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A Comprehensive Look at the Benefits of Traditional Ecological Knowledge of Native American Indigenous Communities for Fire Management Practices in Northern California

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A Comprehensive Look at the Benefits of Traditional Ecological Knowledge of Native American Indigenous Communities for Fire Management Practices in Northern California

By

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Abstract

Wildfires are currently ravaging California, destroying the land and the livelihood of many vulnerable communities. This research explores the value of Traditional Ecological Knowledge (TEK) as a tool to aid in the fight against wildfires. Revitalization of Native American culture and traditional practices, such as prescribed burns, can transform current fire management practices. This research examined the connections among three aspects of fire management: Native American TEK, non-native ecological field studies and modelling, and current government fire policies and management practices. Through primary interviews and case studies, this research found that the Native American communities in the West have a wealth of knowledge on fire management. A key challenge is how to help non-native scientists understand and quantify place-specific TEK so it can be implemented in today's practices. Barriers such as fire suppression, human encroachment in the wildland-urban interface, and restrictions in state and federal regulations make it difficult for tribes to perform their time-tested practices. Increased trust between non-native scientists and native scientists is needed to implement their TEK, and collaboration is needed to develop new fire management strategies for resilience in man-made climate disruption.

Chapter 1: Introduction

This study explores the use of Traditional Ecological Knowledge (TEK) by Native American Indigenous communities to manage the natural resources of their traditional territories, and how such knowledge can benefit today’s fire management practices. The goal is to bridge the gap between western science and TEK, creating the best management practices that benefit both the environment and the Northern California Native American Indigenous communities. TEK has been around for thousands of years, before Western science ever came into existence. Native American culture has a long history of living off the land by using the plants and animals sustainably. They learned to live in reciprocity with life, taking what they need to survive while leaving behind enough for the plants and animals to sustain themselves (Flato 2/07/20). They developed many natural resource management practices that created a balance and mutual benefit among the people and the environment. These practices embedded within their culture

are vital to the livelihoods of many Native American Indigenous communities, for they are some of the most vulnerable to the impacts of climate change on the resources they need to survive. This knowledge was gained over generations through careful observation and testing. Native Americans were able to perfect their own management practices in order to achieve different sets of objectives (Wells 2014). The added effect of non-native overpopulation and consumption of resources is occuring at an alarming rate, causing negative impacts on their land. Their Native lands are suffering from extreme weather events such as drought, loss of Native food, and polluted waters (Fillmore et al. 2018). The climate crisis has reached a point where the mix of Western science and traditional knowledge is necessary for the survival of life on the planet.

1.1 Motivation

For thousands of years, Native Americans Indigenous communities have lived on the land of North America. They are rich in culture and view the environment as more than just the land they lived on. Their culture and religion are rooted in how they manage the land. They have a high level of respect for what it means to use the resources they need to survive. However, with the colonization by Europeans in North America and the genocide of the Native people, their culture and their management practices diminished with every passing generation (Eric W. Sanderson et al. 2008a). North America soon became a place where resources such as timber and water were taken for granted. These resources were extracted at alarming rates to advance industrial development. An example is the near extinction of the American bison. Native people had a long symbiotic relationship with the American bison, hunting them to sustain their own livelihoods. They respected this creature for what it gave them and made sure they took care of the bison, the way the bison provided for them. This practice was deeply rooted in their culture (Flores 1991). Upon arrival, the European colonizers immediately saw the bison as a major resource and began hunting them at startling rates for commercial profit and slaughter (Eric W. Sanderson et al. 2008b). These bison went from a thriving population to a nearly extinct animal. Today, they only reside on a few protected areas of land. As the bison began to disappear, so did a huge part of the Native American culture. This is a clear example that if there is a new resource that will benefit humans, then that resource will be taken without thinking of the consequences.

Today, the United States and Canada recognize over 570 tribes. This does not account for the thousands that were lost over the generations. These tribes primarily live on tribal lands and reservations. These pieces of land are in some of the worst conditions and are the main reason for returning traditional knowledge to Native Americans to help benefit the environment (Kornfeld 2017). Figure 1 depicts the aftermath of the over hunted bison that were almost brought to extinction. This photo sparked my interest in exploring human interactions with the environment. The pile of skulls showed disrespect for the animal as a resource and as a living creature which goes against the basis of Native American practices. If managed properly, it is possible to use these different resources sustainably. However, from this photo it is easy to see how resources that are not managed correctly can result in catastrophic events.

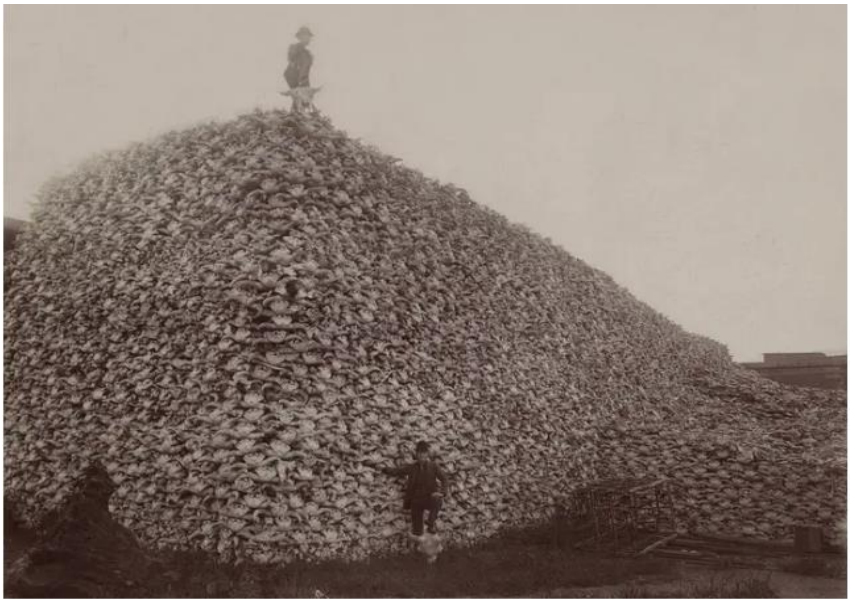

Figure 1: Photograph depicting the brink of extinction for the American Bison due to over killing for resources. Photo taken in 1870 (Robinson 2016).

1.2 Problem Statement

Wildfire management is an area of environmental management where TEK was lost and is now causing major problems. Today, wildfire is becoming a huge problem throughout the world. It is a natural phenomenon that is caused by lightning and other factors (Running, 2006). Historically, these fires help the environment in a variety of ways, such as increasing the

biodiversity of plants and help reduce the risks of major fire events. The impact of increasing global temperatures is causing a greater frequency of extreme weather events such as wildfires, due to a longer fire season, higher build-up of fuel loads and high winds in forested areas. Not only are these forested areas at risk, but also the people who are living in those areas. More and more communities are moving to high risk areas making them vulnerable to wildfire. When communities begin to develop in new places, it brings a greater risk of human caused wildfires. (Jin-Ho Yoon et al. 2015). Figure 2 shows high risk areas of extreme wildfire by showing moisture deficit and where wildfires have been occuring. It shows where the least amount of soil moisture availability is, and where the most wildfires have been occuring. Some of the highest risk areas in Northern California are where many Native American Indigenous communities are located. These communities are living in vulnerable areas and need support in mitigating wildfires using their own TEK.

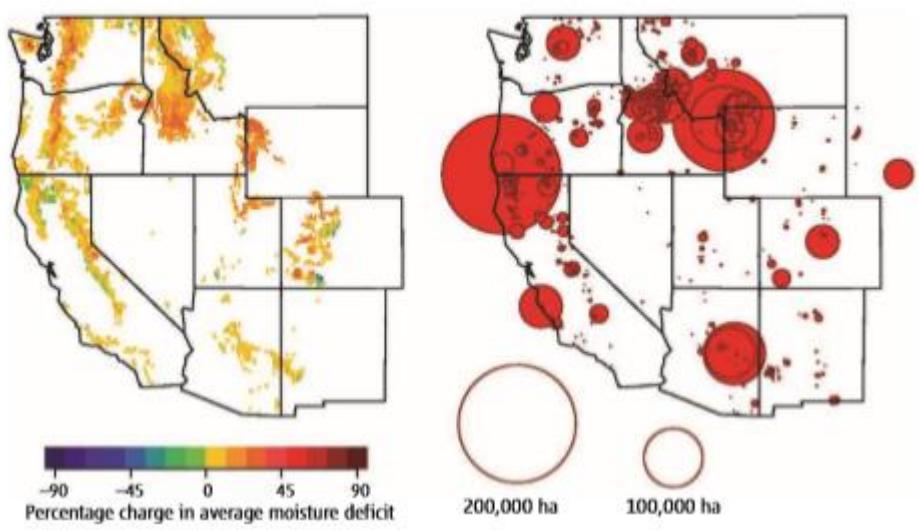

Figure 2: The figure on the left shows the decrease in moisture availability and the figure on the right show's wildfire events exceeding 1000 ha. These two figures show a direct correlation between the two variables (Running, 2006).

Another factor that Native American tribes are vulnerable to wildfires is where their tribal land is located. Before colonization, tribes adapted to the land and moved when needed. After colonization, the lands tribes could live on were restricted They were moved to a reservation or land that wasn't their own. They have had to adapt to new land and get used to

new resources. Now, with encroaching wildfires, they have nowhere to move to escape these vulnerable areas (Brown et al. 2020). Their ancestors lived in large regions where they used fire as a tool to combat the changing environment. They knew how to move with the season and to use the land properly. Limitations on their ability to move hinders their culture and survival.

1.3 Research Question

The main research question of this study is to find out what the main benefits of TEK are, in terms of wildfire management, specifically prescribed burns. Subsequently, to see whether TEK can be incorporated into current fire management practices, mitigating the occurrence of large intense wildfires that destroy the land and people's homes.

The sub questions to this study will include how bringing back TEK of Native American Indigenous Communities have added benefits that go beyond wildfire management. It will explore how TEK will also aid in preserving their own cultural traditions, revitalizing their own Native American people. This will also include looking at how to best quantify Native American TEK in terms of wildfire management (Christianson 2015). This will be done by reviewing different case studies where this has been attempted. The reasons why traditional wildfire management was initially suppressed will be examined, as well as, the current status of wildfire management practices in Northern California.

The final section of this research paper will look at the three sub questions and how they all answer the initial research question on what the exact benefits of TEK on current wildfire management practices are. There will be a further exploration on how TEK can be properly implemented and consider the challenges they face in doing so.

1.4 Study Area

The main research area will be centered around Northern California, Central California and parts of Oregon. They encompass a variety of landscapes and ecosystems. The tribes that will be looked at will be in Central California, Northern California, Oregon and parts of Canada. Some of the tribes that will be researched through interviews are the Guidiville Rancheria of Pomo Indians, and the Clear Lake and Amah Mutsun tribes. Others will be researched through literature reviews such as the Yurok, Karuk and Anishinabe tribes. California has over 150

federally recognized and unrecognized tribes, all of which have different cultures and traditions. The goal is that by examining multiple tribes, it will provide a sense how wildfire management is practiced.

Figure 3: Map of Federally Recognized Tribes (Pacific Southwest Region)

1.5 Methodology

In order to understand the benefits of TEK on current fire management, this research uses a multi-method approach to examine the different perspectives to the problem. There are three areas of focus that will be discussed to explain how TEK can help create successful fire management practices.

The first area of perspective is to look at the cultural connection and tribal knowledge revolving around fire management. Fire is an essential cultural component for different Native American Indigenous communities, contributing to many aspects of their knowledge and culture. However, much of TEK has not been documented in written or recorded form over the years (Huntington 2000). Interacting with different tribal members who are working in fire management is required to gain a proper perspective of TEK. The use of interviews will be a main tool to understand Native American Indigenous communities fire management practices and how it benefits their own community and the land that they live on. These interviews will be

a good opportunity to get their perspective on the challenges that they are facing today as a vulnerable community. The use of other forms of research will include webinars on fire management, gatherings of tribal members, and attending conferences that offer hands on work to gain a better understanding of current practices.

The second area of focus is to look at what quantitative research is being done to measure and test TEK, to provide quantitative evidence on indigenous management practices that are beneficial for fire management. A set of case studies will be reviewed that use ecological modeling to test the benefits of TEK on fire management practices. In order to integrate TEK, there needs to be a set of baseline data that show the results of certain wildfire management practices. For example, the idea of controlled burning can be tested to show if it helps reduce fuel loads, manage desirable vegetation and reduce future wildfires (Stigler et al. 2005). This research uses a comparative case study analysis to observe any commonalities among these different sets of practices.

The third area of focus is to look at current wildfire management practices and how TEK can potentially fill in the missing gaps of information. The goal of this study is to look at all the variables to give proper management recommendations and help influence policies. Figure 4 shows the three sides to a triangle with each side being of equal importance for successful fire management.

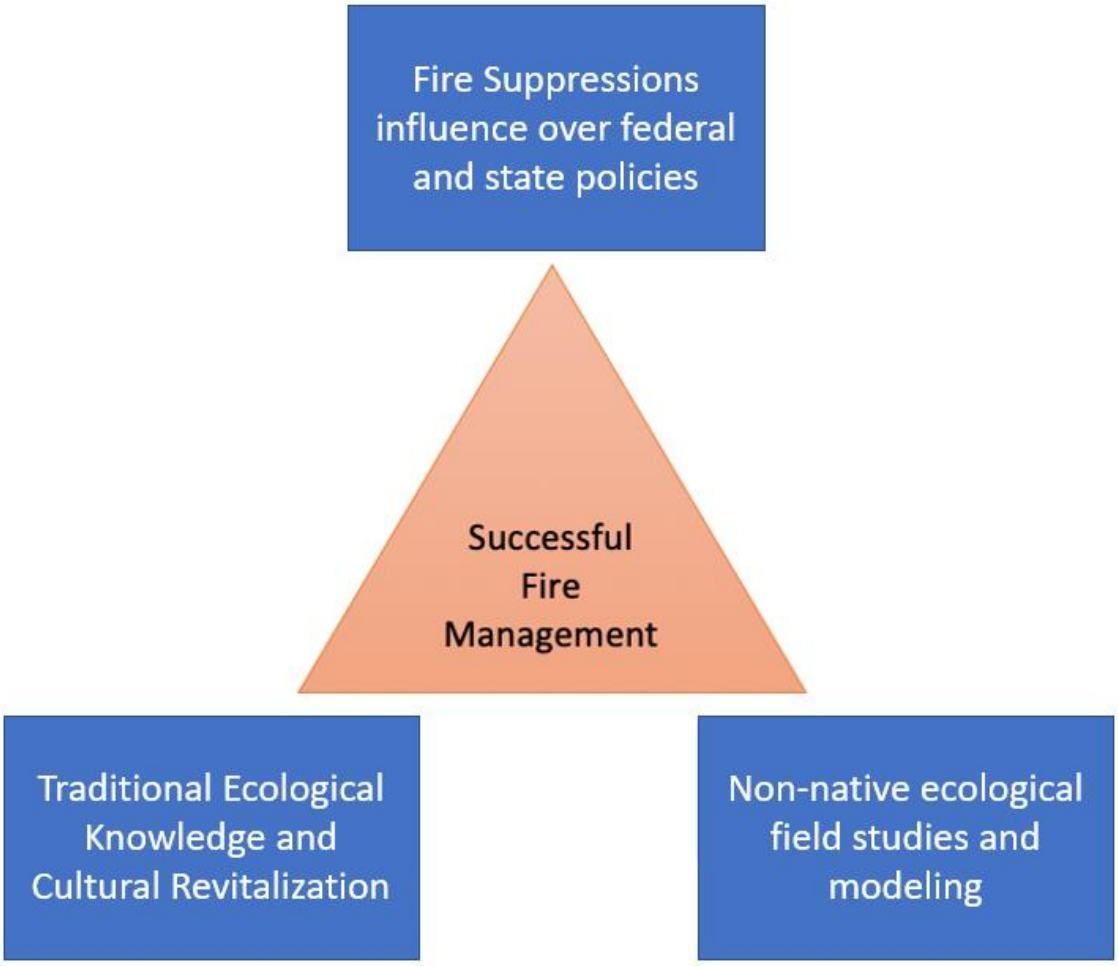

Figure 4: Methodology that will be utilized to research successful fire management practices. The triangle represents the three angles of analysis required to make improved fire management recommendations (Source; Author).

The above model will be the main form of analysis for this research project. By looking at different tribal perspectives and case studies, a comparative analysis will be used to see what the similarities and differences are amongst the different sets of knowledge. Ecological modeling will be used to look at what is currently being done in the field to test different sets of TEK and will ascertain future areas of research. These studies will show the importance of data collection and how it can benefit tribes' own use of TEK. Lastly, an analysis of current practices will be

looked at to determine where there are gaps in the management practice. The goal is to see how TEK can bridge these gaps to develop better fire management practices.

1.6 History of Traditional Ecological Knowledge

The concept of Traditional Ecological Knowledge (TEK) is not a new set of knowledge. TEK has been around for thousands of years and it represents the knowledge and culture for many Native American Indigenous communities around the world. TEK has developed in many communities through the concept of trial and error. It is even thought that scientists, such as Charles Darwin, sought out TEK of the local communities he encountered on his early voyages, to provide additional information of the ecosystem and wildlife he was trying to understand (Nelson and Shilling 2018). As the concept of western science continued to evolve, TEK became an afterthought in the realm of environmental management practices. Western scientists saw TEK as problematic because of how this knowledge was collected. TEK was mainly passed down through generations via the method of oral history and narratives such as their creation stories. This knowledge was not measured in a quantitative way and reduced the credibility of TEK practices. Even if a traditional practice was shown to make improvements on the environment, there were no sets of data that supported the benefits of these practices. The word "tradition" also added negative connotations to TEK. It was thought that TEK was savage and barbaric. It created a narrative that surrounded TEK for generations and caused many negative effects such as the loss of TEK itself. When generations pass who do not utilize these different management practices, the knowledge can no longer be passed down in informal methods such as their creation stories. This lack of use causes the knowledge to become undocumented and lost.

In the 1980s, researchers and social scientists started to understand the value of TEK on current management practices. Anthropologist Claude Levi-Strauss and philosopher Paul Feyerabend, were two of the pioneers that spurred an interest in TEK and how it can benefit current management practices. They researched different communities to understand how they managed and maintained their livelihoods (Nelson and Shilling 2018). They saw the value in these different native communities. Levi-Strauss and Feyerabend understood that native communities have lived off the land for thousands of years and adapted to develop the best

strategies to manage the land to survive on. This research led to the International Conservation Union (IUCN) establishing TEK as an important area of research. The focus of IUCN is to help influence societies on the importance of conservation. It made it more acceptable for researchers to invest their time into understanding the benefit of TEK and how it can help current management practices (Berkes et al. 2000). It is now thought that TEK can fill in the gaps of today's management practices. TEK has been gathered for so long that it should be considered a wealth of knowledge for Western scientists. There needs to be an understanding of how the land came to be, and that it is something that can be found in the history of Native American Indigenous communities.

1.7 Definition of TEK

"TEK is the cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down in generations by cultural transmission, about relationships of living beings (including humans) with one another and with their environment" (Martin 2009)

Traditional Ecological Knowledge is present around the world among their native communities. TEK differs in many ways, but all have similar key elements. The knowledge was gained over hundreds to thousands of years perfecting their management practices on the land that they were living on. There was this sense that everything is interconnected. Every little change you make will cause a ripple effect within the ecosystem. This interconnectedness is why it is of the utmost importance to consider all factors when making environmental management decisions. TEK has multiple components which makes it such a valuable tool (Martin et al. 2010a). Figure 5 shows how complex of a system TEK is and how every component is essential to environmental management. A single change to the system will alter the other components. This is the viewpoint from an eco-engineer's way of viewing TEK. An eco-engineer is someone who looks at ecosystems and the different components that affect it. After looking at all components, outcomes can be predicted (Martin et al. 2010b). Figure 5 shows the system's different inputs and outputs accounting for factors such as sun, wind, rain, river, supplies, and labor. In order to predict outputs of an ecosystem, all factors that affect it need to be considered especially when it involves human interactions.

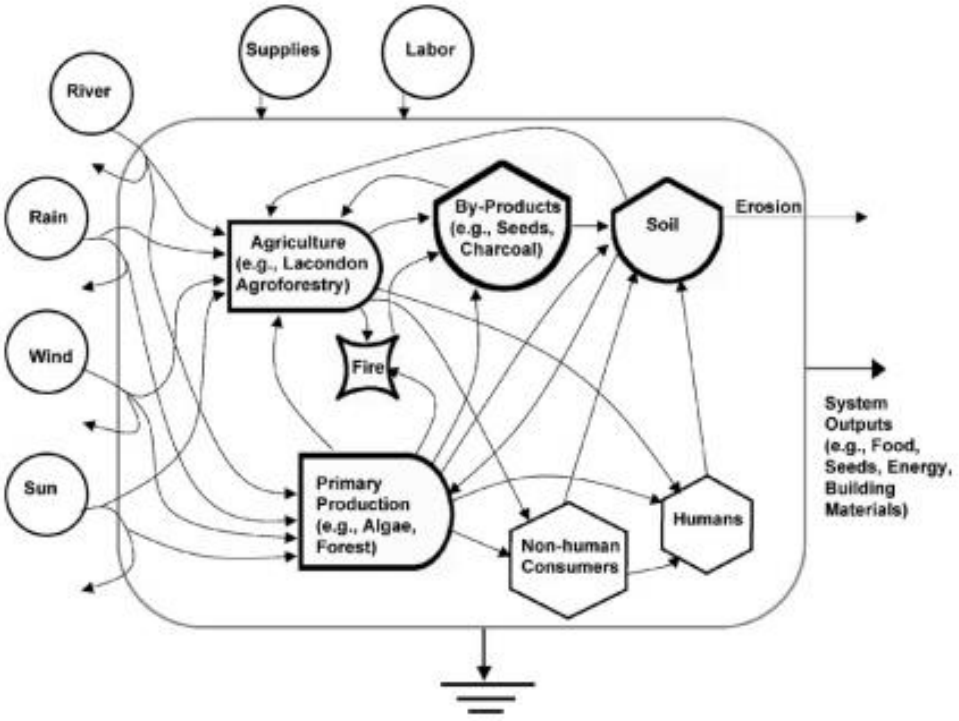

Figure 5: Represents the complexity of TEK through an Energy Systems Diagram (Martin et al. 2010).

This is consistent with the view that TEK stems from viewing ecological problems in a holistic approach vs. a singular problem. The idea that we view the planet as one entity is an important concept when making any type of management decisions. If we view the planet as a person then we can have a better idea of how to fix it. For example, if the human body gets sick, we must take action and treat it. We initially give that person medicine to reduce the symptoms, but then we need to focus on long term care so that illness doesn't come back. This is the same idea with our environmental problems. We tend to put band aids on the problems, but don't truly think of the long-term consequences of our actions. Therefore, we are in the current state we are in with our climate. We became used to putting bandages on our environmental problems and now it's beginning to show the aftermath of those actions. We need to return to TEK and view the planet in a holistic manner to make better environmental management decisions in the future (Egan et al. 2011).

Chapter 2 - Traditional Ecological Knowledge and Cultural Revitalization

The goal of this chapter is to observe different sets of Traditional Ecological Knowledge (TEK) in terms of fire management to see if there are any key elements that can help influence current management practices. The idea is that TEK is knowledge that can give a better framework for fire management. In order to do this, there needs to be an understanding of TEK itself, as well as, how it is specific to each tribe. Through the use of interviews, webinars, workshops and literature reviews, there will be a comprehensive view of TEK and the key elements that make it a successful management practice.

2.1 Case Study 1: Guidiville Rancheria of Pomo Indians (Mendocino County) and Clear Lake (Lake County)

Tribal Leader: Meyo Marrufo**,** Guidiville Rancheria

Meyo Marrufo is a tribal leader who works with both Guidiville Rancheria in Mendocino and Clear Lake in Lake County. She brings a perspective of fire management from two tribes living in two different types of ecosystems. Guidiville Rancheria is made up of oak, shrubland and grasslands. Lake County is located next to Clear Lake, one of the largest lakes in California (Sanchez). She first describes Traditional Ecological Knowledge from the perspective of the tribes she is a part of and works with daily. TEK is a term that has been coined and used for many years. TEK has become a global term and is studied across many communities. The important thing to remember is that TEK is very different depending on what community one is speaking with. Oftentimes, when one term encompasses a large topic, it devalues that specific term and how it can be used to benefit different communities. It relates to the idea when early Westerners created a narrative around the word “tradition” in terms of Native American knowledge (Marrufo, 2020). The narrative generalized traditional knowledge and practices of all tribes. In California there are over 100 federally recognized tribes. Each tribe has different cultures, traditions and knowledge. It is important to acknowledge that tribes cannot be grouped

together, because that will continue the cycle of forgetting the vast amount of knowledge they bring. The more TEK evolves, the more generic it can become. It becomes a cliché idea of what traditional knowledge is. It makes everyone think of TEK as a mystical or magical idea when it is very different to today's version of TEK. When it comes to TEK, there are six different components that need to be thought of during development and implementation. These components are cultural identity, scientific identification, research, data collection, field work and traditional gatherings (Marrufo, 2020). These are necessary components when working with TEK, for it incorporates oral history and traditional gathering techniques and understanding with scientific observations.

2.1.1 Tribes Cultural Connection with Fire:

Guidiville Rancheria and Lake County views on fire management differ in terms of their location. There are many variables that need to be taken into consideration when implementing any type of fire management on the land. The most important thing they consider is what the objective of fire is. Fire has many benefits on the land according to the tribe's traditional knowledge. Natural fires are known to increase biodiversity of plants, add important nutrients to plants and soil such as nitrogen, increase food production of acorns and reduce the risk of catastrophic wildfires (Marufo, 2020). The tribe's TEK has been developed over thousands of years and they have perfected their own management styles. Fire has always been an important part of their culture and helped maintain their ability to live off the land, and better sustain their communities. They use fire to fight fire. It is important to note how tribes used fire to create the landscapes they needed to survive. This shows how over generations, they were able to perfect their techniques of wildfire management and the landscape they were living on (Andrew Martin Miller and Iain Davidson-Hunt 2010a).

2.1.2 Good Smoke vs. Bad Smoke:

The idea of good smoke vs. bad smoke refers to the different types of fire, and their effects on the land. Good smoke is when a fire is fast moving at a low intensity. Bad smoke is

when it is a slow fire at a high intensity. Good smoke is a method used by Native Americans through smaller prescribed burns. The smoke from these small prescribed fires act as an antiseptic for many Oak Trees. It helps the trees become more fire resistant while reducing the fuel load of the surrounding area (Marufo, 2020). The smoke fills in the gaps of the Oak Tree which are necessary to protect them. It is thought that when filling in these gaps with good smoke, it helps prevent diseases such as Sudden Oak Death. Sudden Oak Death is a disease that is spread through a certain type of pathogen. It is known that this pathogen is spread more commonly during wet and rainy seasons. It gets into the oak trees causing the high mortality along the California and Oregon coasts (California Oak Mortality Task Force 2014). Another benefit of these low intensity grass fires is it provides a better harvest of acorns, a staple food source in many Native American cultures. Acorns are more abundant because the health of the plant is improved from the additional nitrogen, and collection is easier when there is less vegetation.

Bad smoke is when there is a high intensity fire and it is slow moving. This occurs when there is a large buildup of fuel making small prescribed burns impossible. When there is a fast-moving fire it scorches the trees rather than smudging them. It creates wounds on the tree creating more opportunity for disease such as the Sudden Oak Death. It is thought this is a major reason why Sudden Oak Death became so prevalent amongst these ecosystems. This is similar to the idea of when a human has an open wound, and if not treated properly, can become infected resulting in a serious illness. An example of this is the Ranch Fire in Mendocino county which burned about 3,700 acres (Michael Mcgough and Mitchel Bobo 2019). The Ranch Fire was a slow, high intensity fire which burned grassland and chaparral habitat. The fire ended up burning large parts of the area at higher temperatures because it started to burn hardwood trees. This fire had many detrimental effects; however, it also cleared the land in order to perform small controlled fires. It reduced the fuel load enough to make small prescribed burns possible and allow for the benefit of controlled fire to occur. It is important to know that small prescribed burns won't work anymore unless proper management was done prior to the burn. The fuel loads must be reduced enough so the risk of a large wildfire doesn't occur.

2.1.3 Understanding Fuel Loads

A major part of fire management is to understand what is being burned. The objective of the prescribed burn will determine the method of burning that should be used. For example, there is a difference when it comes to management of grasslands and shrublands for fuel load reduction. In Lake County, they would burn old Tule from the lake to promote a healthier Tule harvest. When they performed these burns, it opened areas for collection and hunting. The burns also allowed for new growth of Tulle for people to use in their cultural traditions and practices (Marrufo, 2020). Another example is the use of fire to promote healthier Bear grass, which is one of the main types of grass that many tribes use to create baskets and other forms of regalia. They used a technique called clump burning which simply meant that they set each individual plant on fire versus a large area (Marrufo, 2020). These burns added nitrogen to the plant and caused it to grow straighter. The straighter the grass, the better-quality regalia and baskets the Natives American were able to create.

These burns are also used to preserve native plants. Fire has been a natural process and many of the plants have evolved to adapt to these fires. These burns are also used to reduce fuel loads of very invasive plants, such as Scotch Broom, which needs fire to reproduce. These fires can help with the reduction of invasive species as they are common in increasing fuel loads. If done properly, fire can be used to increase biodiversity of plants and promote growth of native plant species (Ryan et al. 2013). If not managed correctly, prescribed burns can again lead to wildfires. The trial and error of using prescribed burn led to the understanding of when to burn in terms of the season. The best time to burn was at the end of winter or the rainy season in order to clear the land and add nitrogen to the soil. This disturbance caused the promotion of native plants to grow and reduce fuel loads.

Native Americans Indigenous communities knew through trial and error, over many generations, how to manage the land with fire properly. They knew that in a forested area, you want to create smaller localized fires, while in grasslands, fire needs to be viewed more topographically. How a burn is performed depends on the location and elevation of the vegetation (Marrufo, 2020). If fire is used properly it can create healthier ecosystems and

biodiversity. If it is mismanaged, it will create even more damage to the ecosystem and the people living on that land.

2.1.4 Challenges of Incorporating TEK with current Fire Management Practices:

For TEK of these tribes to be implemented into current management practices, the understanding that TEK is different depending on the objective is imperative. Since TEK is oftentimes generalized, many western scientists miss the goals of TEK. TEK differs depending on the type of burn. What works in one area will not work in another (Marrufo, 2020). There needs to be involvement of all tribes when it comes to incorporating their knowledge on specific locations.

Another challenge is how do tribes such as Guidiville Rancheria and Lake County quantify their TEK, so their practices are taken seriously. As of now, only a few organizations such as Cal Fire, are starting to incorporate TEK into their management practices. However, they are faced with many challenges in understanding the basics of TEK. There needs to be more work where TEK is quantifiable to show the benefits.

2.2 Case Study 2: Amah Mutsun Tribal Band - Santa Cruz

Tribal Member - Alexii Sigona Phd Student - UC Berkeley

Alexii Sigona is a PhD student at the University of California at Berkeley, as well as, a member of the Amah Mutsun Tribal Band, located mainly in Santa Cruz County. Before colonization, the tribe was made up of 20 politically distinct tribes that were connected through the common language group of the greater Aloney speaking people. The tribe lived on the coasts of California for over 13,000 years. They were stewards of the land and believed in the land curator as their creation story (Sigona, 2020). Their obligation was to take care of the land and have reciprocal relations with it. The tribe performed cultural ceremonies on the land and its resources. Burning was one of these ceremonies that was performed to properly take care of the land. Due to colonization in the late 1700s, tribes were taken to Mission systems, which caused the loss of knowledge and the genocide of their people (FIVE-YEAR STRATEGIC PLAN: 2014

-2019). The Spanish colonization forced the tribes into a different way of life which instigated the loss of their land management practices, such as cultural burning. Spain banned fire in 1793 which was the beginning of fire suppression (Sigona, 2020). In the 1920s, one of the eldest survivors of the Mission system was Maria Ascencion Solorsano, a cultural healer and doctor. An ethnographer, J.P. Harrington, recorded her knowledge and history of the Amah Mutsun people. She recorded language, knowledge and tradition in order to save her own people. This culminated in nearly 60,000 pages of field notes, which became the basis of revitalizing the Amah Mutsun Tribe (Warner et al. 2007). The Amah Mutsun Tribe is not a federally recognized tribe, which means that they don't have any rights to their native land, which makes it extremely difficult to bring back their lost knowledge. However, just because they are not federally recognized, it does not devalue their knowledge and practice.

2.2.1 Bringing Back Knowledge with Academia

The first steps the tribe took to bring back their knowledge was simply returning to their land. Through collaborations with state and national parks, the tribe has been able to start implementing their own cultural and land practices. The tribe would mainly burn in patches. Every year, they would burn in different areas to promote growth. The tribe relies on sets of documentation to actually figure out their own burning practices. This required working with archaeologist James Kent Lightfoot, who studied these areas to figure out their burning practices (Lightfoot and Lopez 2013). By examining the different areas, they were able to assess that they burned in intervals over a 10-year period. Over the past 10 years, the tribe has been able to implement their burn practices which were uncovered from academic research of the tribe's past (Sigona, 2020). This gives importance to understanding how many tribes used prescribed burns to shape the landscape around them (Lopez 2013). The idea of bringing back these burning practices is not only good for the land, but also for the Amah Mutsun Tribe. There has been trauma inflicted upon them through genocide. Burning is also viewed as a form of healing for both the land and their own bodies, which shouldn't be viewed as a dangerous entity. There needs to be more discussion about fire diversity and all the ways it can benefit the environment.

2.2.2 Viewing burring as a Mosaic

The Amah Mutsun Band of Mission Indian believed in viewing their land as a mosaic which involved burning in patches to reduce fuel loads and to increase essential plant species important to their tribe. To perform their cultural burning practices, there needs to be a large amount of manual labor prior to performing these burns. The Amah Mutsun Tribe were able to form a land trust which helped them create a group called the Native Stewards Core (NSC) (Sigona, 2020). The Core employs many tribal members to teach them about land management practices. One of their biggest roles is to manually reduce fuel in certain areas through mechanical methods such as chainsaws. This is a necessary step because their land has not had proper fire management for a very long time. This is unfortunately the main problem for most Native American Indigenous Communities who are trying to implement their burning practices. The areas in which they live have been suppressed for so long that it is almost impossible to bring back their burning practices, unless a major wildfire occurs which is what we are seeing happen today. Sadly, the tribe is having to prove to people that their burning practices work for it to be accepted as a credible land management tool. Even though they know it works, since it has been practiced for thousands of years, they must continually convince the people who own the tribe's native land to practice TEK and bring back their own culture. The tribes also must remind people that the method of burn is a low intensity type of fire. This fear people have with fire is outweighing the benefit of it.

The main idea behind burning starts with taking care of the entire ecosystem. One needs to think about the animals and plants living on that land as well (Hankins, Don L. 2009a). Fire is used as a long-term benefit to the land but shouldn't be viewed as a quick fix. They learned to burn in patches every 6 years to promote new forms of growth. They view the land as a mosaic, because they knew by burning in patches, they were benefiting multiple factors. It is important to give plant species time to grow and to prosper from the benefits of that fire.

2.2.3 Current Challenges and Future Recommendations

The Amah Mutsun Tribe recognizes that they have a unique contribution to land management, and that it is different from that of their ancestors. This is the reason why cultural

revitalization is important to this group of people. They view Traditional Ecological Knowledge as a valuable concept which needs to be incorporated into current practices. The issue that this tribe has is that they are hesitant to work with any outside organizations. Their people, as well as all Native American Indigenous communities, have constantly been taken advantage of. Even today, they are being denied access to their own lands. They have good reason not to want to openly work with people in academia and give their knowledge away freely. The question of why tribes must quantify their own knowledge when they know from their own experience that it works, troubles them (Sigona, 2020). New challenges such as climate change altering the land, have been an issue in most Native American Indigenous communities. They knew they had to adapt their TEK to the land. Not all TEK is going to work perfectly at first, but with the basic idea of trial and error, they believe the proper way to manage the land can be.

To address these changes and to help push the agenda of TEK being a part of current management practices, there needs to be more liaisons that bridge the gap between western science and TEK. Alexi Sigona discusses how he hopes to be a liaison by having his upbringing and the knowledge of his tribe, while learning the quantitative side of environmental management. He hopes to be able to bring the two sides together to benefit the land altogether. However, he notes that by taking this path, there is a risk that he might isolate himself from his own tribe by taking this academic route (Sigona, 2020). In the end, it is necessary to trust tribes to take care of the land, the land needs to be given back, and all tribes must share their own TEK with each other. Tribes recognize that their TEK has been lost over generations and needs to be brought back. The only way is if they can work together and develop new practices that fit today's current climate.

2.3 Case Study 3: Yurok and Karuk Tribes of the Pacific Northwest

The Yurok and Karuk Tribes are well established, federally recognized tribes that are in the Pacific Northwest. They reside along the Klamath River which is where a major part of their knowledge and culture.

2.3.1 Salmon People

The Yurok tribe thrived off salmon as a staple and developed their own proper management practices. They are an example of how their own TEK and knowledge influence

environmental management decisions. One of their primary examples is the removal of dams along the Klamath River. The Yurok Tribe have lived off salmon from the Klamath River for centuries, and a resource that became embedded in their culture. They understood the value It gave them for survival and developed their own management techniques to sustain the wild salmon population for generations (Apostol 2006). With the introduction of European settlers, over-fishing began. New technologies such as salmon hatcheries, dams and fish farms were introduced to help keep the population high to feed the growing population. These new technologies instead, ended up hurting wild salmon populations. The Yurok Tribe collaborated with western science in order to solve this environmental issue. They observed that the more disturbances people were creating, the worse the wild populations would do. They were not given the chance to rebound to these environmental changes. With the support of Native American Indigenous communities and western scientists, they were eventually able to approve the removal of the Klamath River dams in order to bring back the wild salmon populations. They knew that if they took out these huge concrete barriers that it would help restore the wild salmon populations. No longer will hatcheries and fish farms be necessary to keep the populations at an appropriate level (Pena 2007).

2.3.2 Fire People

The Karuk tribes have made many changes in the way they interact with non-native scientists and are truly making an impact in environmental management. In terms of wildfire management, they are also one of the leaders among tribes who are setting a good example on how to implement it. Before European colonization, they were implementing burns for millennia (Apostol 2006). They consider themselves fire people with the idea that it is the giver and taker of life. They are constantly renewing their relationship with fire through cultural and traditional ceremonies involving fire. They saw that fire benefited them as well as the plants and animals that coexisted with them (Oliver 2019). For example, fire cleared thick forest that allowed elk, bears and deer to move around which was essential to their survival. They even saw the benefit of wildfire smoke on how it maintained cooler rivers by blocking sunlight during summer months. They learned to embrace fire since it's a natural event that happens seasonally. The introduction of fire suppression caused a complete stop to their practices. They even adapted the land to support their traditional practices that focused around basket weaving (Anderson 1999).

They used fire as a tool to grow the best type of plants to continue this tradition which was an essential part of their culture. They not only used it for practical reasons but used it to pass down knowledge from generation to generation (Anderson, 1999) Both Federal and State policies restricted their own burn practices. The 1911 Federal policy made it illegal to practice prescribed burning which meant a complete loss of the Karuk's tribe TEK and cultural practices (Kari Marie Norgaard 2014). This caused the forest to thicken, fuel load to build up and catastrophic fire that destroyed landscapes rather than aiding it. The Karuk tribe currently do not have full jurisdiction over their land which makes it difficult to bring back their own practices. They need to work collaboratively with the U.S. Forest Service to bring back their own cultural practices. However, due to the current situation of wildfires, the tribes have been able to make historic changes in terms of collaborating with the U.S. Forest Service. In 2018, 1.6 million acres were burned from the Campfire, which is causing the U.S. Forest Service to now turn to Native American Indigenous communities for new solutions to mitigate further effects of these problems. This helped develop the 2018 Western Klamath Restoration Project. This project aims at educating people about the importance of wildfire and getting support in acquiring a crew to implement these practices. The Karuk tribe have developed a fire crew that will now go out to thin the forest to prepare it for prescribed burns on their land. The issue now is that these areas are too far gone without fire to bring it back. They don't have the people or resources enough to get ahead of the current state that they are in. These tribes don't only need fire to benefit the land, they need it to revitalize their own culture. This means bringing back their own cultural materials, regalia, traditional foods, and medicines using fire (Kari Marie Norgaard 2014).

Chapter 3: Non-Native Ecological Field Studies and Modeling

The goal of this chapter is to look at different case studies in which ecological modeling is used to test different sets of TEK. One of the main issues is how to give more credit to TEK by using data collection to show the benefits of fire management. This chapter will look at a variety of cases to see if there are any similarities or differences that will provide recommendations to further research and current management practices.

3.1 Prescribed Fire - Increase in Biodiversity

Ecological Study 1: The effects of indigenous prescribed fire on riparian vegetation in Central California.

This ecological study focused on assessing the effects of prescribed burns on riparian vegetation. The goal was to look at traditional practices of Native Americans Indigenous communities in Central California to see how effective their management practices are compared to current management practices. Native Americans have been setting fires to this type of ecosystem for thousands of years. They have developed the strategies to make this a successful practice (Hankins, Don L. 2009b).

Fire was used to maintain these important riparian ecosystems. Riparian ecosystems are considered a very important ecosystem service to the local tribes and surrounding communities. It also serves as an important habitat for wildlife. Prescribed burns were used to increase biodiversity of important plant species such as aspen and cottonwood (Hankins, Don 2013). The issue of current fire management practices of prescribed burns is that it is used for specific objectives, i.e. if there needs to be a clearing of vegetation. Although having an objective is very important, it is more important to understand the timing of the burn and what season to burn in. According to traditional knowledge, if one burns in the wrong season it can make matters worse. Traditional Knowledge explained that one's objective will determine the timing of one's burn. For example, burning during the wet season provided new growth while burning during the dry season focused on fuel reduction.

This ecological study was done in Central California on tribal lands in the Miwok and Wintun territories. The goal was to compare two different types of burns according to season. Burns were conducted in the wet season and dry season. Prior to the burn, manual management of the areas was conducted. This entails people to go into these areas and physically take out vegetation to initially reduce the fuel loads (Hankins 2013). According to traditional knowledge, it is known that one cannot perform prescribed burns without proper management of the site. If this management does not occur, one runs the risk of larger wildfires. The study area was outlined by transects, then prescribed fire was started by burning the transect along the edges of the study area. The prescribed burn was completed using a drip torch. After the fire, Hankins collected data on species richness and abundance of native plants.

This study showed that there was an overall maintenance of native plant species richness. The burns during the wet season, also known as winter season, had the best result in terms of increase in richness and abundance (Hankins 2013). This parallels with traditional knowledge that burns during the wet season provides an increase in native plant species. This may be due to native plant species adapting to fire over time and becoming more resilient to a prescribed burn. The burns during the spring or dry season did not see a decrease in fuel load. However, other factors may have altered the effects and further testing may be required. Figure 6 shows the results of the prescribed burn in terms of evenness of plant diversity. The higher values mean that there is higher plant diversity. The graph shows there is an overall increase in plant diversity compared to the study areas which had no prescribed burns. It also shows that fall and spring burns have the highest values when it comes to plant diversity and summer burns have a much lower value.

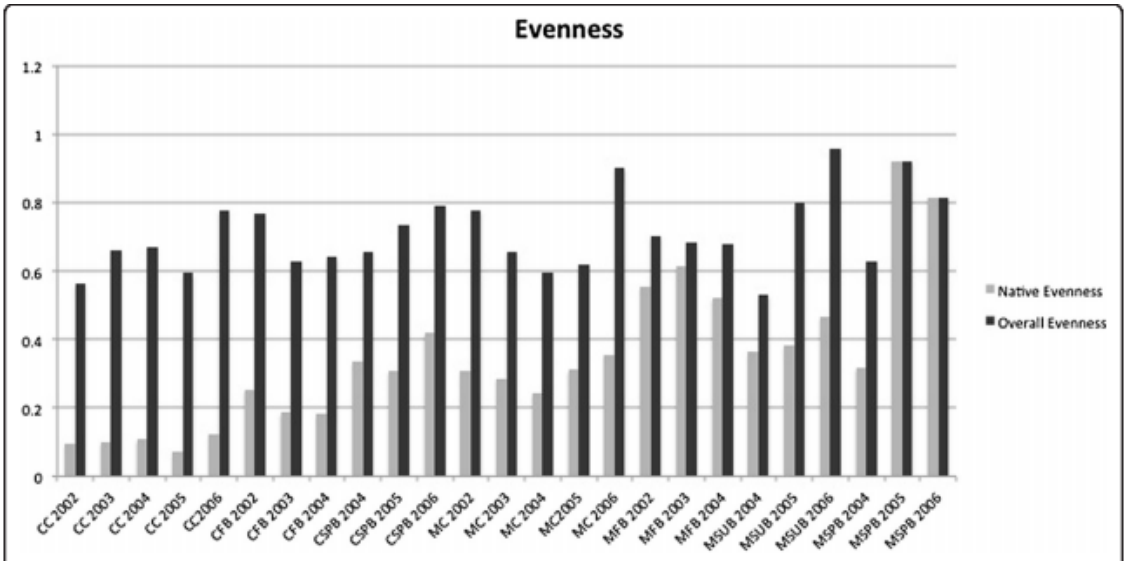

Figure 6: This graph shows the effects of the study area after the prescribed burn was performed. C: Control FB: Fall Burn SPB: Spring Burn SUB: Summer Burn (Hankins 2013)

This ecological study demonstrated the effectiveness of using TEK in current management practices. Seasonality of burn is a component that cannot be overlooked and is the basis of most TEK when it comes to fire management and prescribed burns. This study was able to quantify the impact of this method. However, there are many gaps within the study that need

to be incorporated when further research is done. TEK encompassed multiple aspects of management. For example, when the study had to be altered because of different migratory birds in the area. Performing further research and testing of their methods, there should be more inclusion of the specific tribes in those areas so they can provide knowledge that will fill in these gaps. This does give a good framework and the beginnings of future studies involving TEK.

3.2 Wildfire Smoke: Cooling Rivers

Ecological Study 2: Wildfire Smoke Cools Summer River and Stream

Wildfire management has many benefits that encompass all parts of an ecosystem. When properly used, wildfire can have multiple benefits that go beyond even the idea of fuel reduction to reduce major wildfires. While that is a main goal for most wildfire management practices, it is important to see how fire can positively benefit multiple parts of the ecosystem. The Karuk Tribe have been using fire as a tool for generations. They use fire to fight fire, as well as see its benefits for important resources that they use such as salmon. In this case study, wildfire smoke from prescribed burns is studied to show how it can help cool river systems and help salmon populations thrive. This study takes quantitative data to understand the benefits of wildfire smoke on river systems. In order to understand wildfire smoke effects, a multi- method approach was used. Studying air quality and smoke is a very complicated endeavor, with many variables affecting the temperature of water systems. Solar radiation and air temperature are the main variables that affect river systems. Other variables looked at were summer wildfire smoke, solar radiation, air temperature, precipitation, river discharge and water temperature. This is what makes this study difficult because many variables become a major factor. This study uses a variety of methods to analyze sets of data, such as looking at smoke though satellite imagery. The study area was focused on the Klamath River Basin where much of the Karuk and Yuruk Tribes reside. The Klamath River Basin has been altered by humans for generations causing negative effects. The building of dams, salmon ladders, and fire suppression have all caused different environmental issues, such as the loss of the salmon populations.

To best assess the effects of wildfire smoke on the Klamath River Basin, multiple analyses were used depending on what variable is being looked at. Water temperature and

wildfire smoke were both looked at separately while solar radiation, air temperature, precipitation and river discharge were looked at together because they all directly relate to each other. Data was collected from multiple sources and then analyzed.

Water temperature data was collected mainly from the U.S. Forest Service and the U.S. Fish and Wildlife from June 1st - September 30th (1996 - 2015). The two locations that were chosen were the Main Stem Klamath River and Klamath River Tributaries. In order to collect water temperatures, digital data loggers were used to calculate daily means, maximums and minimums. In this case seasonality and times when wildfire smoke seemed too sporadic, along with other factors, were removed from the analysis to avoid any bias information. In the end, the main values used were the daily mean and maximum deviations to see what effects wildfire smoke has on water temperature.

Wildfire smoke data was collected from satellite imagery. This was the best way to track smoke because it was easy to distinguish from a satellite image. A database of U.S. Wildfire was also used to double check that what was seen on the satellite images were from a wildfire event. The more complex factor was the decision to measure the Aerosol Optical Thickness (AOT). AOT is an important variable because it measures how much light it blocks through absorption and scattering. This is a value that is measured from 0-4 and has no unit of measurement. This AOT data was collected from the satellites that pass throughout the day. This data was then quantified using statistical analysis such as spatial interpolation algorithms to infill any null values.

Solar radiation was measured in $W\ m^{-2}$ from 2003 - 2015. Only the maximum values were observed. Air temperature data was gathered from 19 remote weather stations surrounding the Klamath River Basin. Daily mean precipitation was of different monitoring location from the University of Idaho meteorological data sets. Daily mean discharge was collected from eight gaging stations from a U.S. geological survey.

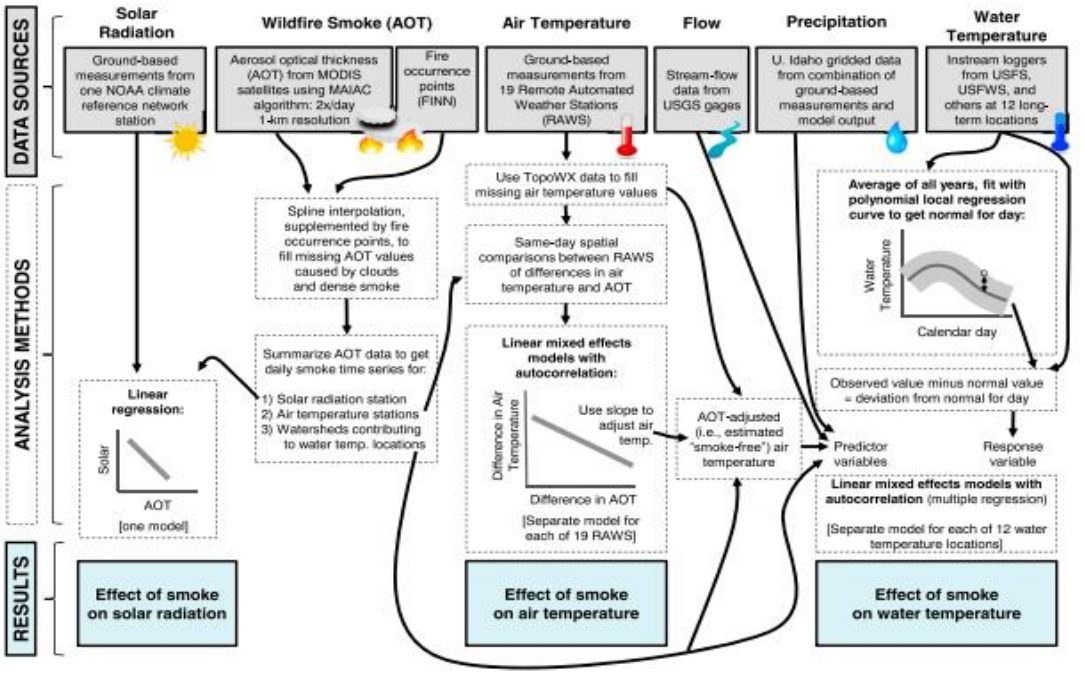

Figure 7: Flow chart depicting each variable's data sources, analysis methods and results (David et al. 2018).

Overall the results from this study concluded that wildfire smoke cools the rivers and streams of the Klamath River. Figure 7 depicts a flow chart showing all the variables and how they interact with each other. It described a holistic viewpoint on the effects of wildfire smoke on the land. This shows that prescribed burns and naturally occurring wildfire have multiple benefits. The cooling of rivers and streams also promotes a better environment for Salmon populations which are a staple to the Yurok and Karuk tribes in those regions. The results showed that a combination of variables aided to why the rivers and streams cooled from the smoke. This includes the scattering of radiation of aerosols therefore decreasing the amount reaching the rivers and streams. It was able to block a significant amount and kept them cool during the summer months. The measurement of AOT showed a 121 -W m^{-2} reduction in the solar radiation. This kept the air temperature cooler compared to no smoke days. The smoke acted like a physical barrier to the solar radiation reaching the rivers and streams. Although this study had an overall conclusion that smoke had a positive effect on water temperatures, it also suggests that there are a lot of areas of uncertainty that need to be included for further areas of

research. Some of the areas according to the study, are looking at how inversion layers affect the river/stream ecosystem, representing days with unforeseen weather conditions that don't involve fire and how to quantify the data better. Another area that should be looked at is how to include the Yurok and Karuk Tribe's wildfire management practices into the data collection. If the study included them as a base set of knowledge, it may have filled some of the gaps missing from the research study. It could also narrow down their study areas in terms of how they assessed salmon populations and when they used wildfire smoke to cool rivers and streams.

In conclusion, this study shows that TEK of the Karuk Tribe are valid in terms of cooling rivers and streams through wildfire smoke. This also shows how wildfires, both small and large, have positive effects on the land. It goes past simple fuel reduction and shows how there are secondary benefits to implementing wildfire management to these different ecosystems. The positives outweigh the initial negative effects, because it focuses on the long-term benefit rather than the short-term. This shows that it can be a major part in terms of collaborating different sets of knowledge involving more than just quantitative research. These sets of research need to go beyond the data and have the tribes participate in the research as much as possible in order to get a well-rounded result (Chief et al. 2016).

3.3 Modeling and Optimizing Prescribed Burns

Ecological Study 3: Modeling and Optimizing Prescribed Fire for Managing Wildfire Risk

Wildfire, in recent years, have been occurring at higher rates compared to previous years. This is largely because of climate change, and fire suppression as a management tool. Amongst all the deadliest of fires, fifteen of them have occurred in the past two decades. The most noted are the Camp Fire and the Woosley Fire that occurred in Northern California and had an estimated cost of 16.5 billion US dollars in damages (Zhuang and Jose March 6th, 2020). Prescribed fire is a tool that has been used to help mitigate large, high intensity wildfires. It is used to reduce fuel on the surface layer and create fire breaks to prevent wildfires. They also improve the health of the ecosystem and its level of biodiversity. To implement prescribed burns, a cost of about $135 per acre is estimated. In California, costs are usually much higher due to stricter regulations (Zhuang and Jose March 6th, 2020). Overall, prescribed burns are not used to its maximum potential because managers are either unaware or due to the strict regulations. Even

though prescribed burns have been around for thousands of years, it was just reintroduced in 1998. Since then, there have been about 19,800 data points collected from the National Interagency Coordination Center on prescribed fire and its benefits across the United States. The goal of this research was to look deeper into the data to help prove that prescribed burns are an effective management tool and that it could save states millions of dollars from the destruction of extreme wildfires. Another goal of this study was to show that it is most beneficial for each state agency to determine how they implement prescribed burns since it differs from region to region. The overall amount of prescribed fires has been increasing from 2003 to 2017, however, there has not much data to show if these prescribed burns were in fact, an effective management tool. There was no measured result except for the general belief that prescribed burns reduced the risk of wildfires because of fuel reduction. The fear of these prescribed burns leading to major wildfire was a continued battle in terms of implementation. Western states such as California, Nevada and Washington burn less prescribed fires than other states due to regulation and different sets of constraints. This is problematic because these areas have the highest rate of extreme wildfire that take up most of the state's resources. Oregon has increased prescribed fires because of the passing of a new air quality rule that allows more prescribed fires where the main set of research takes place. Recent research shows that the smoke from prescribed fire is three times less harmful than wildfire smoke, which was the main reason that allowed them to loosen their policies (Zhuang and Jose March 6th, 2020). They are focusing on areas with high fuel load. Through this study, a least cost prescribed fire model was developed in order to show the benefit of prescribed fire. This formula included variables that focused on the losses due to wildfires and the cost to perform them. A report from the Oregon Fire Council provided data from the 2017 season to find out the cost of wildfires. This estimate included fire suppression, travel and tourism, transportation, wood products industry, and private resources lost. This analysis, including these different variables for cost, came to a total of $518,492,000 in damages from wildfires, while the cost to perform prescribed fires totaled $142,190,000 (Zhuang and Jose March 6th, 2020). Through this, the optimal prescribed fire was calculated based on cost. This model was repeated for 2012 – 2017 in order to value the most optimal amount of prescribed burns. Figure 8 shows the cost savings in Oregon. The graph on the left shows the cost of prescribed fires per year. The blue is the optimal amount while red is the actual amount. The overall cost of wildfires reaches almost a billion dollars vs. the cost of prescribed fires. On

average the savings is about half a million per year. Oregon now performs about 155,900 acres of prescribed burns on average each year which could save the state about $482,044,441 per year (Zhuang and Jose March 6th, 2020). This research shows that prescribed burns are beneficial on both a financial level and a land management level. With wildfires increasing it is important to use this data to show land managers that prescribed burns are a tool that needs to be used more.

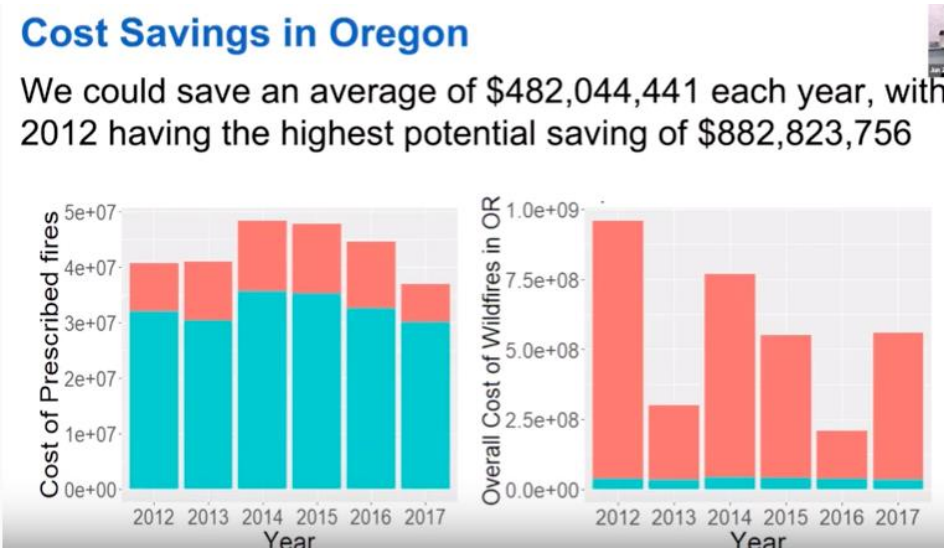

Figure 8: Model showing the cost benefit of prescribed fire in Oregon giving quantitative data that more funds should be directed to prescribed fires. Showing the optimal and actual amounts spent on prescribed fire vs. the effects of wildfire (Zhuang and Jose March 6th, 2020).

This set of data shows how prescribed burns can save states from the massive costs of wildfires. This research focused only on a baseline data while not going into depth about each region's method of performing prescribed fire. This is something that can help substantiate Native American Indigenous communities TEK and show managers that this knowledge is valid. This has the potential of combining non-native and native research to help push the agenda of how and when to implement this type of management, especially on the West Coast where wildfires are prevailing. This is an example of how both sides of knowledge can be used together, despite coming from different backgrounds and different ways of observing data. It

needs to be reminded that both sides are trying to accomplish the same objective: to reduce the number of extreme wildfires with prescribed burns and develop a better way of managing land.

3.4 Archaeological Study on Prescribed Burns

Ecological Study 4: Fire, Agency and Scale in the Creation of Aboriginal Cultural Landscapes

This ecological study takes a different approach to research of the benefits of prescribed fire. It shows the value of also collecting qualitative research to help provide a framework and understanding of how to best implement prescribed fire as a management tool. The Anishinabe Tribe of Northwest Ontario was researched to gather information on their cultural landscape and how to best manage the land in terms of fire. The tribe viewed fire as having a spirit and deemed it a necessary entity to create the landscapes they needed to survive and maintain a balance. Like most tribes, the Anishinabe Tribe also went through a long period where fire was suppressed, and their knowledge was lost (Andrew Martin Miller and Iain Davidson-Hunt 2010b). Carl O Sauer, an early researcher, was one of the first to explore the importance of cultural landscapes. Cultural landscape explores how people altered the land using different management techniques to live off it sustainably. In this case, the Anishinabe Tribe used fire.

In order to learn more about their cultural practices, an anthropogenic study needed to take place on the people who still perform their cultural practices. For this to take place, there needed to be a sense of trust between the native and non-native researchers (Jon E. Keeley 2002). There was a long-standing collaboration which built this level of trust with the tribe respecting outsiders and sharing their knowledge. This collaboration involved community elders sharing their knowledge and history. After learning all that they could about how they used fire, the non-native researchers presented them with their own project plan. This led to the researchers being taken out to the field to observe some of their native practices, as well as interviewing other tribal members to get a better sense of how fire was used. This form of research is an ethnological approach, in which they rely on a qualitative set of understanding of how the land should be managed (Andrew Martin Miller and Iain Davidson-Hunt 2010). Through this method of collecting knowledge, the researchers were able to uncover the tribe's philosophy of land management that they kept in their oral traditions and language. Figure 9 shows how many of the

native terms were translated to different types of fire and described the actions needed to manage it. These terms show how well adapted they were to their own land and how they were able to pass down their knowledge to future generations who would practice their cultural traditions.

Table 1 Pikangikum elders recognize several named fire behaviors which are best confronted with different suppression strategies

Fire type	Anishinaabe term	Description	Action
Crown fire	*Keesheeyahkeetaah*	Fire moving rapidly through the tops of trees. Very dangerous.	Impossible to fight with hand tools. Escape.
Underground smoldering fire	*nooswuhkeekay auhnuhmuhguhmeeg*	Slow moving—Difficult to detect. Frequently occurs when fire gets into roots of large balsam fir.	Fire fighter needs to feel under the ground with bare or gloved hand. Requires "a good sniffer"—one who can smell new smoke several days after fire has stopped active burn.
Fire burning up a hill	*Aaheekkuhmuhcheewayauhkeetaak*	Fast moving fire	It's not safe to fight an up hill moving fire from above.
Fire burning down hill	*neesuhcheewee yuhkeetay*	Slow moving fire	Usually burns itself out.
Fire burning on level ground	*keetuhqwaag auhkee*	Usually can be contained	Can be fought using hand tools. Clear vegetation and organic soil.

Figure 9: Table showing how language is a key method in terms of Native Knowledge and fire management (Andrew Martin Miller and Iain Davidson-Hunt 2010).

Their oral histories and language held so much knowledge because it went back many generations. They were the ones who created the cultural landscapes that are being studied today and had the ability to show the impacts of fire over a period of time. Figure 10 below shows how the tribal knowledge from the elders would show the impact of fire over a 100-year timeline. It shows the impact of forest fires, when to implement prescribed burns and how it benefited plant and animal species. It also shows that fire is a tool to help maintain ecosystem health for the long term and that it is not a short-term solution like many management tools are used today.

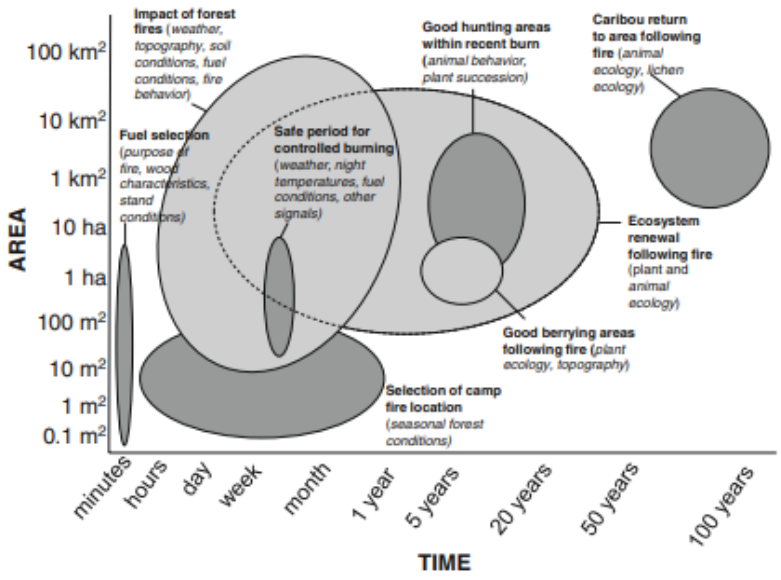

Figure 10: Graph showing the effects of fire over a 100-year timeline showing long term changes (Andrew Martin Miller and Iain Davidson-Hunt 2010).

This shows how abundant native knowledge is when it comes to caring for the land and in this case, how fire affects the land. It further proves the fact that it makes beneficial changes in current fire management. There needs to be a focus on the past. The past shows how the land came to be and the different trends it has gone through. All this knowledge is found in Native American Indigenous communities' history and language. It is needed to move forward in the current changes it is going through with the changing climate.

Chapter 4: Current Management Practices and Policy

The goal of this chapter is to better understand how fire suppression was one of the main causes that devalued native knowledge and practice surrounding wildfire management. It created a narrative that lasted thousands of years, causing our lands to be where it is today. How this negative narrative influenced state and federal policies, such as the implementation of more and more restrictions making it almost impossible to continue the practice of prescribed burns, will be examined. By looking at these different areas and gaps in management practices, a better understanding of how to bring back prescribed burns into policy and regulation will be analyzed.

4.1 Fire Suppression

Prescribed burns have been a practice that has been performed for generations on a global scale. It is a practice that was deemed necessary to maintain many kinds of ecosystems. It promotes biodiversity, reduces fuel loads and is a necessary resource for human survival. Many plant and animal species even adapted themselves to benefit from the occurrence of natural wildfires (BAKER 1992). It was a method to keep everything in balance. When fuels are built up to a certain level, a natural wildfire would occur to prevent any disastrous types of wildfire seen today. The issue that is faced now is due to the presence of fire suppression. To many, fire only has a negative connotation. The public perception of fire has had a narrative of destruction and violence, which is true, if not properly managed. Wildfires have been increasing in more urban areas and communities continue to live-in high-risk areas (Keeley et al. 1999). Fire is used for everyday reasons such as cooking and keeping people warm, however, to intentionally set small fires to benefit the land has always been looked down upon (Paveglio et al. 2009). It started with early colonization and people not valuing the native practice of prescribed burns. They forced many Native American Indigenous communities to stop all forms of prescribed burns because they thought they knew better. Unfortunately, this caused the loss of their own native knowledge and now left the land in a vulnerable state. This did not stop with early colonizers but stemmed into government regulations and the continued narrative of only preventing wildfire rather than using it for its benefit.

Preventing wildfires is an idea that was well adopted by most people. The goal was to primarily teach people how to not be the cause of a major wildfire event. This started with educating people on how to function outdoors and mitigate any risk factors. For example, the importance of putting out a campfire completely when camping. The mascot of this narrative was the use of a popular childhood character named Smokey the Bear (Ballard et al. 2012). Figure 11 depicts this character which became the spokesperson for this initiative. He even claimed a popular saying, “only you can prevent forest fires.” This narrative, although initially having a good message, transformed into this overall prevention of fire to maintain ecosystems. It further ingrained in people's minds that fire is bad and should not be used in any type of land management practices (Geoffrey H. Donovan and Thomas C. Brown 2007). The indirect effect of this is what further caused the suppression of Native American Indigenous community’s knowledge surrounding prescribed burns. It halted all practices, and the idea of leaving areas in

their natural state was the best management practice. They believed that if humans left areas alone, the land would be able to bounce back as a healthy ecosystem. This did not occur because they were fire dependent ecosystems. Once fire was eliminated as a management tool, it caused fuel build up to occur for hundreds of years, reaching a state where the land needed more attention to return to its original state. It will require a huge set of manual labor to prepare these sites to have prescribed burns implemented safely and effectively. These ideals created influence over the way state and federal policies were created. They made them very strict and nearly impossible to perform over the fear of starting a catastrophic wildfire.

Figure 11: Sign depicting Smokey the Bear sending the message that only you can prevent forest fires (m) USDA Forest Service, 1993).

4.2 Federal Policy and Land Managers

This narrative surrounding fire suppression has influenced policy and land managers across the United States, which further maintained this idea that fire suppression was the solution to major wildfires. Fear influenced the development of policy and land managers. Land managers felt so much push back in implementing prescribed burns because the public thought it would simply be the root cause to even more major wildfire events. There were many social and cultural constraints to prescribed fire that added to the influence of federal policy (Quinn-Davidson and Varner 2012). Figure 12 describes a list of issues that burn managers faced when implementing prescribed burns. This list was collected through a series of surveys to understand the barriers more clearly.

Impediment	Federal ($n = 34$)	State ($n = 13$)	Private ($n = 12$)
Narrow burn window	7.9	8.7	8.4
Regulations	6.6	7.6	8.5
Lack of adequate personnel	5.8	7.2	6.3
Environmental laws	5.7	6.5	7.0
Residential areas near burn	5.6	7.2	5.7
Lack of adequate funding	4.4	7.9	6.8
Liability	4.6	5.5	7.8
Fuel loading	5.4	5.5	5.5
Planning costs	4.2	6.7	5.4
Public opinion	4.0	4.7	6.3
Preference for alternative strategies	4.3	4.7	3.8
Burn unit preparation	3.8	5.4	3.7
Insurance limitations	2.5	3.3	6.3

Figure 12: Table depicts result from a survey on the impediments facing the implementation of prescribed burns from federal, state and private sectors (Quinn-Davidson and Varner 2012).

Federal policy, when it comes to fire management, was only taken seriously in 1886. However, it only focused on suppressing all fires in order to mitigate major wildfires. This paralleled the narrative from Smokey the Bear, that fire prevention was the main management tool. There was some collaboration with Native American Indigenous communities about the benefits of

prescribed burns, but it was quickly forgotten because of the public perception of fire. It wasn't until about 50 years later in 1943, that prescribed burns were once again being considered as a management tool. However, it wasn't until about 20 years later that implementation finally took place in California. By this time, fire was eliminated for so long that it made it nearly impossible to bring back prescribed burns properly without running the risk of major wildfires, pushing further the narrative that it is not an effective management tool. Since then, the rate of wildfires exponentially increased. The early 2000's is when policies were created recognizing the benefits of prescribed fire, and that it needs to be a research area of study to properly implement it. This brought the 2001 Federal Wildland Management Policy that included both fire suppression and prescribed fires (Scott L. Stephens and Lawrence W. Ruth 2005) . Unfortunately, the process in which it was created, made it just as difficult to allow prescribed fire. The different land managers were seeing this as a huge liability and risk. It quickly detoured them away from exploring this idea because they didn't want to accidentally be the cause of more wildfires and costly damages to the land. It also wasn't seen as an effective method because immediate results were not produced. Prescribed fire is meant to have a long-term goal on the land, in terms of fuel reduction. It wasn't simply a band aid to a problem like fire suppression has been, because now that wound is even more exposed and vulnerable. The issue amongst policies is that the Federal Government restricts states in different ways according to state regulations. Different policies such as the Endangered Species Act and Air Quality control regulations are just some of the limiting factors on prescribed burns. Not only do managers find it difficult to adhere to different regulations, the information to perform these types of prescribed burns is not widely available. Since one style of burning doesn't work in every place, different methodologies need to be adapted. There needs to be a focus on the function of fuels, the topography and how the climate plays a major role. Prescribed fire is becoming more and more a focus as a beneficial tool as more research and careful observations are being documented. With this, more issues arise in terms of implementation. For example, the Federal Government is often more focused on the acres burned vs. the impact. It is looked at as a numbers game. Prescribed burns may be finally looked at as a potential solution, but now it's about how many acres this can be implemented on. It should be known that it's not about how much you can burn, but how you do it.

The next steps that need to be developed in terms of implementing prescribed burns, must involve social, economic and political factors. The policy that we follow today is a response

method vs. a mitigation effort. Prescribed burns must be viewed as a long-term goal. However, with the increase in wildfire events in the Pacific Northwest, all funds are being drained by disaster relief which mainly involves fire suppression efforts. With each passing fire season, more and more resources are directed towards relief and less on implementing prescribed fire. As of now, the Federal Government pays $400 million for fire management programs across the country, which is a small amount compared to the amount of damage a single wildfire can produce. Unfortunately, on top of strict regulations, funding of these programs is the next biggest limiting factor.

Table 1: (Scott L. Stephens and Lawrence W. Ruth 2005) Set of recommendations that must be considered for a new federal wildfire policy

1) Restate the objectives of fuel-management programs to be the reduction of potential fire behavior and effects.
2) Adopt policies and programs that are straightforward and pragmatic, and that also reflect awareness and sensitivity to the environmental and social impacts of these programs.
3) Improve the budgeting process for both fuel management and fire suppression to ensure funding is enough to achieve overall and annual program objectives.
4) Initiate a vigorous adaptive management program that utilizes a rigorous program of monitoring, experimentation and research to improve fire and fuel management policies.
5) Periodically evaluate strategies and progress toward overall objectives of reducing potential fire behavior effects.
6) Utilize and publicize the results of adaptive management to educate land managers, other agencies, elected officials, scientists and the public.

4.3 Statutory, Regulatory and Legal Constraints on Prescribed Fire in the USA

The long history of fire suppression has left the United States in a vulnerable position. One of the key events that shifted this narrative was the 1988 Yellowstone Fire. The National Strategy needs to change, although the Federal Government is slowly changing its mind set. The next issue is how to convince more private landowners to allow prescribed burning. The United

States consists of huge amounts of private land. If prescribed burns do not have access to private land, it will be impossible to reach goals of implementation. Each state has a different set of their own statutory regulations. Many states even implemented statewide open burning bans which caused even more push back. Landowners became fearful that they would be liable for the risk of using prescribed burns. In the Southeast, where most prescribed burns have been done, they started to implement the Right to Burn Act which protects the private landowner from any risky situations and spells out the level of liability (Wonkka, 2020). However, this came with more regulations such as the Certified Burner Program (CBP). Florida and Georgia were some of the first states to implement these acts in order to promote prescribed burns. California, however, still has very strict policies in order to regulate and avoid major wildfires. There are more factors such as the high fuel loads and weather that make it riskier to implement prescribed burns. However, this caused California to rethink their management strategies. SB 1260 was created to shift the mindset in California from fire suppression to allowing prescribed burns as a tool to mitigate wildfire. However, like in Georgia and Florida, this created more and more regulations forcing pre-certification programs and extensive plans on how the prescribed burn will be implemented (Wonkka 2020). These steps are meant to help push the process forward. If a burn manager has all these credentials, then in theory, it makes it easier to burn.

Chapter 5: Analysis - Integrating the Three Perspectives

Key Findings

Table 2 summarizes the findings of chapter 2, Traditional Ecological Knowledge and Cultural Revitalization of the Guidiville Rancheria of Pomo Indians, Amah Mutsun Band of Mission Indians, Karuk and Yurok Tribes. After conducting interviews and gathering literature on the four Native American Indigenous Communities, there were many benefits and challenges that stood out. The benefits of Traditional Ecological Knowledge are that it holds a wealth of knowledge. It described land management practices from generations of knowledge that aides how we can manage the land today. For example, the Guidiville Rancheria of Pomo Indians, describes their many years of using low intensity smoke to help fireproof trees, as well as, preventing dangerous plant pathogens. It is also important to understand how the land came to be

in terms of its past land management methods. TEK is a set of knowledge that encompasses generations of knowledge like the Amah Mutun Band of Mission Indians described. Through a set of archeological research, the tribe was able to uncover many of its lost management practices to bring back and adapt to their lands.

The challenges that these three tribes face is preventing their TEK from benefiting today's management practices. For example, the fact that TEK is often generalized by non-native researchers has a negative effect. There needs to be a focus in incorporating infidel tribes in making management decisions on the land they have lived on for thousands of years. In the case of the Karuk tribe, who have been working along the Klamath River, had their fire managment practices restricted due to the influence of fire suppression. They are currently attempting to bring back their TEK, however, due to lack of funds and support makes it very difficult to do so.

Table 2: Traditional Ecological Knowledge (TEK) and Cultural Revitalization

Case Study	Benefits	Challenges
Guidiville Rancheria of Pomo Indians	● Black Oak Death prevented from prescribed burns ● Understanding benefits of good smoke and differences in fuel loads ● Location, elevation and time are key factors of prescribed burns	● TEK is a global term and often generalized ● Prescribed burns are different according to region ● Application of TEK can have negative effects if not done properly
Amah Mutsun	● Archeological findings helped uncover Tribal history ● Land was viewed as a mosaic and fire was a major factor in its overall health	● Not allowed to practice traditional prescribed burns practices because they don't have their own rights to the land ● Not enough people who can bridge the

	• Began practicing prescribed burns with private landowners which brings back their culture and knowledge	gap between nonnative and native scientists • Fear that nonnative science will corrupt traditional knowledge. • No trust because of genocide
Yurok and Karuk Tribes	• They already have the knowledge and skill to bring back prescribed burns as a tool to combat wildfire • They have leveraged power in other environmental cases through activism and TEK • They consider themselves fire people, you must use fire to fight fire	• Not enough funds or people to help implement prescribed burns • Fire suppression caused too much loss and too much fuel to return to normal state. • Their land is limited in terms of where they can implement prescribed burns

Table 3 summarizes chapter 3, Non – Naïve Ecological Field Studies and Modeling. After assessing the four ecological studies (Effects of Indigenous Prescribed Fire on Riparian Vegetation in Central California, Wildfire Smoke Cools Summer River and Steams of the Klamath River, Archeological Research of the Anishinabe Tribe, Modeling and Optimization of Prescribed Fires), benefits and gaps were identified. These studies quantify TEK, showing the benefit of a certain practice. Many of these studies did a good job, performing proper research on the specific tribe they were basing their study on. They would use methods such as informal interviews to capture the key elements to their style of burning. The research validated the existing knowledge of the tribes. However, in many cases it also helped document tribal histories such as with the Anishinabe Tribe. Through the archeological research done, they were able to understand 100 years of fire management history which helps with future planning. The

collaboration between native and non-native research is becoming a powerful tool when it comes to influencing the public and policy makers of the benefits of TEK prescribed fire practices.

The gaps that come with non-native research is the idea that we must prove that TEK is something that benefits the land. It causes the assumption that TEK is not worth using unless these studies occur to quantify them. Instead, there should be a collaboration of monitoring and evaluating their current practices to help document and improve their own process. Often, the research seemed to be done without tribal involvement. If they had the opportunity to collaborate, many missing gaps had the potential to be filled by both native and non-native researchers.

Table 3: Non-native ecological field studies and modeling

Ecological Study	Benefits	Gaps
Prescribed Fire Increasing Biodiversity	● Prescribed burns benefit riparian ecosystems ● Seasonality is an important factor for when to perform prescribed burns ● Overall increase in biodiversity when prescribed burns performed in winter/wet seasons	● Not enough involvement from Native Practitioners ● Issues occurred in study that prevented testing in certain locations ● Variables such as weather and location preventing certain tests therefore not giving the best results
Wildfire Smoke Cooling Rivers	● Many databases used to assess that wildfire smoke cools rivers and streams ● Quantitative approach to showing benefits of wildfire smoke ● Diagram showing how multiple	● Study affected by unforeseen factors such as weather and wildfire events ● Data analysis did not include native practitioners

	variables affect each other	
Modeling and Optimization Prescribed Fires	• Gathered data from many sources showing the cost benefits of prescribed fire vs. wildfire • Results can be used by land managers to implement more prescribed burns	• No mention of method of prescribed burns • Generalizes prescribed burns and how to implement
Archaeological Study on Prescribed Burns	• Prescribed burns embedded in language and culture • Helps revitalize Native culture and practices • Gives non-native scientists a better understanding of TEK	• What are the next steps to properly implement? • TEK is shown to be a benefit, how can they be more involved in management decisions?

Table 4 summarizes the findings from Chapter 3, Fire Suppressions Influence Over Federal and State Policies by looking at 2001 Federal Wildland Management Policy, Right to Burn Acts and California SB1260. The benefit of fire suppression is simple, to help prevent major wildfires. However, it had a negative effect in terms of the use of prescribed fires as a management tool. It was clear how the early adoption of the Smokey the Bear narrative influenced how policies are enacted today. The early 2001 Wildland Forest Policy mainly focused on a response to wildfire vs. a mitigation strategy. State regulations such as the Right to Burn Act and California SB1260, focused heavily on creating pre-certification programs to help prevent the risk of wildfire. Having the main efforts being focused on preventing wildfires, made it nearly impossible for prescribed burns to occur, especially for Native American Indigenous communities. The outcomes are that fuel loads in many areas of Northern California are too high. It is nearly impossible to implement prescribed burns without investing in manual labor and thinning of the forest to accept prescribed burns.

Table 4: Fire Suppression and federal/state polices

Current Management Practices and Policy	Benefits	Outcomes
Fire Suppression	• Immediate action for wildfire and how to respond • Raised awareness for people to prevent wildfire	• Overall negative perception of any type of fire, including prescribed fire • Using fire as a management tool looked down upon • Fuel build up across the country making it higher risk for wildfire
Federal Policy and Land Managers	• Too many restrictions • Land managers fear liability for prescribed fires	• Not enough prescribed burns are implemented • Knowledge gap on how to best implement
Statutory, Regulatory and Legal Constraints of Prescribed Fire	• Regulations put in to make sure prescribed burns are done properly to avoid risk of wildfire • Shift to private land for prescribed burns	• Too many regulations which make it difficult to be allowed to implement prescribed burns • Private land is controlled by the landowner

This set of research examined three main areas to help understand the benefits of TEK on current wildfire management practices in Northern California. To achieve a full understanding of how to achieve positive management recommendations, a variety of methods were required. The first two chapters looked at a tribal perspective of fire management, and a non-native perspective of how to best quantify their practices. The main points the tribal perspective and their TEK showed how extensive their knowledge is surrounding the use of fire. It is embedded in their culture and represents a way of life to many Native American Indigenous communities. The method they use to document is teaching future generations their knowledge. For example, the

Guidiville Rancheria of Pomo Indians talk about the benefits of smoke on the ecosystem. It helps protect trees when wildfires are present. When it comes to TEK, oftentimes it is not taken seriously because it is not deemed credible amongst the scientific world. Many studies have been done to assess TEK to make it quantifiable and prove that it is a proper management method, i.e., the research done focusing on the seasonality of burns in terms of increasing biodiversity. The basis of that study was looking at prescribed burning practices of tribes in Central California. This study proved many points that the tribes already knew. There were certain gaps in the study where native TEK could have filled, when conducting the study. On occasion, research bases their study on TEK, but oftentimes, forgets how to properly include them in their study. There needs to be a methodology created that shows how native and non-native scientists can work together to create a positive impact on the land. The goal is to bridge the gaps between the two sets of knowledge to achieve the same goal, which is improved fire management and the prevention of wildfires.

Chapter 3 briefly looks at the history of fire suppression and the limitations of federal and state policies. The narrative around fire suppression must change regarding the fear of using fire as a necessary management tool. This narrative has caused fire to be eliminated from fire dependent ecosystems. There needs to be more outreach and education showing how prescribed burns is necessary to avoid the risk of wildfires. It has left land managers resistant to implementing prescribed burns over fear from the community, as well as, liability concerns. This also pushed the narrative that Native American TEK is not credible and is dangerous. Many strict policies and regulations have also made it nearly impossible. Fire is so feared that many regulations were placed even if a land manager wanted to pursue prescribed burns. To move forward with management recommendations that are created through the collaborations of native and nonnative scientists, there needs to be more trust from state and federal governments to allow these practices to happen. This is the reason for the push toward private lands and working with them to avoid these barriers to bring back prescribed burns as a necessary management tool.

Chapter 6: Conclusion and Management Recommendations

This set of research shows how vast Native American knowledge is when it comes to using fire as an effective management tool. TEK coupled with non-native research can impact policy and regulations in order to make positive change. These two sets of knowledge can potentially help influence the people who decide these policies in how we manage the land. This positive change not only can benefit the land, but also, the revitalization of Native American culture. In order to bring back their TEK, we also need to preserve their cultural tradition. This can be done in supporting tribes and helping them document their own history. This demonstrates how many challenges that we are facing now, such as increased wildfires, that can be mitigated with the right set of knowledge. It simply takes the participation and collaboration of the Native American people with non-native scientists and land managers, working together to achieve the communal goal: to improve how we interact with the land regarding fire. It is extremely important to embody the idea that it will take a multi-method approach to develop the right decisions when approaching current environmental problems. The next step is to understand how TEK can impact current polices and regulations focused around the use of prescribed fires. It is widely known that TEK is beneficial to the land, however, it is not being used to its maximum potential. Many policies and regulations focus on preventing wildfire vs. mitigating wildfire. They need to involve Native American Indigenous communities when making important decisions on how we manage the land.

I conclude with five areas of recommendations that are needed to make positive changes to fire management practices, which will in turn, benefit the cultural revitalization of the Native American Indigenous communities. These five categories focus on returning land to Native American Indigenous communities, education, developing climate adaptation plans as a way of documenting TEK, loosening state and federal regulations and continuing to facilitate the collaboration between native and non-native researchers.

Returning Land

The main management recommendation is to return land to all Native American Indigenous communities in order to revitalize their culture and bring back their traditional practices. There is a realization that many of these tribes' management practices need to adapt to current conditions and climate change. However, this can't be done if the original scientists of the land can't conduct their own sets of research. That is the way they developed their knowledge in the beginning, through careful observations of the land. Native Americans are educated and can carry this out with the help of non-native scientists. However, collaboration is needed to develop understanding and trust in what they do, including a careful plan to monitor and evaluate the fire management practices. There is also the need for more funds that are allocated specifically for the implementation of prescribed burns. Native American communities are knowledgeable as to how to bring balance back to the land. However, access to their land, money, time and people are what limit this from occurring. Further work is needed to develop and implement a return of native land management, whether through land trusts, collaboration with private landowners, or outright return of traditional territories.

Education

Education can be one of the simplest, but most effective management recommendations. One of the main issues is the fact that people are unaware of the importance of TEK and the impact it can have on fire management practices. If Native American Indigenous communities start to educate the public about their practices, it has the potential to influence policy. The goal is to include Tribal Knowledge. We need to reverse the narrative that has been adopted for generations to bring balance back to the lands, especially with hotter summers and increased wildfire events. Its imperative that we start preparing the land to accept prescribed burns once again.

Education can be one of the keyways to promote the mix of traditional knowledge and western science. The youth of Native American Indigenous communities are the future and it is their livelihoods that are at stake. The idea is to promote the youth of Native American Indigenous communities to pursue higher education in Natural Resource Management to give back to their communities within their career paths. This is an example of blending their own personal connection with the environment with the ideas of western science. It will give them the

tools to have an interdisciplinary approach to different environmental issues (Gervais et al. 2017). It takes away the issue of having scientists collaborating with Native people, by simply turning them into the scientists themselves with their already existing tribal knowledge. However, there are many challenges that face Native American Indigenous communities in terms of the pursuit of higher education as a life path. Many of these communities that live on the reservations are living in poverty. They often lack access to education in general, which becomes a huge barrier to employment beyond the reservation. Many people don't have the financial means for higher education and are focused on other livelihood aspects. Another issue is the lack of university role models within Native American Indigenous communities. When the youth don't see their own members pursuing higher education, it decreases the chances of them thinking it is a possibility.

Developing Climate Adaptation Plans on Fire Management

To bring together different sets of knowledge and to avoid the generalization of TEK amongst different groups, Climate Adaptation plans are becoming a tool for tribes to use to clearly show how they will address environmental issues such as fire. These plans can include a history of the tribe and their cultural connections to the land. The Yurok and Karuk tribes have started to develop these plans in order to show non-native people the benefits of their knowledge. This can help personalize each tribe's plan in terms of documenting the differences and similarities. It is known that every tribe has a different way of managing the land according to their own tribal traditions. This can also be used in terms of information sharing amongst tribes to help each other develop these plans and can also be used as a tool to help bring back certain sets of knowledge that have been lost. The University of Oregon developed a Climate Adaptation guidebook working with over thirty tribes in Pacific Northwest gathering their knowledge on how to adapt their practices with the effects of climate change. It included steps to properly work with tribes on specific environmental problems while respecting their own knowledge (Dalton, Chishotm, Peterson, 2018). Figure 13 shows the steps needed to tackle different environmental issues. This guidebook has the potential to be adapted for a fire management specific tool for different tribes to use when trying to figure out how to implement their own sets of knowledge.

Figure 13: Diagram showing the 5 steps that are needed to implement a climate adaptation plan. 1) Center the tribes Adaptation Effort 2) Identify Concerns and gather information 3) Assess Vulnerability 4) Plan for Action 5) Implement and Monitor Action (Dalton, Chishotm, Peterson, 2018).

Federal and State Policies

Federal and State polices do a good job in terms of responding to wildfires, as well as, putting a focus on making sure people are educated enough to perform prescribed fires through certification programs. However, there needs to be a different set of regulations when it comes to involving tribal knowledge. There needs to be policy that is adopted that includes tribal members as the experts when it comes to land management and working with other organizations to help implement these programs. We need to put the land back in the hands of the tribe in order to allow them to properly manage the land so they can teach others to do the same.

Collaboration between Native and Non-native researchers

The final recommendation is to continue the collaboration between native and non-native researchers. It has been shown that both native and non-native research are valuable in their own ways. One focuses on the generations of information gathering, while the other focuses on the monitoring and evaluation of management practices. These two sets of knowledge represent two sides to management that are necessary in order to make positive change in todays climate. If these two sets of knowledges were used properly together, they have the potential to achieve the

same goals, such as influencing policy and regulations surrounding fire management. In order to facilitate this, both non-native and native researchers must learn how to collaborate. For example, there should be a set of guidelines when it comes to non-native researchers developing their study. They should always incorporate a specific tribe's TEK, as well as, involving the tribal members in the study in order to get the best results. It must be recognized the Native American Indigenous communities are the original stewards to the land. They hold the answers to many of our current environmental problems. It is also understood that TEK is knowledge that is always adapting with the climate. If it is coupled with other forms of research, better management decisions can be made.

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