholder groups.

- Include additional stakeholders at meetings and workshops and give them a fair amount of time to make suggestions, share their experiences and insights, and an ability to contribute to the decision-making processes. Interviewees and survey respondents expressed a strong interest in increasing collaborative efforts with tribes in the region. However, this often plays out as inviting tribal leaders to sit in at meetings and workshops, without giving them an equal amount of time to voice their insights, concerns, and suggestions for management, as well as often excluding them from having any say in the decisions being made. True

collaboration begins with having conversations but does not end at this stage; instead it is imperative to incorporate tribal members' insights and strategies into the decisions being made on the landscape, with input from tribal leaders at every stage of this process. There should be a shift towards giving tribal spokespeople at these meetings decision-making capabilities.

- Increase collaboration between agencies, as ecological stressors are not confined within a single park's boundaries. There was a consensus among participants that funding and resource-related issues related to cross-boundary projects can be better resolved with increased collaboration. Collaboration across agencies allows for more actions focused on specific ecosystems, which may span across multiple park boundaries. Increasing collaborative efforts also extends the spatial scale at which actions can be taken and can reduce the timeframes it will take to implement larger-scale projects, if staff members can work together and resources can be shared.
    - One example, provided by an interview participant illustrated this well: training for crises, such as wildfire or flooding events, would benefit greatly from including participants from multiple agencies in a given region, as well as nearby community leaders, determining plans of action and what resources can be shared and how to best go about this, for instance sharing a helicopter during a wildfire
- Increase collaboration between stakeholders in order to make a stronger case when advocating for agency-level changes and policy changes. There was a consensus that there is strength in numbers when stakeholders advocate for

policy changes and for greater ability to implement adaptive actions. Having numerous stakeholders advocating for proactive management tactics will encourage greater funding and support from agency leadership and once stakeholders agree on common concerns and plans for action, this approach has the potential to lead to successful policy changes

    - An example of such an effort is 4FRI (Four Forest Restoration Initiative), 4FRI was pointed to by participants as a success in terms of collaboration and community support, attributing this to the project receiving support largely due to its interagency and community wide collaborative nature. Respondents discussed how the public may be distrusting of a given federal or state agency's action, but community members were encouraged that a wide network of agencies and stakeholders were advocating for the project

- Prescribed fire should be implemented widely and rapidly across this region, in order to prepare ecosystems for change. Managers across agencies support this action, but the primary limitations are due to the influence of fire suppression policies, misunderstandings of the benefits of fire in healthy ecosystems, and due to escaped prescribed fires. Increasing public education and community support of "good fire" is essential to promote prescribed fire efforts. Once again, interagency, stakeholder, and community collaboration in these efforts will lead to more successful results.
- While it is challenging to address climate tipping points at the planetary scale, addressing "regional tipping points" is more actionable due to the smaller spatial

scale. It is important for managers to identify potential socio-ecological "regional tipping points," their likelihood, and the timeframes in which they could occur. Regional tipping points could lead to more abrupt and/or severe ecological transformations and have the potential to cause large-scale impacts. Managers should work in collaboration with other stakeholders managing similar ecosystem types within the region to share knowledge, resources, and contribute to proactive planning efforts to prepare for scenarios where tipping points are crossed. There should be emphasis on interagency collaboration on implementing adaptive actions across ecosystems, rather than limiting actions to park boundaries, which may reduce the likelihood of these threshold-level changes occurring, or at least may have the potential to reduce the impacts.

- Management for the preservation of biodiversity to the greatest extent possible should be prioritized to increase ecological resilience and promote ecosystem function, as one respondent said, to "keep intact systems intact." This is opposed to the frequent prioritization of managing for preservation of historic conditions, which are often subjective and not the conditions of the landscape prior to Western colonization.

V. Recommendations for Changes to Federal Land Management Agency Institutional Structures and Policies:

- There is an urgent need for easier methods for managers to reallocate funding to other projects on the landscape, in the case of ecological change outpacing the planned adaptive interventions, as respondents discussed. This is also crucial as

well as if ecological conditions change and priorities shift towards urgent management needs.

- The current seasonal nature of positions, especially for on-the-ground employees, needs to be reconsidered. This structure leads to the turnover of staff members that have gained ecological knowledge and familiarity with the landscape, and this valuable knowledge is being lost every time employees have to take seasonal positions in new regions. Retention of staff members in the same geographic region should be encouraged and incentivized, both for seasonal and long-term staffing positions. As discussed by managers, it is not easy to rehire staff members from the previous season due to agency hiring structure, which directly contributes to a loss of knowledge that could contribute to successful management efforts. Promotions within agencies often rely on relocation, which also leads to loss of management expertise and knowledge, though this constraint is often due to lack of funding to support additional higher-level positions.
- Staff housing needs to be expanded, made more affordable, and accessible in order to draw in new employees, and staff members need to be paid a wage that is commensurate with living expenses and costs of moving to the region.
- As one survey participant insightfully suggested, there should be hiring of additional staff with an educational background in climate science and/or climate adaptation planning assigned to work at a specific park unit or region. This position will focus on adaptation research, strategic planning for on the ground implementation, and assisting with monitoring of results of actions, and work

closely with park managers and scientists to determine best adaptive approaches, as well as reduce the workload of already overburdened staff.

- The competitive approach to receiving funding needs to be reassessed. Policy changes should include that funding is not dependent on how popular or valued a particular park unit or national forest is to the public, it should be determined by the ecological needs and conservation benefits that the funding will provide. There should not be incentives for spending funds in order to meet quotas, without showing the potential ecological benefits of using the funds for effective management
- Business-as-usual approaches should not be misrepresented as adaptation actions, as this leads to confusion about what climate adaptation entails and diminishes the credibility of the term. Agency leadership should not encourage misuse of this term in order to get funding and support.
- There is a necessity for a Constitutional Amendment and/or Supreme Court judgment that provides a lasting, unchangeable precedent for natural resource managers, scientists, and agency leaders to have the freedom to discuss, research, and manage in response and preparation for climate change induced ecological stressors. Science censorship must be prevented at the government policy level, so managers are not constrained by shifting government priorities and values, which are often influenced by corporate interests that benefit from climate change denialism.

VI. Towards a Critical Natural Resource Management:

As shown throughout this thesis, managers have a multitude of adaptive approaches and strategies they would like to implement in this region, but face barriers and limitations that prevent the amount of adaptation they wish to implement from taking place. Future research directions, which include incorporating tribal perspectives and approaches to adaptation, and incorporating the findings of this study with those working for tribal land management agencies could provide benefits of additional collaboration and understanding of challenges and possibilities for adaptation in this region. Currently, adaptation is often discussed by decision-makers apolitically, with a focus on ecological adaptation and on the ground applications. However, as highlighted in this thesis, many adaptation strategies and approaches face limitations between the planning and the implementation phase. Without understanding that adaptation is fundamentally political, many of the underlying causes of barriers and limitations cannot be fully addressed. Understanding adaptation as political also addresses the frustrations and challenges experienced by managers who feel limited in their ability to enact adaptation as climate change leads to more severe environmental degradation and ecological stress across landscapes at multiple scales. Understanding adaptation as political in nature also provides a starting point to address barriers and challenges at the policy level.

Further research and greater emphasis placed on natural resource management through critical geography perspectives applied to the study and practice of adaptive management, would allow for greater investigation of barriers and opportunities for

adaptation. Studies in critical natural resource management allow for a greater understanding of power relations and agency discourse, the social and political contexts of adaptation, allow researchers and managers to challenge existing assumptions and current business-as-usual approaches, and have the empowering normative goals of achieving socioecological equity and applying adaptation actions in order to preserve public lands and ecosystems for the benefit of future generations, as well as the planet's biodiversity.

APPENDICES:

Appendix A: Interview Guide

***Aim*:** To understand perspectives and strategies of natural resource managers that have dealt with major ecosystem transformations due to drought and/or wildfire, and climate change, and to share these insights with resource managers that have yet to experience such changes.

***Demographic Information**

What is your job title?

How long have you worked in your current job? (how long)

What ecological systems do you work in now and which systems have you worked in the past?

What is your educational background?

****Part One*:** Perceptions on Climate Change

1. What kind of ecological transformations due to climate change in combination with other stressors have you experienced, or can you anticipate, for the lands you work on?
2. How would you characterize the degree to which climate change and associated stressors have and will affect the lands you work on (barely at all -> severe transformation)?
3. How do you view risk to your landscapes in the context of climate change and associated stressors? Will systems slowly respond to stressors and there are few risks, or does there need to be a paradigm shift on how we manage because change will happen so quickly and strongly?

4. Were you anticipating climate-induced changes to the lands you manage before they happened or were they a surprise?

5. Looking back on your experience, what advice or insights might you give for other managers whose lands will likely experience climate change induced shifts in land condition? (Follow up to draw out as many specifics as you can)

Part Two: Perceptions on Adaptation and Management

Based on your perceptions from the above questions, this next set of questions asks questions about how land managers can adapt their management to address the consequences posed by climate change, fire, and drought.

1. What values or assets on the lands you work on are at risk from ecological stressors and change?
    1. Do you see those changes as primarily arising due to climate change or other stressors? (Is climate change the driver of all stressors on their lands)
    2. Are there any planned efforts to prepare for or mitigate impacts?
2. When you hear the term adaptation what do you think of or what does it mean to you?
3. How do you define adaptation?
4. Is the concept of “adaptation” clear?
5. Have you or your agency implemented any actions that you consider to be adaptation?
    1. If so, what actions have you taken?

2. How do you think your agency should adapt – what specific actions should you take?

6. What are your perceptions about how other land managers and agencies perceive adaptation?

Part Three: Ability to Prepare and Respond to Change

Given the above discussion, here are a few additional questions to help clarify your thoughts on responding to landscape scale change

1. Is the disturbance you are seeing on the lands you manage happening at scales and time frames outside what you would characterize as 'normal?'
    1. What is the time-scale (months -> decades) at which you are observing changes happening on the lands you manage?
2. At what point do you feel like you can intervene from a management perspective to address stressors and ecological change? (Important question, emphasize, follow up)
3. Based on your risk assessment for your system, have you felt prepared, or what would you need to feel prepared, to respond to shifts in land condition induced by climate change and associated stressors?
4. Has the way your agency responded to ecological change been adequate/sufficient/helpful/strategic/?
5. In retrospect, would you have managed and responded differently if confronted with the same challenge now?
    1. If you would have made different choices, what specific actions would you have taken or done differently?

6. Did you have enough information at the time to respond effectively?
7. Did you have sufficient resources to do so?
    1. What resources do you currently need most to adequately prepare and respond?
8. Do you view your responses as successful? Why or why not?
9. Looking back on your experience, what advice or insights might you give for other managers whose lands will likely experience climate change induced shifts in land condition? (Follow up to draw out as many specifics as you can)

Conclusion:

1. How do you see the relation between climate change, drought, and wildfire and what should we do to address their linkages?
2. In conclusion, what are your thoughts on landscape scale change and what should we be doing to address current and projected change?

Appendix B: List of Thematic Codes Used in Analysis

ADAPT: identifies strategy categorized as “adaptation” being implemented by the managers

ADVICE: specific insights and suggestions for addressing landscape-scale change

AGENCY: discussion of variation in perspectives based on agency

ASSIST: perspectives on implementation of assisted migration

COLLAB: emphasizes need for collaboration across agencies

CLIMATE: addresses climate change in a broader context

COPLATEAU: discussion related to climate, wildfire, and drought specific to the CO Plateau region

CRITRES: managers identify a“critical resource,” values/assets of greatest importance on the landscape

DROUGHT: discussion of drought in a broader context than specific landscapes

DEGCHANGE: the characterization/scale of how drought, wildfire, and climate change have affected the landscape the manager works on

ECOSTRESS: discussion regarding the ecological stressors faced on the landscape

ECOTRANS: discussion of ecological transformation experienced by the respondent/or expected to be experienced

ECOTYPE: ecosystems managed and worked in

EXSTRESS: external stressors that influence the landscape, both ecological and human

FIRESUP: discussion of impact fire suppression has had on the landscape

HOPECL: discussion of optimism and sharing of hopeful views related to climate adaptation

HISTCON: historic conditions and broader historical context are addressed

IMPTCLIM: specific impacts caused by climate change

IMPTDROU: the impact drought has had/is predicted to have on the landscape

IMPTFIRE: discussion of impacts of wildfire on the landscape

IMPTINTR: impacts of introduced species as a threat to the landscape/region

IMPTOTH: other impacts to the landscape, both human and ecological

IMPTWILD: impacts of ecological stressors on wildlife species on the landscape

INTERPOS: perceived positive aspects of implementing interventions/adaptation strategies

INTERNEG: perceived downsides of implementing interventions & adaptation strategies

KNOWGAP: identifies gaps in knowledge where managers and scientists point out areas where there is a lack of desirable knowledge and/or where to obtain the knowledge needed

LIMITAD: broader discussion of limitations to adaptation

LIMITAGNCY: discussion of limitations placed on respondents by agency policy/leadership

LIMITCLIM: mention of limitations due to large-scale climate impacts and uncertainty

LIMITGOV: discussion of limitations based on government policy & broader discussion of federal limitations such as presidential administrations support/lack of support

LIMITRES: limitations caused by lack of financial resources, lack of funding, and inability to hire staff needed to carry out adaptive management strategies

LIMITSCI : limitations caused by lack of scientific knowledge/gap between scientific understanding and successful implementation

MANFIRE: specific discussion related to management of fire

MANINV: specific discussion related to management of introduced species

MANWAT: specific discussion related to management of water resources

MANWILD: specific discussion related to management of wildlife

MANVEG: specific discussion related to management of native plant resources

MNGCOMM: discussion related to management decisions/ideas related to science communication

MNGDEC: specific decisions/actions made by managers

MNGPOS: specific decisions/actions made by or planned for by managers with perceived positive outcomes (not climate adaptation specific)

MNGNEG: specific decisions/actions made by or planned for managers with perceived negative outcomes (not climate adaptation specific)

NEEDRES: identifies specific needs related to resources

NEEDLEAD: identifies specific needs related to agency/government leadership

NEEDSCI: identifies specific needs related to science

NOVEL: novel ideas and perspectives related to adaptation and/or management

PREPARE: discussion of the ability/inability to prepare and make proactive decisions

PROJECT: addresses projected changes to the landscapes being managed

PSYCH: addresses psychological aspects of management/dealing with climate change and biodiversity loss

PUBLIC: discussion of the public's perception of the issues related to management

QUOTES: specific quotes to highlight in the thesis, that may not fit easily into other categories, primarily a location to quickly refer to significant quotes

RAD: discussions of utilizing Resist-Accept-Direct framework

REFER: refers to other agencies/organizations/research that is helpful to their work

RESILIENCE: discussion of ecosystem resilience

RESTORE: identifies efforts categorized as restoration implemented/planned by the manager

SPATIALSC: refers to the spatial context of landscape change and implementing adaptive strategies, and/or the management challenges this poses

STRATBLM: discussion of policies, strategies, commentary on Bureau of Land Management efforts to implement adaptation

STRATFS: discussion of policies, strategies, commentary on Forest Service efforts to implement adaptation

STRATNGO: discussion of policies, strategies, commentary on National Park Service efforts to implement adaptation

STRATNPS discussion of policies, strategies, commentary on National Park Service efforts to implement adaptation

TEMPORAL: refers to the timescale of landscape change and implementing adaptive strategies, and/or the management challenges this poses

TYPECON: mentions type conversion of ecosystem to a different seral stage

UNCERTAIN: describes uncertainties in either management or science

UNINTEND: mentions possibilities or outcomes leading to unintended consequences of interventions

VULNER: specific mention of vulnerabilities

WILDFIRE: broader discussion of wildfire beyond specific landscape/region

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