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Historic Ohlone Resource Distribution within the Alameda Creek Watershed

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HISTORIC OHLONE RESOURCE DISTRIBUTION WITHIN THE ALAMEDA CREEK WATERSHED

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Naseem Fazeli

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HISTORIC OHLONE RESOURCE DISTRIBUTION WITHIN THE ALAMEDA CREEK WATERSHED

by

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APPROVED FOR THE DEPARTMENT OF ENVIRONMENTAL STUDIES

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ABSTRACT

HISTORIC OHLONE RESOURCE DISTRIBUTION WITHIN THE ALAMEDA CREEK WATERSHED

by Naseem Fazeli

The Alameda Creek watershed is located within the ancestral homeland of the Muwekma Ohlone Tribe of the San Francisco Bay Area. Their ancestors historically utilized a variety of plants for food, medicine, ceremonies, and building materials, with their understanding of the value of the plants based on traditional ecological knowledge (TEK). The arrival of Spanish, and later Anglo/American, colonists beginning in the mid-18th century introduced urbanization and European agricultural practices, which have degraded wildlands and impacted species richness and diversity. As interest in environmental restoration has been increasing in recent decades, the present-day Muwekma Ohlone Tribe has an opportunity to once again access ancestral lands and educate the public on their TEK practices. A vegetation survey was conducted to analyze the distribution of historic plant resources, native plants species, and non-native species in a riparian corridor in the Alameda Creek watershed. Areas with greater anthropogenic land use, specifically grazed lands and seasonal service roads, had the lowest levels of biodiversity, traditional plant resources, and native species presence. Undisturbed and restored sections of the corridor, in contrast, were found to have the greater amounts of resource presence and diversity. Although the effects of Western urban expansion have drastically altered the traditionally managed environment, reintroducing Ohlone TEK could help support ecological biodiversity and allow a marginalized group to reclaim their culture and traditions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

Motivation and Scope

Throughout time, societies all over the world have discovered that human survival is connected to the survival of the natural world. Following this understanding is the creation of a knowledge base—a system of beliefs—that incorporates human interaction with the environment. This system of knowledge, culture, and ecological management is known in the Western academic sphere as traditional ecological knowledge (TEK) (Berkes, 2018). In general, TEK establishes a practical relationship between humans and their environment, in which resources may be extracted while ecosystem composition and function are supported (Berkes et al., 2000).

However, TEK has been on a global decline, due to colonialism, resource extraction, and urban expansion set into motion by the Industrial Revolution (Gómez-Baggethun et al., 2013). Industrialization, globalization, and an increasing human population, which have led to habitat loss and fragmentation, have also become tools to oppress and eradicate TEK (Gómez-Baggethun et al., 2013; Scolozzi & Geneletti, 2012). Ecosystems have been taken over by non-native species, and the once abundant native species used as historic resources are becoming scarce (Anderson, 2005; Bocek, 1984; Laurance & Yensen, 1991; Lightfoot & Parrish, 2009). In recent decades, there has been a greater global interest in conserving the resources we have left by creating environmental preserves or implementing more sustainable management practices (McKinney, 2002). Unfortunately, TEK is often developed by marginalized groups who have little to no power to advocate for its use during management planning (Usher, 2000). Given historical political injustice and the pressing need to have effective management, scientists should be motivated to incorporate sustainable, underrepresented knowledge and practices within restoration management plans.

Literature Review

TEK in California

Defining and Contextualizing TEK. Berkes' (2018) description of TEK is one of the most widely-cited and agreed upon definitions: "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (p. 8). TEK expands beyond the concept that ecological knowledge is a list of information commonly used in Western science. It specifies appropriate human behavior and incorporates human actions into a belief system based on accrued environmental knowledge. Simply put, it contextualizes humans, their needs, and the environment's needs within an ecosystem (Berkes, 2018).

It should be noted that there is not a consensus on the term's use or definition. Because *traditional* generally signifies some historic practice or belief rooted in culture, some think it is arbitrary to carve out a point in time and label previous practices as traditional (Berkes, 2018). Additionally, TEK is adaptive, and given that culture, the environment, and subsequently TEK, may change over time, the idea of adaptation within tradition appears paradoxical. As a result, some researchers prefer the term *indigenous ecological knowledge* to shift the focus to indigenous people and land they have stewarded (Berkes, 2018). Others prefer the term *local ecological knowledge*, as this includes all environmental knowledge gathered through similar diachronic means as TEK without excluding people who are not indigenous to the area (Charnley et al., 2007; Davis & Wagner, 2003). Furthermore, *ecological knowledge* is a concept rooted in Western science, and not one that all holders of traditional knowledge identify with. For example, indigenous peoples of the Canadian North hold *knowledge of the land*, in which *land* refers to the surrounding biotic and abiotic environments (Berkes, 1993). Because TEK is often practiced by marginalized or oppressed groups, there is often prejudice and resistance against incorporating the people and their knowledge into modern management (Usher, 2000). Usher (2000) defines TEK as “all types of knowledge about the environment derived from the experience and traditions of a particular group of people” to avoid any superfluous prestige values placed upon the owners or executioners of such knowledge (p. 185). Although hereafter the diachronic knowledge gathering process defined above in Berkes (2018) will be referred to as TEK, the term’s contentious standing is recognized.

Built upon qualitative observations of the environment and local people’s needs, TEK is holistic in scope and tends to be adaptive, responding to stresses and changes in the ecosystem (Berkes et al., 2000; Hoagland, 2017). The methodology behind TEK, which is carried out by members of the local groups themselves, may be incorporated into a spiritual or cosmic belief system. Through long-term trial and error practices of resource cultivation, local people build these practices that are then passed onto the next generation (Berkes, 1993). In Western science, often a researcher who is not a member of the community enters the scene to collect data, run an analysis, then return to their academic sphere to incorporate their findings into the large vault of Western scientific knowledge. Historically, this process has been viewed as more rigorous, and thus, more acceptable within the Western scientific community (Berkes, 2018). Information about natural systems and plans to regulate resource use are then based off of these culturally removed scientific experiments.

The aims of TEK are often not so different from the goals developed by Western conservationists. Many TEK practices preserve ecosystem functions and processes through methods like rotational management and cultivating mutualistic species (Berkes et al., 2000). In some cases, TEK has an advantage over the Western scientific approach. In areas where there are rare species or unique biotic communities, TEK offers background knowledge and methodology tailored to the specific environment, saving time and resources when developing management plans (Baldauf & Maës dos Santos, 2013). Oftentimes, case studies that are used to inform management policies take considerable time to complete, review, and publish (Hoagland, 2017). In the worst cases, exploited environments become increasingly degraded as studies and plans are shuffled through a bureaucratic system. To save time during policy development, researchers could consult local TEK to design more effective research methodology (Hoagland, 2017). By ignoring local and indigenous peoples who have lived off the land for generations, their intimate and specialized knowledge of the environment becomes a crucially underutilized resource.

Impact of TEK. As humans evolved, they hunted and foraged for food for hundreds of thousands of years. Archaeological findings show that there was a slow shift starting around 50,000 years ago from large game hunting to hunting a variety of smaller wildlife, namely mammals, fish, and birds. Following this transition, about 23,000 years ago, people began collecting a wider array of plants that they would later domesticate. Human population was increasing during this time and large mammals were dying out due to the end of the Ice Age and potential over-hunting by humans. 12,000 years ago, drier climates marked the beginning of the Holocene period and the development of agriculture in the Neolithic Revolution. Permanent settlements such as cities began to appear after another 7,000 years (Tauger, 2013). Societies built upon agriculture relied on domesticated plants and animals. This was a shift from previous practices of hunter-gatherers, who relied less on domestication and more on cultivating native species in their environments. Most TEK still in use today similarly relies on environmental cultivation rather than environmental domination and domestication (Berkes, 1993; Berkes et al., 2000; Tauger, 2013). TEK dates back to times before civilizations and empires, despite the term itself entering the ecological lexicon in the 1980s. It is only in the most recent decades that Western scientists have begun to realize the rigor and complexity of ecological knowledge gathered by indigenous peoples (Berkes, 1993).

Some scientists suggest that by 11,500 BCE, early peoples from Asia had traversed an above sea level land bridge at the Bering Strait and spread southward through the American continents (Tauger, 2013). Others have found archeological and geological evidence supporting the possibility of a kelp highway, a linear network of kelp forests from northeast Asia through the North Pacific to the Americas. Maritime travelers may have taken advantage of the stable climate, easy access to fresh water, and high density of food resources offered by kelp forests to reach the western North American coast by 14,000 to 13,000 BCE (Erlandson et al., 2007). By 10,000 BCE, humans had reached the southernmost tip of South America (Tauger, 2013). At the time, the American continents had fewer herding animals and wild grasses than Asia. Domesticating the land would take much longer without the aid of livestock and abundance of grassland (Tauger, 2013). Thus, it is unsurprising that as people spread across the Americas and formed complex societies, they continued to cultivate resources instead of domesticating them on the same scale as Asian and European agriculture (Sassaman, 2004).

Before the arrival of European colonists, California housed the most diverse set of tribes at the highest density when compared to the rest of the continent (Anderson, 2005; Lightfoot & Parrish, 2009). Contact with European colonizers marked the beginning of indigenous population decline due to genocide, forced relocation and assimilation, and disease. As a result, much of the ethnographic information recorded during this period reflects the views of the settlers rather than a Native American perspective (Lake, 2007). In California, most maps of tribal distribution pre-contact and from the initial time of settlement divide tribes geographically by language. However, it is estimated that there were 500 to 600 distinct sociopolitical groups of indigenous people, some of which shared a language. The true diversity and sociopolitical structure of pre-contact California is impossible to know because ethnography from this time is scarce (Anderson, 2005).

Within the United States, California has always had uniquely diverse climates, geographic features, and biotic communities. Of California’s 6,300 native plant species, one-third of them are endemic, only found in California’s soil (Anderson, 2005). This uniquely diverse land was stewarded by the many tribes who lived there. Between remnant oral history, scant ethnographic records, and archaeological findings, insight into Californian TEK has survived until today (Anderson, 2005; Cuthrell et al., 2016). Hunter-gatherer tribes tended to particular plant and animal species, using cultivation methods such as burning, coppicing, weeding, pruning, thinning, selective harvesting, and sowing for food and resource gathering (Lightfoot & Parrish, 2009). Burning, in particular, drastically changed the landscape of California by altering the structure and composition of plant communities, creating habitats for game, increasing biodiversity, and reducing the likelihood of critical fire disturbances. The historic management in California was far more nuanced and involved than practices in use today (Anderson, 2005). Several biotic communities such as valley oak savannas, coastal prairies, and montane meadows only exist due to TEK exercised before contact. TEK was integral to maintaining the level of species diversity and abundance that Native Americans relied on to sustain their populations. Once tribes were forcibly removed from their land, these areas began losing their biodiversity and abundance (Anderson, 2005).

The Anthropocene

Human-Caused Biodiversity Loss. Global biodiversity is periodically shaped through global cataclysms, and currently, humans are causing what scientists are calling the Sixth Mass Extinction (Pievani, 2014). Geologists propose that the Holocene has already ended because species extinction catalyzed by human actions in recent centuries is on par with catastrophes like asteroid strikes and volcanic super eruptions (Lewis & Maslin, 2015; Piervani, 2014). The current epoch is the Anthropocene, the age in which humans drive environmental change (Lewis & Maslin, 2015).

A significant factor in this widespread ecological degradation has been population growth, especially in the global North, where urban inhabitants use a disproportionate amount of resources (Grimmond, 2007). Urbanization and conversion of wildlands to accommodate the increasing population are threats to biodiversity, species distribution, and ecosystem functions (Scolozzi & Geneletti, 2012). More than 5% of land in the United States has been transformed into urban and other developed spaces. The Nature Conservancy, a global environmental organization focused on habitat conservation, has less land under its protection through the national and state park systems. Unlike other disturbance types, habitat loss due to urbanization is more lasting. Urban development is generally permanent and has a tendency to expand, especially through suburban sprawl (McKinney, 2002).

In the United States, more than half of all species listed as endangered by the federal government are at risk because of urbanization, specifically direct habitat loss for urban development and agriculture (Czech, 2005; Radeloff et al., 2005). Urbanization has serious harmful effects on adjacent undeveloped wildland as well, such as increased disturbance frequency, habitat fragmentation, invasive species introduction, and species diversity loss (Radeloff et al., 2005). The ecological changes caused by the wildland edge abruptly meeting development is known as the edge effect. Changes in microclimate, sunlight and wind exposure, and non-native animal encroachment due to the edge have degrading effects that ripple towards the heart of the undisturbed wildland. The smaller the wildland remnant or the more irregularly shaped it is, the stronger these negative effects impact it (Laurance & Yensen, 1991).

Following urbanization, the next greatest threat to endangered species are invasive species (Czech, 2005). Invasives are highly adaptive non-native species that spread rapidly and homogenize ecosystems by outperforming native species. In addition to reducing local biodiversity and native species abundance, much research has been done exploring how invasives impact overall ecosystem function and structure (C. E. Lee, 2002; McKinney, 2002). Invasive species and urban development are often linked, as urbanization disturbs wildlands and creates niches for invasive takeover (Czech, 2005). Previous studies have found that the number of invasive species increases closer to urban centers while the number of native species decreases (Laurance & Yensen, 1991). Approaching urban development centers, there are gradient changes such as increases in human population, road density, pollution, temperature, and other disturbance factors that aid in invasive proliferation (McKinney, 2002).

In addition to urban sprawl and non-native takeover, agricultural practices often lead to land degradation, including habitat fragmentation and biodiversity loss. Modern farming practices yield greater returns at the cost of altered vegetative composition, degraded soil and water quality, and overgrazing by livestock (Foley et al., 2005; Liu et al., 2015). Despite variation in management across different communities, humanity's current approach to food production is based upon short-term gain at the expense of long-term sustainability (Foley et al., 2011). Farmlands and pastures now make up almost 40% of the planet's ice-free terrain (Foley et al., 2005). Broken down, about 12% of the most-suitable land is allocated to crops and 26% is pastures. The remaining almost two-thirds of the Earth's terrain is unfit for farming, consisting of urban centers, deserts, tundras, mountains, ecological reserves, and other areas (Foley et al., 2011).

An Uncertain Future. Projections for the future are uncertain, yet bleak. The majority of the human population lives in urban, rather than rural, settings, and it is expected that the number of urban dwellers will continue to grow (McDonald et al., 2008). Although the population growth rate fell below 1% in 2020, the lowest rate since 1950, the population is predicted to grow from approximately 8 billion in 2022 to a peak of 10.4 billion in the 2080s

(United Nations Department of Economic and Social Affairs, Population Division, 2022). New residents will likely live in small cities within developing countries, pushing urban expansion to close the distance with protected habitats and strain ecologically sensitive environments and biodiversity (McDonald et al., 2008). The growing population's demand for natural resources will also spur increased agricultural practices, that have already been shown to have negative long-term consequences (Foley et al., 2005; McDonald et al., 2008).

Another area of concern when predicting future environmental health is climate change, as its reach extends to areas that are untouched and undisturbed by humans (Malcolm et al., 2006). Many plant species will not migrate to higher elevations or latitudes faster than the increasing global temperature. Those left behind will have to adjust rapidly to the new climate, or die out. Fragmented habitats are particularly vulnerable, and many plant species may undergo genetic alterations. Community structures will experience unpredictable shifts in composition and species abundance and may be less equipped to handle future disturbances. Ultimately, scientists are concerned at the increased likelihood of wide-spread extinction (Jump & Peñuelas, 2005).

Contemporary Management and Environmental Justice

Adaptive Management and TEK. Because species diversity increases as the area of habitat preservation increases, there is an interest in maximizing the amount of preserved land during habitat restoration. Fencing off remnant land is a common and inexpensive way to encourage native biodiversity, although these areas still remain vulnerable to invasion (McKinney, 2002). In some cases, the creation of these preservations displaces locals who were practicing TEK or cuts off access to historic resources (Gómez-Baggethun et al., 2013).

In recent decades, movements for more active habitat restoration have been gaining popularity in America. Starting from the 1970s, there has been greater interest in management that connects people with nature (Eden et al., 1999). More involved methods of restoration involve hands-on human management, in which native plants are cultivated and invasives removed (McKinney, 2002). The ideal goal of environmental restoration is to return to ecosystem composition and function that existed pre-human disturbance. More realistically, most management goals aim to improve an ecosystem or a particular component of an ecosystem or to establish natural recovery (Eden et al., 1999).

Conventional management practices often lack adaptive capabilities and cannot handle unstable ecosystems (Berkes et al., 2000). Adaptability has become increasingly important given projected future environmental stressors, so a recommended approach is to apply adaptive management. A basic assumption in adaptive management is recognizing that humans have a poor grasp of the complexity of ecological systems. As a result, adaptive management uses learning and observation to build its foundation. By first identifying gaps in human ecological knowledge, practices that test these uncertainties are carried out early on. This is an alternative to more conventional management that establishes end goals and practices before experimenting on or understanding the local system. Adaptive management seeks to modify human behavior to effectively steward the land and promote naturally occurring functions by essentially relying on trial and error, making it time-consuming. In many practical instances, adaptive management is not feasible (K. Lee, 1999).

Politically, adaptive management also allows for the restoration process to become more democratic. Having multiple stakeholder participation in developing and maintaining the management plan better captures the needs of a particular socio-environmental system. Institutional support that encourages feedback from all stakeholders not only adapts the environmental plan to suit the relevant circumstances, but also gives potentially marginalized groups a chance to voice their needs and concerns (Stringer et al., 2006).

Ecological Responsibility and Justice in Reintroducing TEK. In recent decades, there has been a rising interest in integrating TEK in modern management, as collaborations have led to successful data gathering while respecting cultural norms and boundaries (Berkes, 2018; Hoagland 2017). TEK is gathered diachronically, fulfilling one of the most difficult requirements of adaptive management. Furthermore, TEK generally does not aim for domination over nature, but rather to sustainably fit humans within the ecosphere (Berkes, 1993, 2000). For example, after decades of aggressive fire suppression in California on top of the warmer and drier climate, wildfires in the state reached catastrophic levels (Miller et al., 2020). Fire suppression policy and attitudes also greatly limited the extent to which Native Americans could cultivate and manage vegetation on public lands (Hunter, 1988). However, in recent years, the prescribed burns that were practiced by Californian Native Americans have been introduced as part of the fuel management regime to reduce the frequency and intensity of wildfires (Miller et al., 2020).

Historically, Western literature states that TEK is based on cultural, political, and geographical contexts, whereas Western knowledge is gathered through systematic, rigorous, and objective methods. However, many Western scholars recognize the myth of objectivity in Western scientific methods, as researchers develop their hypotheses and methods based off of their own learned observations and scientific lenses (Agrawal, 1995; Bernard, 2011).

Other researchers go further and challenge the dichotomy between Western science and TEK, noting that both are sensitive to the particular cultural and political context during which they developed (Agrawal, 1995).

Delegitimizing TEK as a valid form of ecological knowledge further pushes the agenda of recognition injustice, as defined by Walker (2009). Supporting the practicing and continuation of TEK through institutional means has two benefits. First, incorporating TEK practitioners into land management, especially when they are local stakeholders, sets up practices that will be environmentally and culturally sensitive, ensuring more effective restoration. Second, to be able to practice TEK and pass it on to the next generation establishes and validates social institutions (Ruddle, 1993). Step by step, environmental degradation and historic marginalization can be addressed through the reintroduction of TEK.

The Muwekma Ohlone Tribe of the San Francisco Bay Area

Ohlone TEK. Prior to the arrival of Spanish colonialists in California, the central coast of California was home to a dense variety of landscapes and peoples (Lightfoot & Parrish, 2009). Ancestors of the Muwekma Ohlone Tribe occupied and managed the land around the San Francisco Bay Area, an area with 13 different plant communities (Bocek, 1984; Field & Muwekma Ohlone Tribe, 2003). They cultivated riparian zones to gather food, medicine, and building materials while supporting ecological diversity and structure (Bocek, 1984; Lightfoot & Parrish, 2009). The cultivation of these resources was regulated through controlled burns, creating open spaces for wild game, encouraging growth of resources, and decreasing wildfire risk by reducing duff and undergrowth (Lightfoot & Parrish, 2009).

The Alameda Creek watershed was one such area that was occupied by Muwekma Ohlone ancestors and once abundant with resources (Stanford et al., 2013). Plants were collected from land and water of the Alameda Creek watershed for food, medicinal uses, basketry, and construction. For example, acorns from oak (*Quercus* spp. L.) trees were eaten, fever remedies were made from red willow (*Salix laevigata* Bebb) bark, salt was collected from a variety of seaweeds (*Porphyra* spp. C. A. Agardh), and sedge (*Carex* spp. L.) roots were used in basketry (Bocek, 1984; Lightfoot & Parrish, 2009). Many communities lived by the waterfront in the summer and then retreated inland, generally to higher elevations during the rainy season. Housing structures adapted to the location and seasonality: brush huts and open ramadas were erected by the water while enclosed tule (*Schoenoplectus* spp. (Rchb.) Palla) or bark houses were built further inland. Redwood (*Sequoia sempervirens* (Lamb. ex D. Don) Endl.) was commonly used for bark-made structures with grass thatching. Those who lived near rivers tended to use tule instead of grass for thatching (Lightfoot & Parrish, 2009).

After the introduction of non-native and invasive plants by European colonists, Ohlone TEK adapted to accommodate them. Several non-native species were gathered and incorporated into their building practices, medicine, and diet. The stems of the invasive redstem filaree (*Erodium cicutarium* (L.) L'Hér. ex Aiton) were eaten, and a typhoid fever remedy was brewed from its leaves. The roots of the non-native broadleaf plantain (*Plantago major* L.) were used to make a fever-reducing remedy and constipation remedy (Bocek, 1984).

Current Status of the Muwekma Ohlone. Pre-contact, the Ohlone peoples in the San Francisco Bay Area lived in complex, culturally diverse groups who spoke related languages (Leventhal et al., 1994; Milliken et al., 2009). It was estimated that there were upwards to 20,000 Ohlone people in 1769. The Spanish expanded their occupation in the middle of the 18th century and established seven missions within the greater Ohlone/Costanoan speaking region between 1770 and 1800. This began a long era of disease, displacement, and persecution (Bocek, 1984; Milliken, 1995). The Spanish colonists set out to missionize the Ohlone, and the oppression came in stages. Ohlone ways of life were initially restricted, then banned, and ultimately destroyed. Cultural and religious practices were forcibly abandoned as the Ohlone people became laborers for the growing agricultural economy based on European practices. Due to poor living conditions and abuse, the population plummeted (Leventhal et al., 1994; Milliken et al., 2009). By 1820, there were fewer than 2,000 individuals left (Bocek, 1984).

Although the efforts to forcibly drive the Ohlone off their land began with the Spanish Empire's military and missionaries during the late 18th century, American federal and state governments continued the oppression from the mid-1800s onward (Field & Muwekma Ohlone Tribe, 2003). California was added as a state to the United States in 1850, and Manifest Destiny now extended to the west coast. In the Bay Area, historic Ohlone lands were passed on to newly arriving white Americans. In the latter half of the 19th century, many displaced and intermarried ex-mission Ohlone, Yokut, and Miwok families gathered together to live at Alisal Rancheria, which was located near Pleasanton's agricultural lands. They also sought refuge at other neighboring rancherias in Niles, Livermore, Sunol, San

Leandro, and San Lorenzo (Leventhal et al., 2017). The Muwekma Ohlone tribal members alive today are descendants of those who resided at Alisal Rancheria and other rancherias (Leventhal et al., 1994).

Members of the Muwekma Ohlone Tribe appeared on the Federal Indian Censuses and became federally recognized as the Verona Band of Alameda County by the U.S. Department of the Interior (DOI) through the Congressional Appropriation Acts for Landless California Indians in 1906, 1908, and later years, as well as other federal actions under Special Indian Agent Charles E. Kelsey beginning in 1906 (Field et al., 2013; Muwekma Ohlone Tribe v. Babbitt, 2001). In 1927, however, the Tribe was removed from the list of eligible tribes awaiting land purchase by the Superintendent of the Sacramento Agency along with 134 other tribes and bands without any formal notice, site visitation, or needs assessment. Nonetheless, Muwekma families enrolled with the Bureau of Indian Affairs (BIA) between 1929 and 1932 under the 1928 California Indian Jurisdictional Act. Children were sent to Indian boarding schools in the 1930s-1940s and enrolled again with the BIA in the 1950s, 1960s, and 1970s as part of the claims settlement over the loss of California. In 1962, the Tribe came together to prevent the destruction of the Ohlone Indian Cemetery, located near Mission San Jose, which contained the remains of over 4,000 Native Americans, some within living memory of their families (Leventhal et al., 2017; Levy, 1978; Milliken et al., 2009).

In 1980, the Tribe began formally organizing their tribal council, and in 1989, the Tribe once again started the process to regain their federally recognized status, a process that is ongoing to this day (Muwekma Ohlone Tribe v. Babbitt, 2001; Slagle et al., 1995). Due to the failure of the Office of Federal Recognition not to fully review the Tribe's submitted documentation or weigh any evidence, the Muwekma Ohlone Tribe has not yet regained its federally acknowledged status. Therefore, they have not been able to reclaim the lands and benefits owed to them by the state (Field & Muwekma Ohlone Tribe, 2003; Field et al., 2013; Field et al., 2014; Leventhal et al., 2017; Muwekma Ohlone Tribe v. Babbitt, 2001; Slagle et al. 1995). A consequence of withholding rightful restoration of their status has been the lack of land on which the Tribe can continue to reacquaint, practice, and pass on their TEK to the next generation.

Problem Statement

Riparian ecosystems are some of the most biologically diverse habitats in the world, home to a variety of plants and wildlife (Naiman et al., 1993). Riparian corridors in particular allow free movement of plants and animals between undeveloped regions, and plant species that might have otherwise been outcompeted as seedlings or left unpollinated can proliferate. In turn, high levels of biodiversity protect the overall sustainability of an ecosystem and prevent local extinction (Damschen et al., 2006). In addition to being a hotspot of biodiversity, riparian areas improve water quality, regulate temperature, and provide nutrients and structural support to the soil (Naiman et al., 1993). However, over the last several centuries there has been a decline in riparian ecosystem presence and structure. As a result of settler colonialism and subsequent urbanization, it is estimated that over 90% of the riparian ecosystems in California have been degraded, altered, or lost entirely. Riparian corridors, which are thoroughfares for at-risk wildlife and vestigial hosts of biodiversity, have been fragmented by urban expansion. Many corridors have been channelized or manipulated for power generation, agriculture, and drainages (National Research Council, 2002).

There is great interest in riparian restoration, and modern researchers are focusing on restoring entire corridors, as past conservation attempts only targeted one plant community or wildlife species (Capon et al., 2013; Harris, 1999). Although there is some disagreement amongst researchers about riparian zones' ability to handle stress caused by climate change, adaptive management has been proposed as the most effective plan of action in the face of uncertain futures (Capon et al., 2013). Previous studies have found that a complex matrix of environmental characteristics, including corridor width, ecological connectivity, catchment position, soil properties, and surrounding anthropogenic uses, have an impact on biodiversity (Ives et al., 2011). Since the early 20th century, the San Francisco Public Utilities Commission (SFPUC) has purchased land within the Alameda Creek watershed with the aim of delivering water to the City of San Francisco. During this process, they have also undertaken restoration and education projects. One such project under development is the Alameda Creek Watershed Center, a center illustrating the watershed's ecological function, importance, and history. The Muwekma Ohlone Tribe has recently partnered with the SFPUC on this project in order to incorporate an exhibit on the Tribe's recovered archaeological heritage site *Síi Tíúupentak* [Place of the Water Round House Site] (CA-ALA-565/H) and history (B. F. Byrd, Engbring, & Darcangelo, 2020).

To contextualize their TEK practices and create an herbarium for the Center, the Tribe sought to discover the current abundance and distribution of historic plant resources that were used by their ancestors. Furthermore, there was interest in understanding how urbanization around the corridor may have influenced resource, native, and invasive plant distribution. Studies on the terrestrial ecosystems in the watershed have looked at projected habitat loss and degradation due to urbanization (K. B. Byrd et al., 2015), reconstructed historical ecological communities (Stanford et al., 2013), and documented rare plants (Nomad Ecology, 2012). However, prior to this research, there had been no plant surveys done on riparian corridors within the watershed focused on plant distribution and influential environmental factors.

Positionality and Project Impact

This thesis was a collaboration between the Muwekma Ohlone Tribe, the SFPUC, and myself. Through their partnership with the SFPUC, the Tribe has multiple ongoing cultural projects and opportunities to learn more about ancestral lands in Alameda County. This project, a vegetation survey with a focus on historic resource species, was the first of its kind for the Tribe. Although I am not a member of the Tribe, my background in the environmental science through San José State University provided me with the resources necessary to develop and execute a vegetation survey. The Tribe hired me as a Tribal Ecologist so that they could effectively support me as I designed this thesis and share ideas and findings throughout the process. After being appointed as a Tribal Ecologist, I gained access to historic Ohlone land and was able to meet and work with employees of the SFPUC, who were familiar with the land in its present state.

As the Tribe uses the survey results to revitalize their knowledge about plant identification and plant uses, they can refamiliarize with their TEK and homeland. The results of this study are a starting point in creating a catalogue of plant resources that can be found within the Alameda watershed. Additionally, by knowing where resources are currently growing, the Tribe will be able to more easily identify, harvest, or cultivate them moving forward. This study will also hopefully encourage more collaborations between the Tribe and landowners on ecological projects and encourage acknowledgement of Ohlone TEK and stewardship as they develop the Muwekma Ohlone Preservation Foundation's Land Trust.

Objectives

The purpose of this research was to characterize the vegetation currently present in a riparian corridor that lies within ancestral Ohlone lands, and to discover any patterns in species distribution related to different anthropogenic land uses, natural environmental characteristics, or the presence of non-natives.

Research Questions and Hypotheses

- RQ1: What current plant resources (both native and non-native) currently exist in a riparian corridor within ancestral Ohlone lands?
- RQ2: Are there variations in vegetation between the different anthropogenic land uses (undisturbed, restored, grazed, and road)?
- RQ2a: Are there variations in species presence (total, resource, native resource, native, and non-native species) between different anthropogenic land uses?
    - $H_0$2a: There are no variations in species presence between different anthropogenic land uses.
- RQ2b: Are there variations in canopy cover, ground cover, grass cover, and clover cover between different anthropogenic land uses?

  - $H_0$2b: There are no variations in canopy cover, ground cover, grass cover, and clover cover between different anthropogenic land uses.
- RQ3: Are there relationships between resource, native, and non-native species presence and environmental characteristics (geological transect subsection, canopy cover, slope, ground cover, length, grass cover, clover cover and aspect)?
  - $H_0$3a: There are no correlations between resource, native, and non-native species presence and geological transect subsection, canopy cover, slope, ground cover, length, grass cover, and clover cover.
  - $H_0$3b: There are no variations in resource, native, and non-native species presence across different aspects (northeast, southeast, southwest, and northwest).
- RQ4: Are there relationships between resource, native, and non-native species presence?
  - $H_0$4: There are no relationships between resource, native, and non-native species.

Methods

Study Site

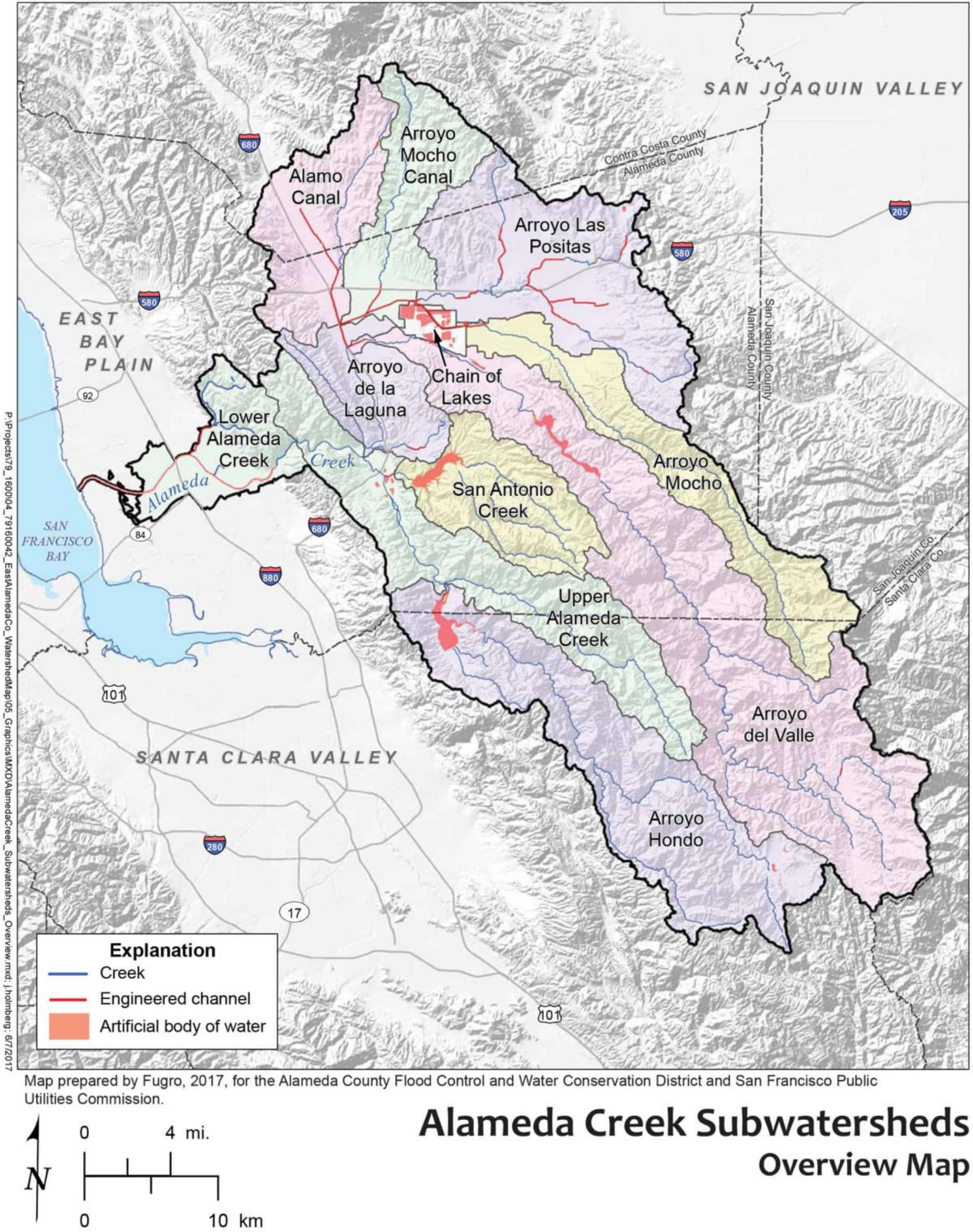
The Alameda Creek watershed covers approximately 1813 square km over Alameda County, Santa Clara County, and Contra Costa County in the Bay Area of California (Stanford et al., 2013; United States Geological Survey & California Department of Water Resources, 1964; Figure 1). Starting at the water's edge of the San Francisco Bay, the land is dominated by marshes, ponds, and sloughs. Travelling inland, there are alkali pools and meadows and then grasslands and wet meadows. Today, the primary use of the watershed is for water capture, storage, and delivery to residential areas. The most prevalent land uses within the watershed are livestock grazing and urbanization, both of which impact native vegetation abundance. Livestock were introduced to the watershed by European colonialists in the 1700s, and have been present to this day (Stanford et al., 2013).

Alameda Creek is about 72 km long, and its source lies approximately 5.6 km northeast of Mount Hamilton on Eylar Mountain (37°23'16"N 121°36'44"W). It runs through two counties: Alameda County and Santa Clara County (Stanford et al., 2013). Originally, it drained into the San Francisco Bay at 37°34'57"N 122°08'36"W. However, the creation of a flood control channel shifted the location of the mouth slightly south to 37°35'40"N 122°08'49"W (United States Geological Survey, 1981a).

The water within the Alameda Creek is supplied from two major drainages that are located within the cities of Livermore and Sunol. The Livermore drainage basin is the largest geographically and lies in the northern and eastern sections of the watershed. It contains about two-thirds of watershed land, supplying approximately one third of the run-off. The

Figure 1

Map of the Alameda Creek Watershed in the California Bay Area



Map prepared by Fugro, 2017, for the Alameda County Flood Control and Water Conservation District and San Francisco Public Utilities Commission.

Note. The black border outlines the Alameda Creek watershed, and subwatersheds are indicated with various colors. Use permitted by Alameda County Flood Control & Water Conservation District (2017).

second major drainage basin within the Alameda Creek watershed is the Sunol drainage basin. The Sunol drainage basin contains about one-third of watershed land and supplies approximately two-thirds of the run-off (United States Geological Survey & California Department of Water Resources, 1964). Of the many waterways that feed into Alameda Creek, Arroyo de la Laguna is one of the main tributaries (Figure 1). Arroyo de la Laguna is fed by naturally formed tributaries and channels constructed in the 1900s in the city of Pleasanton (Stanford et al., 2013). Its source is at 37°40’36”N 121°54’44”W in Pleasanton, and it joins Alameda at 37°35’17”N, 121°53’28”W in Sunol (United States Geological Survey, 1981b).

The region has semi-arid Mediterranean climate, and precipitation varies from year to year. Most rainfall occurs during the interval from October through April, with hilly areas receiving about 50-76 cm and lowlands receiving less than 41 cm a year on average (Stanford et al., 2013). Pleasanton, which lies along Sunol’s northern border, has recorded average maximum temperatures of around 32ºC in July with daily extremes reaching 38ºC. Average minimum temperatures in December are around 3ºC, with extreme lows falling below freezing (The City of Pleasanton, 2013). Much of the watershed runs dry in the summer. However, there is perennial flow in the two creeks that lie within the study site, Arroyo de la Laguna and Alameda Creek (Stanford et al., 2013).

Records from the time of contact show that Native Americans lived in a series of villages throughout the watershed and spoke Chochenyo Ohlone, one of the dialects of the ancestral Bay Area Muwekma Ohlone. Although there are sparse written records of TEK practices in the area, accounts from the early 1800s from European settlers depict indigenous burning, indicating that TEK management had been influencing local species distribution for generations (Stanford et al., 2013).

The study site is the riparian corridor bordering Arroyo de la Laguna and Alameda Creek. The site's northernmost point (N 37° 37.607' W 121° 52.961') lies on Arroyo de la Laguna in Verona, a residential community on the border of the city of Pleasanton (Figure 2). The creek and corridor then run south through Sunol, a small unincorporated town in Alameda County. Sunol has a predominantly white (84.5%) population of around 900 inhabitants (United States Census Bureau, 2018). At Sunol's southern edge, the Arroyo de la Laguna and its corridor turn west, joining Alameda Creek. The site's furthest western point (37°35'34"N 121°54'1"W) lies on Alameda Creek. The southernmost point (37°32'20"N 121°51'22"W) is upstream in Alameda Creek, before Arroyo de la Laguna joins it.

Accounts by missionaries in the 1770s mention that parts of Sunol was dominated by oak (*Quercus* spp.) savanna and grassland, where oak cover was notably sparse. Records from the next hundred years indicate that most of the oaks were cut down by the end of the 1800s. Where the land narrowed and vegetation became more densely packed, the corridor became a mixed riparian forest and contained additional tree species such as alders (*Alnus* spp. Mill.), willows (*Salix* spp. L.), and California sycamores (*Platanus racemose* Nutt.). Further south, cottonwoods (*Populus* spp. L.), sycamores, and various oaks joined the willows alongside the water (Stanford et al., 2013). Within the sampling site, Alameda Creek's corridor contains both savannas and mixed riparian forests. In the 1800s, upstream Arroyo de la Laguna was described as having a heavy flow and lined by dense willow thickets (Stanford et al., 2013).

Figure 2

Study Site: The Riparian Corridor Bordering Alameda Creek and Arroyo de la Laguna

Note. Study site of the riparian corridor within the Alameda Creek watershed indicated by yellow border. Accessed 2/1/2022 (Google, n.d.).

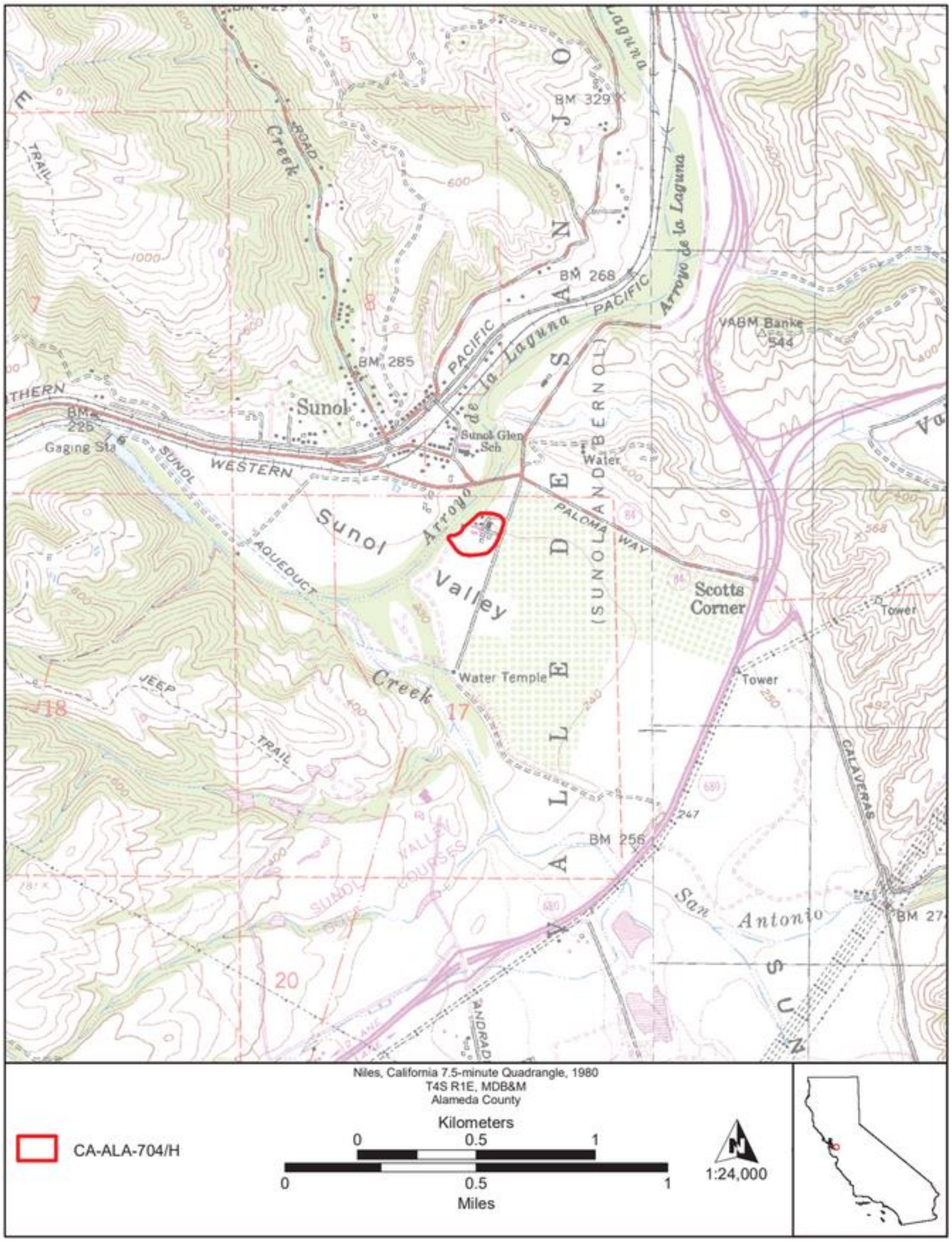
The site captures this section of the corridor along Arroyo de la Laguna that is lined with willow-dominated thickets.

Today, the riparian corridor is owned by the San Francisco Public Utilities Commission (SFPUC) and is fenced off from the public. It is unclear exactly when public access of the area was restricted. Spring Valley Water Company previously owned parts of the site around Sunol and was diverting water from Alameda Creek to San Francisco. The SFPUC purchased the Spring Valley Water Company and its land in 1930 (Hanson et al., 2005). Fences would have been erected as soon as the SFPUC bought the land if there were no barriers already in place.

Motivation to choose this section of the creeks for study came from the Muwekma Ohlone Tribe. Ohlone remains were discovered near the confluence of Arroyo de la Laguna and Alameda Creek at their ancestral heritage site *Rummey Ta Kuččuwiš Tiprectak* [Place of the Stream of the Lagoon Site] (CA-ALA-704) (Figure 3). In addition to being ancestral lands, the site is adjacent to the Alameda Creek Watershed Center, which is being built adjacent to the Water Temple in Sunol.

Figure 3

Pre-Contact Ancestral Muwekma Ohlone Burial Site in Sunol



Note. The pre-contact burial site *Rummey Ta Kuččuwiš Tiprectak* [Place of the Stream of the Lagoon Site] (CA-ALA-704), which was found near the Sunol Water Temple and sits just west of the currently under-construction Watershed Center. Use permitted by B. F. Byrd, Engbring, & Darcangelo (2020).

Study Design

Based off of the recommendation of SFPUC employees, there were six primary access points from which samples were taken along the two creeks. To understand the current distribution of species in the watershed, vegetation surveys were conducted in randomly placed meter-wide transects that ran perpendicular from the water's edge. Within each transect, the number of all species present was recorded along with environmental characteristics and the type of anthropogenic land use. After data collection, statistical tests were used to determine whether there were differences between species presence or cover between various land use types or if there were any relationships between species presence and environmental characteristics or between different types of species.

Past research has indicated that urban development near wild areas has significant negative effects on the wild ecosystems, including increasing extinction rates of native species and introducing non-native weeds (McKinney, 2002; Radeloff et al., 2005). The different types of anthropogenic land use were classified into four categories, which are based on the categorizations of habitat replacements in McKinney (2002) and the management practices by the SFPUC (Table 1).

The corridor is not accessible to the public and is fenced off within the limits of Sunol. The only people who are permitted to enter the study site are SFPUC employees, park rangers, and permit holders.

From 2010 to 2011, the SFPUC started a restoration project along a section of the Arroyo de la Laguna. This included bank stabilization through in-channel structures, which prevented erosion and created habitat diversity in the stream, and native species planting. A

Table 1

Anthropogenic Land Use Types of the Sampled Transects

Land Use Type	Description
Undisturbed	Infrequent human foot traffic
Restored	Bank stabilization and vegetation management
Grazed	Cow pasture
Road	Unpaved seasonal service road

total of 16 different native tree, shrub, and herbaceous species were planted, with replacement plantings of a total of seven species in the winters of 2011-2015. The restored area was a total of 0.47 ha and 152.4 m (Alameda County Resource Conservation District & Natural Resources Conservation Service, 2021a, 2021b). In addition to the project, further restoration was done through weeding whacking, seed head bagging, and species removal along the banks of the Arroyo de la Laguna in June 2020. Targeted species included *Ailanthus altissima* (Mill.) Swingle, *Arundo donax* L., *Ficus carica* L., *Centaurea solstitialis* L., *Hirschfeldia incana* (L.) Lagr.-Foss., *Conium maculatum* L., *Stipa miliacea* (L.) Hoover var. *miliacea*, *Phalaris aquatica* L., and annual grasses, amongst others. The weeded areas include the restoration project site. All samples taken from areas with bank stabilizing, tree planting, or weeding were categorized as restored.

Data Collection

Data was collected in April and May of 2021. Samples were taken from 30 meter-wide transects. Transects were of variable length, beginning at the water's edge and running perpendicular to the creek to the corridor's edge (Russell & Terada, 2009). The corridor's edge was determined by a change in vegetation, a transition usually from riparian vegetation to the dominant ecosystem of the area observed in the upland. When there was no natural edge to the corridor, the upland segment was ended after 5 m. Based on changes soil, slope, and vegetation, each transect was divided into geographical subsections: floodplain, valley wall, and upland. The subsections were numbered ordinally, increasing in number the further they were from the water. The length of each geophysical subsection was recorded.

For a baseline survey conducted in an area where there are no known variables affecting species distribution, unbiased randomization is recommended (Rew et al., 2006). The initial transect was randomly selected, and subsequent transects were selected from within the site using field randomization techniques (Lazzeri-Aerts, 2011). Transects were a minimum of 5 m apart from one another (Russell & Terada, 2009).

The land use type of each transect was noted (*Table 1*). Within each transect subsection, each species and was identified and the number of individuals recorded. Unknown species were given a unique identification number. Percent covers were recorded for grasses and clovers, and they were not included in the total species count. The following features were also recorded for each geographical subsection:

- Percent ground cover recorded using ocular estimates (Russell & Terada, 2009);
- Canopy cover recorded from the center of the transect using a spherical densiometer (Korhonen et al., 2006);
- Slope recorded from the center of the transect using a clinometer;
- Aspect recorded once for each transect from the center of the transect at the water's edge (Lyon & Gross, 2005).

Data Analysis

A list was made of all identified species, and each species was catalogued as either native or non-native and resource or non-resource. Native status was determined by whether the plant was native to California or not. Plants were marked as resources if there was literature that indicated plant use by Muwekma Ohlone ancestors or general use by Californian Native Americans (Anderson, 2005; Bocek, 1984; Lightfoot & Parrish, 2009; Peralto et al., 2008). For plants that could not be identified to the species level, they were identified to the genus or family level. These plants were categorized as native, non-native, resource or non-resource based on the species of those genus or family previously observed in the watershed by Nomad Ecology (2012).

The following descriptive statistics were calculated for each species on the identified plant list using Microsoft Excel. The mean count, mean density, and mean dominance for all species were calculated. Count (#/subsection) was defined at the number of individuals of a species per transect subsection. Density (count/m^2) was the count of the species divided by the area for each subsection. Dominance (species count/total count) was the count of the species divided by the total count of all of the species for each subsection. Bar graphs were made using Microsoft Excel.

Five species groups (total species count, resource species count, native species count, native resource count, and non-native species count) were tallied in terms of richness and abundance per transect subsection. Richness is the number of difference species per sample, and abundance is the total number of individual plants counted per sample. Density and dominance of these five species groups were calculated per transect subsection for both species richness and abundance. Unknown species were omitted for these calculations.

The following statistical tests were performed using IBM SPSS (Statistical Package for the Social Sciences) (version 28). Alpha equaled 0.05 for all tests. The Kruskal-Wallis test was used to compare the distributions of native resource, native, resource, and non-native species for count, density, and dominance of richness and abundance. For each significant result, Dunn's post hoc test with the Bonferroni adjustment was used to determine which species category (native resource, native, resource, and non-native) distributions differed from one another. The Kruskal-Wallis test was also used to determine whether there were differences in species presence (count, density, and dominance of the richness and abundance of the five species groups listed above) between different land use types. Dunn's post hoc test with the Bonferroni adjustment was run on each land use pair to determine which pairs had significantly different species presence. Similarly, the Kruskal-Wallis test was used to compare canopy, ground, grass, and clover cover between land use types. Dunn's post hoc test with the Bonferroni adjustment was run again for each land use pair. The graphs for these analyses were made using SPSS.

A two-tailed Spearman's rank correlation coefficient was used to check the relationship between geological features (canopy cover, ground cover, slope, and geological transect subsection) and species presence. Aspect, which was measured in degrees, was sorted into four directional categories: northeast (1°-90°), southeast (91°-180°), southwest (181°-270°), and northwest (271°-360°). A Kruskal-Wallis test was run to determine whether there were differences in species presence across the four directional categories.

Spearman’s correlation was used to test the relationship between non-native species presence and total, resource, native, and native resource species presence.

Limitations

The list of historic resources and their uses presented in the following sections were gathered through a review of Western academic literature. Descriptions of historical Ohlone TEK were gathered from an outsider’s perspective, as opposed to being learn from a Tribal member or practitioner.

Due to timeline and resource constraints, there were restrictions on the scale of the study site and sampling. The vegetation survey only covers a small section of the riparian corridor that runs along Alameda Creek and Arroyo de la Laguna. The resulting species list is representative of the corridor for the entirety of the creek and ecosystems it runs though. This restriction is partly due to the Tribe’s localized interest in the area around Sunol, as it is near the Watershed Center and Muwekma ancestral heritage sites: *’Ayttakiš ’Éete Hiramwiš Trépam-tak* [Place of Woman Sleeping Under the Pipe Site] (CA-ALA-677); *Rummey Ta Kuččuwiš Tiprectak* [Place of the Stream of the Lagoon Site] (CA-ALA-704); and *Síi Túupentak* [Place of the Water Round House Site] (CA-ALA-565) (B. F. Byrd, Engbring, & Darcangelo, 2020; B. F. Byrd, Engbring, Darcangelo, & Ruby, 2020; Leventhal et al., 2017). Furthermore, data could only be collected from SFPUC-owned land, in which there were limited entry points with access to the corridor.

Information on soil was not collected during the survey. Soil texture and moisture have a relationship with species richness (Box & Fujiwara, 2011; Ives et al., 2011). The survey does not take into account changes in soil type or how it may correlate with species presence.

The survey was conducted in the spring. Plants that flower during other times of the year may have been missed during the survey. Several plants, like mustards (*Brassicaceae* Burnett) and docks (*Rumex* spp. L.), had not yet flowered during the time of data collection, making identification down to the species level difficult and impractical.

Erodium cicutarium and *Erodium botrys* (Cav.) Bertol. were both present during sampling, though it was oftentimes difficult to distinguish between the two of them. For consistency and accuracy, all instances of both plants were counted under the label *Erodium* spp. L'Hér. ex Aiton and categorized as a non-native non-resource species during statistical data analysis. However, *E. cicutarium* was adopted as a non-native resource by Muwekma ancestors, so its uses were listed despite its abundance being unknown.

Additionally, there was not enough time or resources to identify most grass and clover species, and only recorded percent cover for both. In previous pilot study of the upland areas of Alameda watershed, Stanford et al. (2013) found the European annual grasses and invasive weeds brought by Spanish colonists have replaced native bunchgrasses and herbaceous species and continue to dominate the landscape to this day. Metrics on species richness and abundance do not fully capture the breakdown of native and non-native species presence because of these limitations.

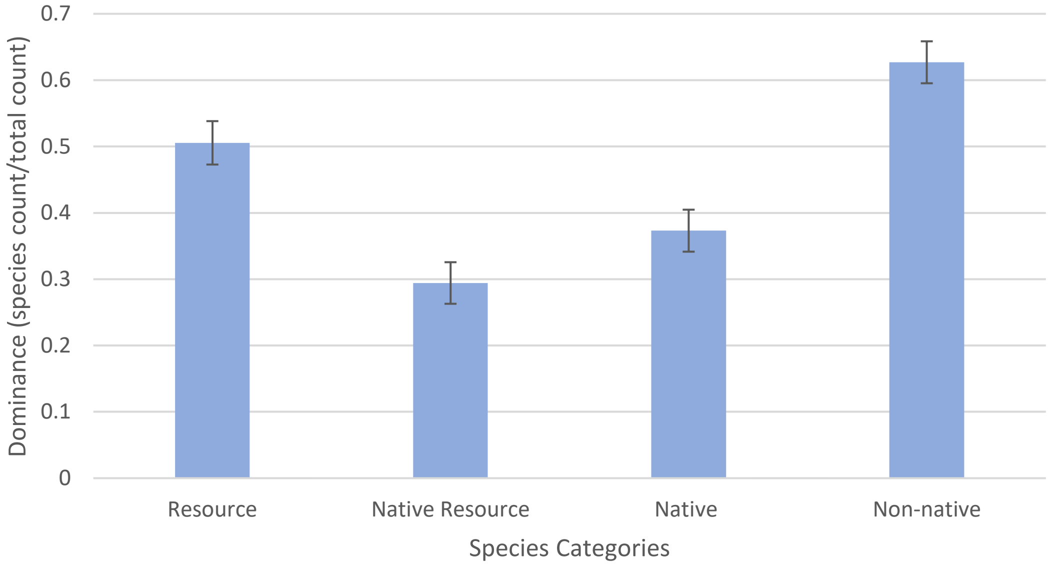
Results

Fifty-four species were identified during the vegetation survey: 25 native resources, three non-native resources, seven native non-resource species, and 19 non-native non-resource species (see Appendix A). Based on average count, density, and dominance, *Galium* spp. L. was the most abundant native resource (count = 12.398, density = 2.919, dominance = 0.061). The most common non-native resource was *Brassicaceae* (count = 21.398, density = 4.680, dominance = 0.209). The most common native non-resource species was *Cardamine oligosperma* Nutt. (count = 6.735, density = 1.790, dominance = 0.073). Unlike the other species categories, two species were measured as the most common non-native non-resource species. For count and density, *Erodium* spp. (count = 25.470, density = 5.216) was the most abundant species. For dominance, *Conium maculatum* (dominance = 0.109) was the most abundant.

The results of the Kruskal-Wallis test showed that the count, density, and dominance distributions of resource, native resource, native, and non-native species were significantly different from one another for both richness and abundance. Dunn's post-hoc pairwise comparisons revealed that, most often, the distribution of native resources differed from those of resource and non-native species. Native resource species richness count was significantly less than non-native and resource species richness count. Native resource richness density was found to be less than non-native richness density. For richness dominance, native resources were less than both resource and non-native species, while native species were less than non-native species. Abundance count and abundance density followed a similar pattern: native resource distribution was significantly lower than resource and non-native distribution, and native species distribution was lower than non-native species distribution. Abundance dominance had the greatest number of differences in distribution; native resource species and native species were both significantly less than resource and non-native species (Figure 4).

Figure 4

Mean Abundance Dominance of Species Categories with Standard Error Bars



Note. Native resource species abundance dominance distribution was less than that of resource (p = <0.001) and non-native (p = <0.001) species abundance dominance. Similarly, native species abundance dominance was less than resource (p = 0.035) and non-native (p = <0.001) species abundance dominance.

Twenty-nine historical resources were identified, 25 of which were native and four non-native (see Appendix B). The uses of the observed resources ranged from food, medicine, tools, basketry, clothing, construction, instruments, and ceremonial materials (Anderson, 2005; Bocek, 1984; Lightfoot & Parrish, 2009; Peralto et al., 2008). As previously mentioned, although the abundance of *Erodium cicutarium* is unknown, it was seen in several samples, so its historical use was provided.

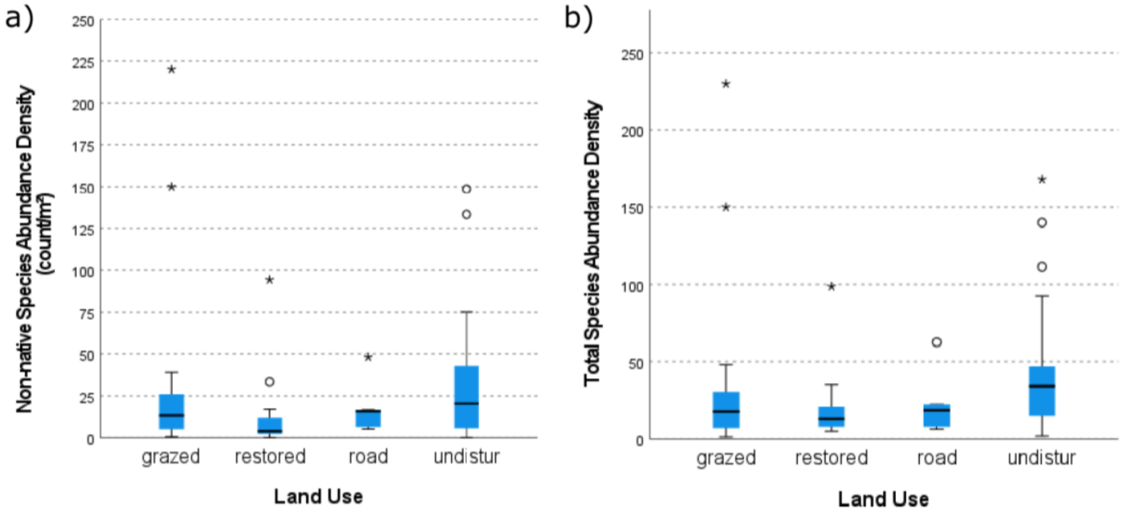
Through the Kruskal-Wallis test, 13 of the 28 species measurements were found to have significant differences when compared across land use types (see Appendix C). Eight of those 13 species measurements were related to native species, three were related to non-native species, and two were related to the total of all species. Resource species richness and abundance, which includes both native and non-native resources, were not statistically significantly different across land use types.

Dunn’s post hoc pairwise comparisons were run for every species measurement that exhibited a statistically significant difference. Except for non-native and total species abundance density, which both found a difference between restored and undisturbed land (Figure 5), all statistically significantly different pairwise comparisons were between grazed land and restored or undisturbed land. Grazed land had different native resource richness count, native species richness count, native species richness density, native species richness dominance, and non-native species richness dominance when compared to both undisturbed and restored land (Figure 6). Grazed and restored land had significantly different native species abundance dominance and non-native species abundance dominance (Figure 7a-b). Grazed and undisturbed land had different native resource richness density, native species abundance count, and native species abundance density (Figure 7c-e).

The distributions of total species richness, native resource richness, and native species richness were lowest in grazed areas. Non-native species richness dominance distribution was highest in grazed areas. In terms of species abundance, grazed land had the lowest native species distribution and the highest non-native species dominance distribution. Although the Kruskal-Wallis found that total species richness count differed across land use types, Dunn’s

Figure 5

Abundance Densities that Differ between Restored and Undisturbed Areas



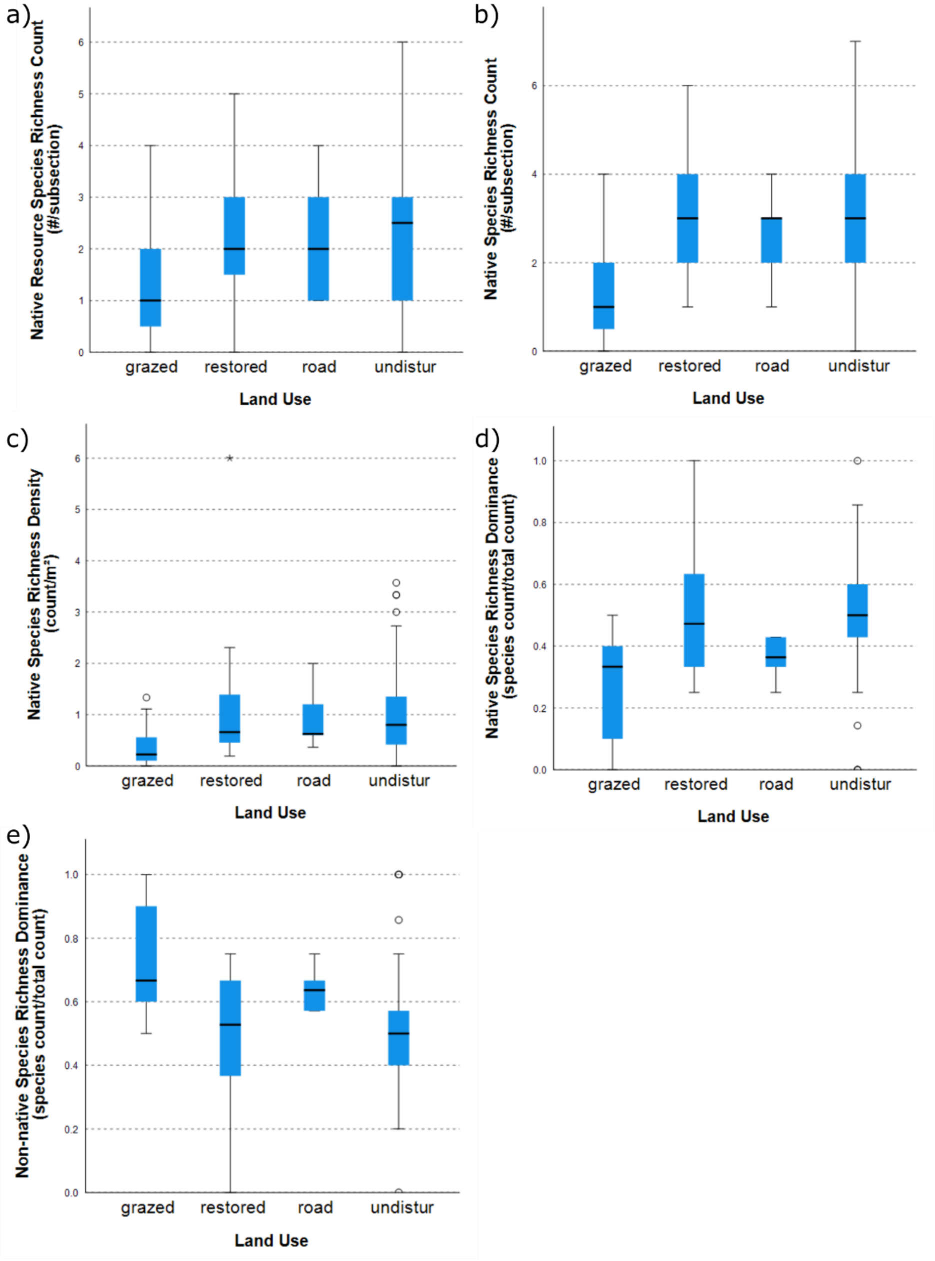
Note. Restored land had significantly lower non-native species abundance density (p = 0.007) and total species abundance density (p = 0.023) than undisturbed land. Boxplot shows the median, first and third quartiles, and range (excluding outliers) of total species richness count for each land use type. Circles represent high potential outliers which are 1.5-3 IQR less than Q1 or greater than Q3, and asterisks represent high extreme outliers, which are more than 3 IQR less than Q1 or greater than Q3.

post hoc pairwise comparison with the Bonferroni did not find any significantly different pairs. The two most significant differences for total species richness count were between grazed and undisturbed areas (p = 0.062) and grazed and restored areas (p = 0.090). In both instances, grazed distributions were lower. For the exceptional cases of non-native species abundance density and total species abundance density, restored areas had lower distributions than undisturbed areas.

Of the various types of vegetative cover measured across different land uses, canopy, grass, and clover cover were found to be statistically different across land use types (Table 2). Canopy cover distribution was statistically lower in grazed areas when compared to both restored and undisturbed areas (Figure 8a). Grazed areas had the highest grass cover distribution overall, which was found to be statistically higher than the grass cover of

Figure 6

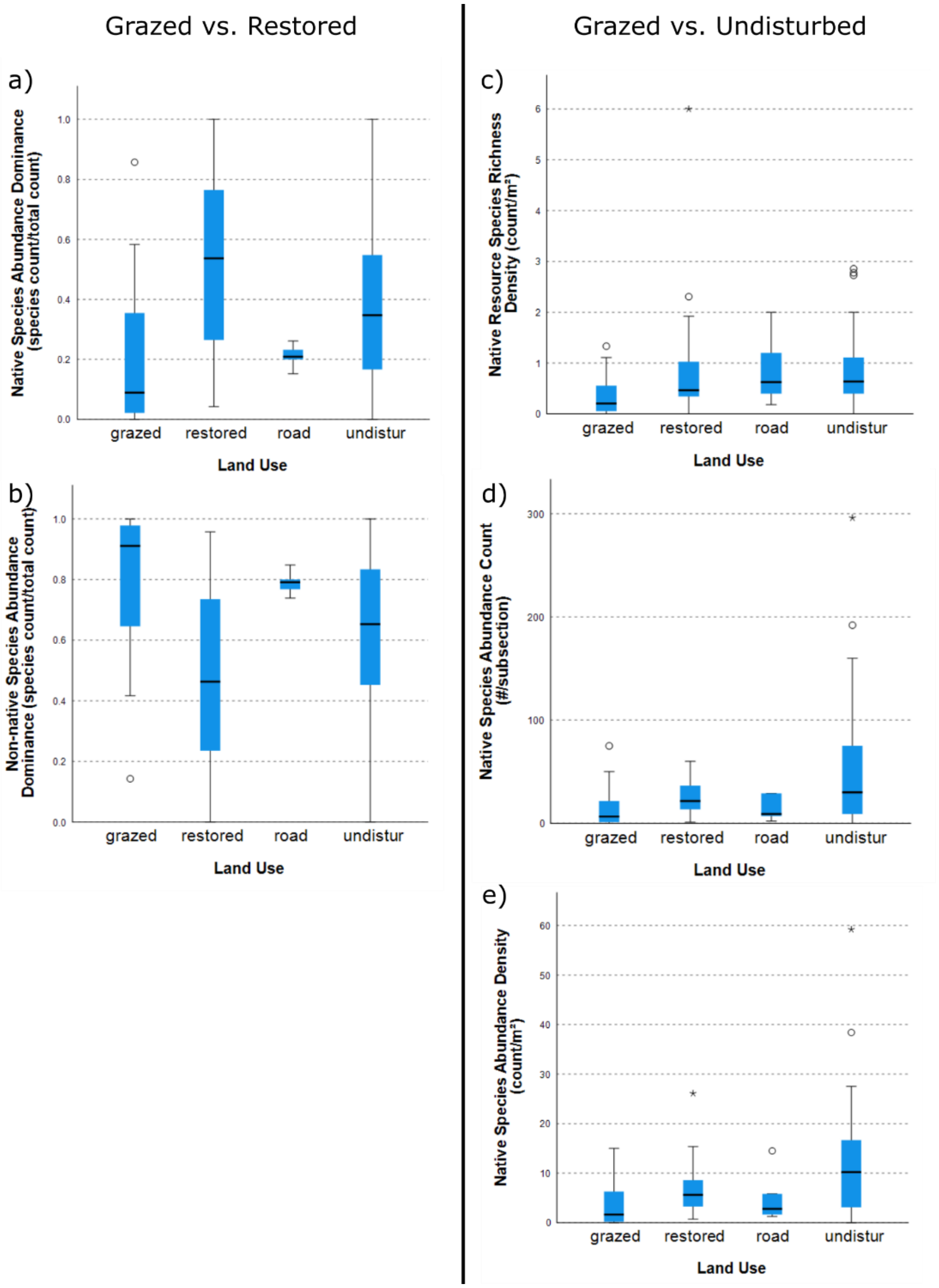
Species Distributions in which Grazed Areas Differ from Undisturbed and Restored Areas



Note. Grazed areas had lower native resource richness count than undisturbed (p = 0.016) and restored areas (p = 0.050). Native species richness count was greater in undisturbed (p = 0.002) and restored areas (p = 0.006). Grazed land had lower native species richness density in undisturbed (p = 0.004) and restored areas (p = 0.030). Native species richness dominance was greater in undisturbed (p = <0.001) and restored (p = 0.012) areas. Grazed areas had greater non-native species richness dominance than undisturbed (p = <0.001) and restored (p = 0.012) areas. Boxplot shows the median, first and third quartiles, and range (excluding outliers) of total species richness count for each land use type. Circles represent high potential outliers which are 1.5-3 IQR less than Q1 or greater than Q3, and asterisks represent high extreme outliers, which are more than 3 IQR less than Q1 or greater than Q3.

Figure 7

Species Distributions in which Grazed Areas Differ from Restored or Undisturbed Areas



Note. Grazed areas had lower native species abundance dominance (p = 0.008) and greater non-native species abundance dominance (p = 0.008) than restored areas. Grazed areas also had lower native resource richness density (p = 0.033) and native species abundance count (p = 0.021) and density (p = 0.002) than undisturbed areas. Boxplot shows the median, first and third quartiles, and range (excluding outliers) of total species richness count for each land use type. Circles represent high potential outliers which are 1.5-3 IQR less than Q1 or greater than Q3, and asterisks represent high extreme outliers, which are more than 3 IQR less than Q1 or greater than Q3.

undisturbed areas (Figure 8b). Despite the presence of outliers, undisturbed land had statistically lower distribution of clover cover than grazed areas (Figure 8c).

Table 2

Results of the Kruskal-Wallis Test on Cover between Land Use Types

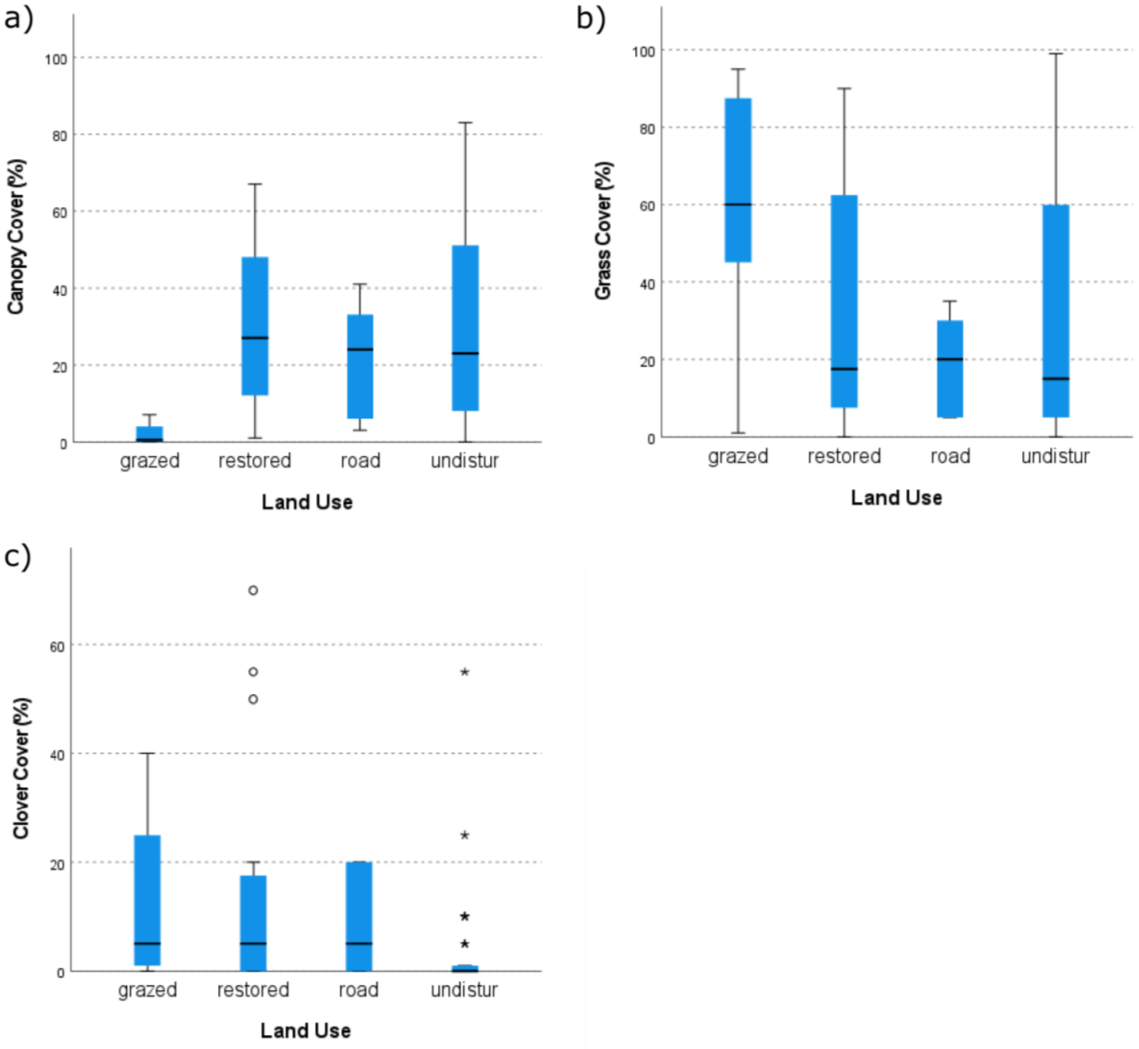
Environmental Features	**P-Value**
Canopy Cover*	<0.001
Ground Cover	0.742
Grass Cover*	0.011
Clover Cover*	0.005

Note. Cover types that differed between land use types are marked with an asterisk (alpha equals 0.05).

Seven environmental characteristics (geological transect subsection, canopy cover, slope, ground cover, length, grass cover, and clover cover) were compared against the various species richness and abundance measurements, resulting in 196 comparisons. The following summary is a breakdown of the 76 statistically significant correlations between species measurements and environmental characteristics (see Appendix D). All species richness decreased as distance from the water's edge increased. Abundance measurements for native species also decreased the further they were found from the water, while abundance measurements of non-natives increased. Resource and native species richness measurements increased under greater canopy cover as non-native species richness dominance decreased. Most native species abundance measurements also increased under greater canopy cover, except for native resource species abundance dominance, which decreased. Non-native species richness dominance decreased as canopy cover increased. As slope increased, richness of all species measurements increased and abundance decreased. Resource and native species measurements decreased in areas with greater ground cover while total and non-native species increased. As the length of the sampling subsection increased, the measurements for all species abundance also increased. For species richness, however, native

Figure 8

Comparison of Vegetative Cover Distributions across Different Land Use Types



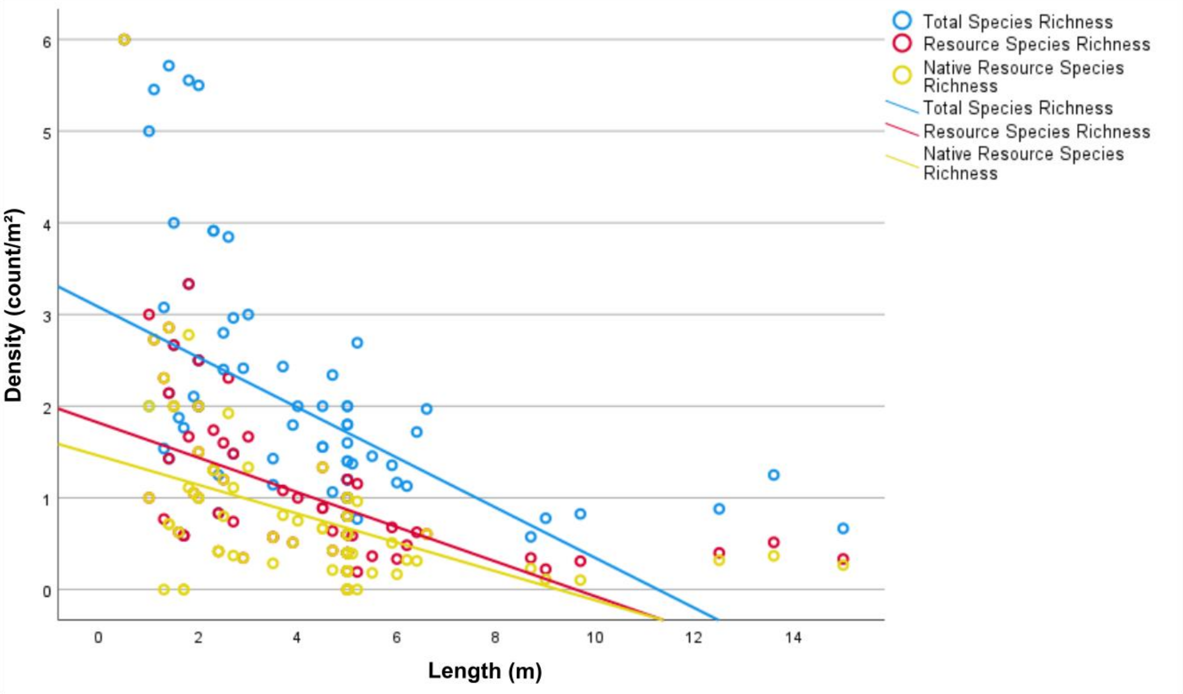
Note. Canopy cover was lower in grazed areas than in restored (p = <0.001) and undisturbed (p = <0.001) areas. Grazed areas also had greater grass (p = 0.011) and clover (p = 0.010) cover than undisturbed areas. Boxplot shows the median, first and third quartiles, and range (excluding outliers) of total species richness count for each land use type. Asterisks represent high extreme outliers, which are more than 3 IQR less than Q1 or greater than Q3.

and resource species decreased while total and non-native species showed mixed results. As grass cover increased, all types of species measurements decreased, except for non-native species measurements, which also increased. Clover cover only had one statistically significant relationship: a positive correlation with non-native species richness count (r = 0.253, p = 0.021).

The strongest correlations were found between species measurements and length. Total species richness density (r = -0.672, p = <0.001), resource species richness density (r = -0.712, p = <0.001), and native resource species richness density (r = -0.608, p = <0.001) had the strongest relationships and all decreased as the transect subsection length decreased (Figure 9).

Figure 9

Correlation between Transect Subsection Length and Total Species Richness Density



Note. Statistically significant correlations between length and total species richness density (r = -0.672, p = <0.001), resource species richness density (r = -0.712, p = <0.001), and native resource species richness density (r = -0.608, p = <0.001). One outlier of total species richness density was omitted from the graph.

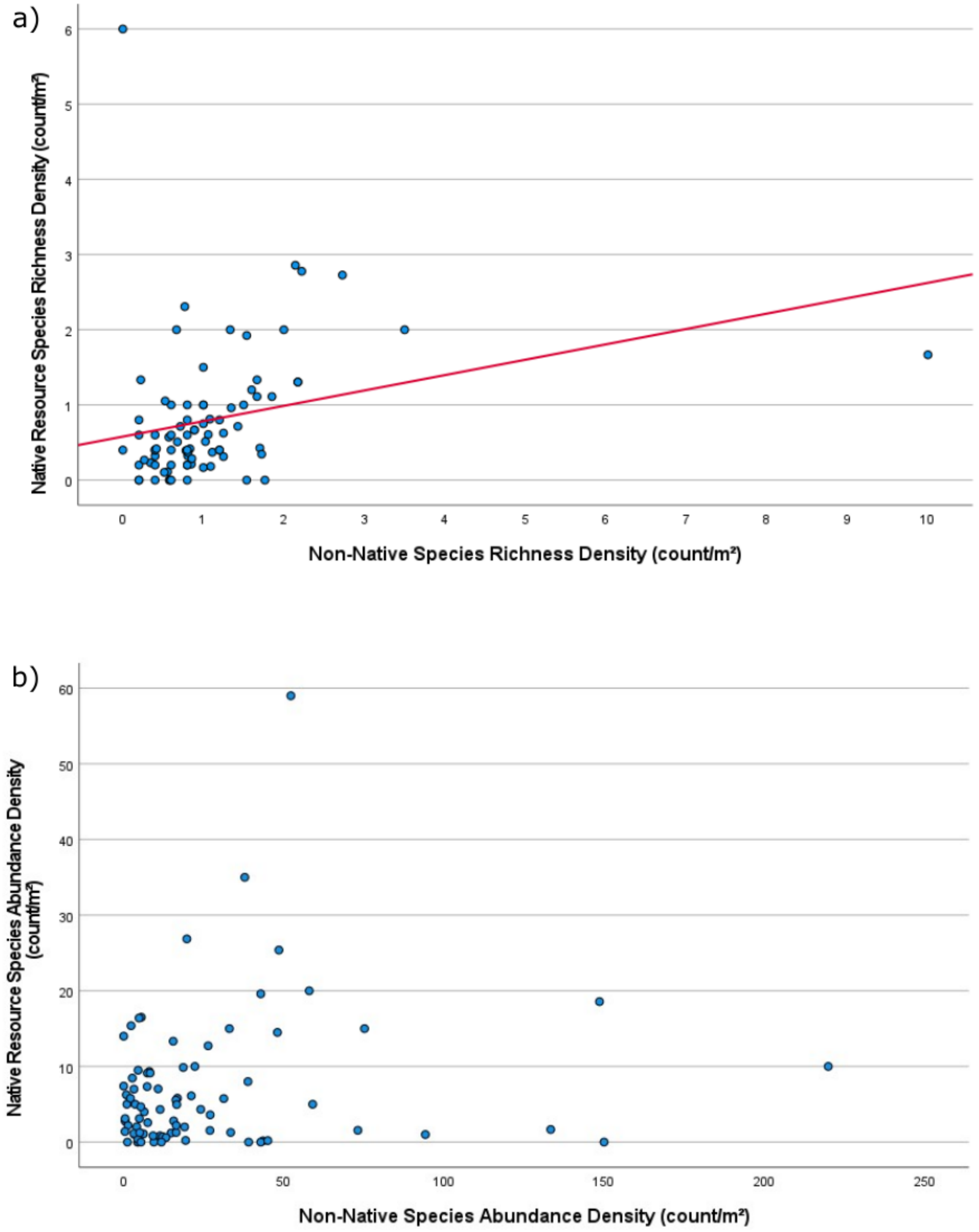
There were no statistically significant differences in species presence across the four directional aspect categories (northeast, southeast, southwest, and northwest). Aspect was the only environmental characteristic that exhibited no statistically significant relationship with any species measurements.

Total, resource, and native species measurements were compared to non-native species, and the following is a summary of the statistically significant correlations that were found (see Appendix E). As non-native species richness count and density increased, the corresponding richness and count measurements of total, resource, native resource, and native species also increased. Conversely, as non-native species richness dominance increased, the dominance of the native resource and resource species categories decreased. The measurements for abundance followed the same overall trend: count and density of total, resource and native species were positively correlated with non-natives, while dominance had negative correlations. However, native resource abundance count and density were not significantly correlated to non-native abundance count and density, respectively. Of all the comparisons, these were the only two relationships that were not statistically significant. Using density as an example to illustrate the asymmetry, it was found that while the native resource richness was positively correlated with non-native richness ($r = 0.429$, $p = <0.001$), native resource abundance had no correlation with non-native abundance ($r = 0.121$, $p = 0.274$) (Figure 10).

For dominance comparisons, the comparisons to native richness and abundance were not included, as native and non-native species were disjoint sets; their correlation coefficient always equaled -1.000. Because native resources are a subset of native species, their dominance measurements were strongly inversely correlated to non-native dominance measurements.

Figure 10

Correlations between Native Resource and Non-Native Species Densities



Note. Resource and non-native species richness density had a positive correlation (r = 0.429, p = <0.001). Native resource and non-native abundance density were not statistically related (r = 0.121, p = 0.274).

Discussion

Before the mid-18th century, ancestral Muwekma Ohlone Native Americans lived throughout the Alameda Creek watershed of the San Francisco Bay Area (B. F. Byrd, Engbring, Darcangelo, & Ruby, 2020; Leventhal et al., 2017). Their relationship with the environment was defined by TEK, cultivating resources while encouraging species richness and diversity (Anderson, 2005; Lightfoot & Parrish, 2009). The arrival of colonizers transformed these undeveloped areas in which native plants were once cultivated and managed by TEK into urban development and large-scale agriculture (Anderson, 2005; Stanford et al., 2013). Non-native plant species were introduced and this, in combination with Western anthropogenic uses, has led to a loss of plant biodiversity (Foley et al., 2005). In California, the widespread degradation of riparian corridors is of particular concern, as almost all riparian areas in California have suffered some amount of degradation and alteration (National Research Council, 2002). The riparian corridors of Alameda Creek watershed are now home to many native and non-native, resource and non-resource plants. Along the way Ohlone TEK adapted to include introduced species in their cultivation practices for as long as they had access to the land. Currently, the Muwekma Ohlone Tribe does not have land on which to implement their TEK as they have yet to regain their federally recognized status (Field & Muwekma Ohlone Tribe, 2003; Field et al., 2013; Field et al., 2014; Leventhal et al., 2017; Muwekma Ohlone Tribe v. Babbitt, 2001; Slagle et al. 1995). The purpose of this study was to understand the current distribution of historic Ohlone resources within the watershed and aid the Muwekma Ohlone Tribe in reconnecting with ancestral lands after centuries of forced displacement.

Through this study, a picture of the distribution of the different species in the Alameda Creek watershed began to emerge. The amount of native and resource species increased as non-native species tended to increase concurrently, showing that areas that support greater amounts of natives and resources also support more non-natives. However, non-native species repeatedly had the highest presence on average, in terms of both richness and abundance. Conversely, native resource species, a subset of the native species observed during the survey, had the lowest presence. Non-native invasive species are known to be one of the mostly prevalent and greatest threat to native biodiversity worldwide (Lonsdale, 1999). Invasives are generally hardier, more adaptable and able to outcompete natives (Laurance & Yensen, 1991; C. E. Lee, 2002). Thus, it is unsurprising where non-natives were present in the Alameda Creek watershed, they tended to thrive over their native and resource counterparts.

Although none of the samples were on heavily urbanized or developed land, there were overall trends suggesting that native species and resources were more likely to be found in undisturbed or ecologically restored areas. Native species in particular were susceptible variations in land use. Less-trafficked areas had higher overall species richness and higher measurements of natives when compared to grazed areas or areas near service roads. Non-native proliferation is aided by habitat fragmentation, and the Alameda Creek watershed has a long history of land alteration, whether it was for urban development or agriculture (Laurance & Yensen, 1991; Stanford et al., 2013). Disturbances are easily introduced where anthropogenic activity meets wildlands, and niches for non-native species are created at this edge (Czech, 2005; Laurance & Yensen, 1991). As a result, species richness and native species presence are negatively affected (Laurance & Yensen, 1991).

Restored lands were home to the largest amounts of native and native resource species. Non-native species abatement by the SFPUC may have supported native growth on restored land. As mentioned earlier, invasives are able to outcompete natives if allowed to proliferate (Laurance & Yensen, 1991; C. E. Lee, 2002), and one of the eight non-native species targeted during weeding were found in various samples throughout the site. These areas also had the lowest levels of grass cover, two species of which were specifically removed during weeding. Additionally, restored areas had the greatest canopy cover on average. Greater canopy cover was found to have a positive relationship with biodiversity and native and resource species presence. Of the 16 species planted during restoration efforts, six were found during sampling: *Salix* spp., *Artemisia douglasiana* Besser, *Baccharis salicifolia* (Ruiz & Pav.) Pers., *Populus fremontii* S. Watson, *Quercus* spp., and *Schoenoplectus acutus* (Muhl. Ex Bigelow) Á. Löve & D. Löve var. *occidentalis* (S. Watson) S. G. Sm. Several hundred plants were planted during restoration work, the majority were woody species that may have contributed to the greater canopy measurements. Increasing canopy cover and removing non-native species appears to be a reliable way to encourage greater native and resource presence within the watershed.

Grazed areas, on the other hand, generally had the lowest overall species richness, native and native resource presence, and canopy cover with the highest amount of non-native species measurements and grass cover. Historically, the land currently used for grazing was a sparsely vegetated braided channel (Stanford et al., 2013). Presumably, the land did not have high levels of canopy cover, so only species that needed little shade grew there. As previously mentioned, previous studies have found that European grasses and herbaceous species have taken over much of the watershed, replacing native grasses and forbs (Stanford et al., 2013). The study found that areas with greater grass cover also had more non-native species and fewer native and resource species. The introduction of dominating invasives to an environment that started with low native species density resulted in an area with low biodiversity taken over by non-natives.

In addition to land uses, certain environmental characteristics were found to have relationships with species presence. Greater biodiversity and higher levels of native and resource species were found closer to the water and in areas where the corridor was more sloped, narrower, and had less ground cover. In the study site, the corridor was narrow and sloped primarily in undisturbed and restored areas. The grazing lands and lands adjacent to the service road were wider and more level. There was no clear distinction between corridor edge and pasture in the grazing areas, the upland areas turning into sprawling herbaceous and grass with very few woody species. Previous research has found that spatial heterogeneity, including changes in landscape and topography, supports biodiversity (Kumar et al., 2006). It is unknown whether the land was altered, flattened to accommodate anthropogenic land use, or whether the original terrain was already suitable for grazing and road development. Regardless, the environment is currently less supportive of biodiversity, and native and resource species are less likely to be found in these areas.

For those interested in riparian health, learning that undisturbed and, in particular, restored lands house greater amounts of biodiversity and native species can help inform future management plans. For those interested in environmental justice, it is also useful to know that historic Ohlone resources are generally found in areas that support biodiversity and native species. This study found that land that was once managed through Ohlone TEK and is now undisturbed or restored has greater amounts of native species and biodiversity than those areas that have been repurposed for anthropogenic land use. TEK from the California Bay Area supported biodiversity while giving instruction on how one should interact with their environment (Anderson, 2005; Berkes et al., 2000; Hoagland, 2017). Reestablishing Ohlone TEK would still meet most modern management goals while allowing the Muwekma Ohlone Tribe to implement historically oppressed culture on ancestral lands.

TEK from other areas of the world may even provide insight when designing local management practices for anthropogenically altered areas. Grazing is a well-known disturbance type that often negatively effects biodiversity (Kumar, 2006). However, TEK that has developed in Europe uses grazing animals to disperse specific plant species, maintaining fine-scale biodiversity in grasslands (Reitalu et al., 2010). Much like how Ohlone TEK sustains native biodiversity in undeveloped land, learning from TEK from other agricultural traditions may provide insight in bolstering biodiversity in farmlands.

TEK’s holistic approach to life within one’s environment incorporates more cultural elements and beliefs than standard Western ecological management, making TEK more than just a method of resource cultivation (Berkes et al., 2000; Hoagland, 2017). Ohlone TEK revitalization would be a form of cultural revitalization. As the Muwekma Ohlone Tribe continues to fight for their rightful recognition from the federal government, opportunities to establish cultural practices help maintain a sense of identity and presence separate from bureaucratic oppression. The Tribe’s current collaboration with the SFPUC on this project and the watershed center exhibition has allowed them to reacquaint themselves with their traditional environmental customs and teach these customs to others. The success of these projects will hopefully open the door for future collaborations with land owners and create more opportunities to teach the public about the past and present of the Muwekma Ohlone Tribe. Furthermore, familiarizing themselves with historic lands after over a century of forced expulsion is a step towards restoring the Muwekma Ohlone as stewards of the land.

Conclusion

The primary purpose of this study was to provide the Muwekma Ohlone Tribe with information on which historic resources are present in the watershed, what uses they have, and where they can be found. After a vegetation survey in a riparian corridor of the Alameda Creek watershed, it was found that riparian areas that most closely resemble undeveloped land were home to a greater amount of Ohlone resources. Modern ecological restoration plans implemented by the SFPUC have helped create an environment that support the highest levels of biodiversity, native species presence, and historic Ohlone resource presence. On the other end of the spectrum, the broad, flat grazing plains that border the creeks of the watershed have the highest levels of non-native species. Due to their lack of federal recognition, the Tribe is not currently managing any of these lands, which are the ancestral lands of the Ohlone people. Past and present colonization has forcibly separated the Tribe from the home and cultural management practices of their ancestors. By understanding where resource species thrive, the Tribe can begin to refamiliarize themselves with ancestral lands and revive TEK. Through education, the Muwekma Ohlone Tribe can teach others about their rich history and pass TEK on to future generations.

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Appendix A

Identified Species of the Alameda Creek Watershed

NATIVE HISTORIC RESOURCES

▪ **Scientific Name** ▪ **Chochenyo Name** ▪ **Common Name**	**Mean Count (#/subsection)**	**Mean Density (count/m^2)**	**Mean Dominance (species count/ total count)**
▪ *Aesculus californica* (Spach) Nutt. ▪ N/A ▪ California buckeye	0.120 (SE = 0.109)	0.020 (SE = 0.018)	0.001 (SE = 0.001)
▪ *Alnus rhombifolia* Nutt. ▪ Máarax ▪ white alder	0.157 (SE = 0.083)	0.072 (SE = 0.35)	0.002 (SE = 0.001)
▪ *Amsinckia* spp. (Lehm.) A. Nelson & J.F. Macbr. ▪ N/A ▪ small-flower fiddleneck	1.072 (SE = 0.910)	0.234 (SE = 0.185)	0.008 (SE = 0.005)
▪ *Artemisia californica* Less. ▪ Miryan ▪ California sagebrush	0.048 (SE = 0.038)	0.010 (SE = 0.008)	0.000 (SE = 0.000)
▪ *Artemisia douglasiana* ▪ N/A ▪ California mugwort	2.036 (SE = 0.792)	0.439 (SE = 0.173)	0.015 (SE = 0.005)
▪ *Baccharis salicifolia* ▪ N/A ▪ mule fat	2.556 (SE = 1.107)	0.541 (SE = 0.150)	0.036 (SE = 0.011)
▪ *Carex* spp. ▪ N/A ▪ sedge	1.880 (SE = 0.816)	0.377 (SE = 0.144)	0.017 (SE = 0.006)
▪ *Claytonia perfoliata* subsp. *perfoliata* Donn ex Willd. ▪ N/A ▪ miner’s lettuce	0.578 (SE = 0.348)	0.124 (SE = 0.064)	0.006 (SE = 0.003)

▪ *Equisetum arvense* L. ▪ N/A ▪ common horsetail	0.422 (SE = 0.278)	0.097 (SE = 0.064)	0.002 (SE = 0.001)
▪ *Equisetum laevigatum* A. Braun ▪ N/A ▪ smooth horsetail	0.229 (SE = 0.206)	0.047 (SE = 0.041)	0.001 (SE = 0.000)
▪ *Eschscholzia californica* Cham. ▪ N/A ▪ California Poppy	0.337 (SE = 0.218)	0.104 (SE = 0.071)	0.006 (SE = 0.004)
▪ *Galium* spp. ▪ N/A ▪ bedstraw	12.398 (SE = 4.418)	2.919 (SE = 0.930)	0.061 (SE = 0.015)
▪ *Lupinus* spp. L. ▪ N/A ▪ lupine	0.988 (SE = 0.641)	0.223 (SE = 0.138)	0.010 (SE = 0.006)
▪ *Marah fabacea* (Naudin) Greene ▪ N/A ▪ manroot	0.024 (SE = 0.024)	0.005 (SE = 0.005)	0.002 (SE = 0.002)
▪ *Nasturtium officinale* W.T. Aiton ▪ N/A ▪ watercress	0.711 (SE = 0.425)	0.349 (SE = 0.212)	0.027 (SE = 0.014)
▪ *Populus fremontii* ▪ N/A ▪ Fremont cottonwood	0.024 (SE = 0.017)	0.027 (SE = 0.024)	0.002 (SE = 0.002)
▪ *Quercus* spp. ▪ N/A ▪ oak	0.108 (SE = 0.045)	0.028 (SE = 0.012)	0.001 (SE = 0.001)
▪ *Rubus ursinus* Cham. & Schltdl. ▪ ’Enésmin ▪ California blackberry	0.831 (SE = 0.371)	0.270 (SE = 0.114)	0.011 (SE = 0.006)
▪ *Salix* spp. ▪ N/A ▪ willow	1.217 (SE = 0.324)	0.416 (SE = 0.118)	0.035 (SE = 0.013)

▪ *Schoenoplectus acutus* var. *occidentalis* ▪ N/A ▪ common tule	0.843 (SE = 0.291)	0.392 (SE = 0.164)	0.029 (SE = 0.011)
▪ *Scrophularia californica* Cham. & Schltdl. ▪ N/A ▪ California bee plant	0.120 (SE = 0.060)	0.039 (SE = 0.023)	0.002 (SE = 0.001)
▪ *Symphoricarpos albus* (L.) S. F. Blake ▪ N/A ▪ common snowberry	0.434 (SE = 0.422)	0.087 (SE = 0.084)	0.012 (SE = 0.011)
▪ *Toxicodendron diversilobum* (Torr. & A. Gray) Greene ▪ N/A ▪ poison oak	0.108 (SE = 0.062)	0.037 (SE = 0.024)	0.003 (SE = 0.002)
▪ *Typha* spp. L. ▪ N/A ▪ cattail	0.108 (SE = 0.087)	0.035 (SE = 0.025)	0.003 (SE = 0.002)
▪ *Umbellularia californica* (Hook. & Arn.) Nutt. ▪ Sokóote ▪ California bay laurel	0.060 (SE = 0.043)	0.013 (SE = 0.009)	0.003 (SE = 0.002)
NON-NATIVE HISTORIC RESOURCES			
▪ *Brassicaceae* ▪ N/A ▪ mustard	21.398 (SE = 4.601)	4.680 (SE = 0.899)	0.209 (SE = 0.031)
▪ *Nicotiana glauca* Graham ▪ N/A ▪ tree tobacco	0.024 (SE = 0.017)	0.013 (SE = 0.010)	0.001 (SE = 0.001)
▪ *Plantago major* ▪ N/A ▪ broadleaf plantain	0.096 (SE = 0.050)	0.012 (SE = 0.007)	0.002 (SE = 0.002)

NATIVE NON-RESOURCE SPECIES			
▪ *Bowlesia incana* Ruiz & Pav. ▪ N/A ▪ hoary bowlesia	0.265 (SE = 0.265)	0.021 (SE = 0.021)	0.001 (SE = 0.001)
▪ *Cardamine oligosperma* ▪ N/A ▪ bitter cress	6.735 (SE = 1.530)	1.790 (SE = 0.426)	0.073 (SE = 0.015)
▪ *Epilobium* spp. L. ▪ N/A ▪ willowherb	0.084 (SE = 0.060)	0.108 (SE = 0.077)	0.001 (SE = 0.001)
▪ *Erigeron* spp. L. ▪ N/A ▪ fleabane	0.193 (SE = 0.170)	0.044 (SE = 0.035)	0.001 (SE = 0.001)
▪ *Hoita macrostachya* (DC.) Rydb. ▪ N/A ▪ California hemp	0.048 (SE = 0.048)	0.007 (SE = 0.007)	0.000 (SE = 0.000)
▪ *Pentagramma triangularis* (Kaulf.) Yatsk., Windham & E. Wollenw. ▪ N/A ▪ goldenback fern	0.012 (SE = 0.012)	0.003 (SE = 0.003)	0.000 (SE = 0.000)
▪ *Rumex salicifolius* Weinm. ▪ N/A ▪ willow dock	0.518 (SE = 0.169)	0.108 (0.036)	0.003 (SE = 0.001)
NON-NATIVE NON-RESOURCE SPECIES			
• *Carduus pycnocephalus* L. • N/A • Italian thistle	1.711 (SE = 0.421)	0.358 (SE = 0.088)	0.015 (SE = 0.004)
• *Conium maculatum* • N/A • poison hemlock	18.759 (SE = 4.826)	3.835 (SE = 0.930)	0.109 (SE = 0.017)
• *Cotula coronopifolia* L. • N/A • brass buttons	0.012 (SE = 0.012)	0.001 (SE = 0.001)	0.000 (SE = 0.000)

• *Erodium* spp. • N/A • filaree	25.470 (SE = 16.036)	5.216 (SE = 3.209)	0.054 (SE = 0.022)
• *Fumaria* spp. L. • N/A • fumitory	1.289 (SE = 1.182)	0.270 (SE = 0.251)	0.008 (SE = 0.007)
• *Geranium* spp. L. • N/A • geranium	13.241 (SE = 3.292)	3.248 (SE = 0.695)	0.097 (SE = 0.019)
• *Lysimachia arvensis* (L.) U. Manns & Anderb. • N/A • scarlet pimpernel	0.241 (SE = 0.101)	0.097 (SE = 0.047)	0.007 (SE = 0.003)
• *Mentha pulegium* L. • N/A • pennyroyal	4.530 (SE = 2.036)	2.575 (SE = 1.572)	0.032 (SE = 0.015)
• *Mentha* spp. L. • N/A • mint	4.542 (SE = 2.449)	2.219 (SE = 1.645)	0.021 (SE = 0.011)
• *Plantago lanceolata* L. • N/A • ribwort	0.060 (SE = 0.040)	0.010 (SE = 0.008)	0.001 (SE = 0.001)
• *Rubus armeniacus* Focke • N/A • Himalayan blackberry	0.169 (SE = 0.105)	0.032 (SE = 0.018)	0.001 (SE = 0.001)
• *Rumex* spp. L. • N/A • dock	0.747 (SE = 0.189)	0.250 (SE = 0.085)	0.011 (SE = 0.003)
• *Senecio vulgaris* L. • N/A • common groundsel	0.060 (SE = 0.036)	0.010 (SE = 0.006)	0.001 (SE = 0.001)

• *Silybum marianum* (L.) Gaertn. • N/A • milk thistle	0.048 (SE = 0.048)	0.008 (SE = 0.008)	0.000 (SE = 0.000)
• *Sonchus* spp. L. • N/A • sowthistle	0.157 (SE = 0.055)	0.079 (SE = 0.044)	0.002 (SE = 0.001)
• *Taraxacum* spp. F.H. Wigg. • N/A • dandelion	0.012 (SE = 0.012)	0.002 (SE = 0.002)	0.000 (SE = 0.000)
• *Verbascum thapsus* L. • N/A • common mullein	0.024 (SE = 0.017)	0.007 (SE = 0.005)	0.000 (SE = 0.000)
• *Vicia* spp. L. • N/A • vetch	6.265 (SE = 2.582)	1.418 (SE = 0.644)	0.040 (SE = 0.015)
• *Vinca major* L. • N/A • bigleaf periwinkle	5.759 (SE = 4.679)	1.213 (SE = 0.953)	0.017 (SE = 0.012)

Note. The count, density, and dominance with standard error (SE) for each species are averages from all samples. If the name of the plant is known in Chochenyo, it is provided (Peralto et al., 2008).

Appendix B

Uses of Historic Resources Found in the Watershed

NATIVE HISTORIC RESOURCES	
• Scientific Name **• Chochenyo Name** **• Common Name**	**Resource Use**
• *Aesculus californica* • N/A • California buckeye	Fruits eaten; toothache and loose tooth remedy made from bark; fruits pulverized into hemorrhoid salve; fruits used to poison fish (Bocek, 1984); Wood used to make fire-drills and bows (Lightfoot & Parrish, 2009)
• *Alnus rhombifolia* • Máarax • white alder	Made into an emetic tea; tea made from bark used for washing; inner bark eaten; tinder made from soft wood of young shoots; inner bark used to make red dye for basketry (Peralto et al., 2008); fruit eaten; flutes made from wood; young shoots made into arrow shafts; wood used as firewood and to make fire drills (Anderson, 2005); bark used to make tea remedy for stomach aches and diarrhea (Lightfoot & Perrish, 2009)
• *Amsinckia* spp. • N/A • small-flower fiddleneck	*A. menziesii* (Lehm.) A. Nelson & J.F. Macbr. harvested for its seeds (Anderson, 2005); *A. douglasiana* A. DC. used for various medicinal purposes (Bocek, 1984)
• *Artemisia californica* • Miryan • California sagebrush	Leaves held against sore wounds and teeth to reduce pain; used in a solution to bathe patients with colds, coughs, or rheumatism (Bocek, 1984)
• *Artemisia douglasiana* • N/A • California mugwort	Burning branches used as torches during night fishing and used to smoke out beehives; used in a decoction remedy for urinary issues and asthma; made into a compress for external wounds or rheumatism pain; earaches treated by holding heated leaves over ears (Bocek, 1984)

• *Baccharis salicifolia* • N/A • mule fat	Wood used to make fire-drills (Anderson, 2005); in some parts of southern Californian desert, used to thatch dwellings, soothe boils, and treat kidney ailments and other aches and pains (Lightfoot & Parrish, 2009)
• *Carex* spp. • N/A • sedge	Various species gathered so that roots could be used in basketry (Anderson, 2005; Bocek 1984; Lightfoot & Parrish, 2009); the Esselen also used roots for cordage and the Kashaya Pomo made torches from leaves (Lightfoot & Parrish, 2009)
• *Claytonia perfoliata* subsp. *perfoliata* • N/A • miner's lettuce	Leaves eaten in the spring, but eaten boiled or steamed later in the year (Bocek, 1984)
• *Equisetum arvense* • N/A • common horsetail	Roots used in basketry (Bocek, 1984); rhizomes used as black lacing (Anderson, 2005)
• *Equisetum laevigatum* • N/A • smooth horsetail	Used as contraceptive and hair wash; used as a remedy for bladder ailments and delayed menstruation; stems used to make abrasive composites (Bocek, 1984)
• *Eschscholzia californica* • N/A • California Poppy	Liquid made from flowers used to kill lice; smell believed to be poisonous so pregnant woman avoided it (Bocek, 1984); used to induce sleep by placing 1 or 2 flowers under the bed (Bocek 1984, Anderson, 2005); also used by Yuki for toothaches, eaten by Sierra Miwok, and used as a treatment for Wintu newborns' navels (Anderson, 2005)
• *Galium* spp. • N/A • bedstraw	Various species used in dysentery treatment; used as a compress for rheumatism (Bocek, 1984)
• *Lupinus* spp. • N/A • lupine	Greens of various species eaten (Anderson, 2005); seeds of various species ground, roasted, and eaten (Bocek, 1984)

- *Marah fabacea* - N/A - manroot	Detergent lather made from roots; paste for pimples and sores made from seeds (Bocek, 1984); used by Coast Miwok to poison fish (Lightfoot & Parrish, 2009)
- *Nasturtium officinale* - N/A - watercress	Leaves and stems eaten (Anderson, 2005)
- *Populus fremontii* - N/A - Fremont cottonwood	Inner bark eaten; broken bones set with a syrup made from outer bark (Bocek, 1984); wood used in the hearth (Anderson, 2005); used by Indians in the southern coast and southern desert of California for construction and to make various external medicines (Lightfoot & Parrish)
- *Quercus* spp. - N/A - oak	Acorns of various species eaten, but those of *Q. agrifolia* Née and *Q. kelloggii* Newb. were preferred (Bocek 1984, Lightfoot & Parrish, 2009); remedy for toothaches and loose teethe made from bark or insect galls; diarrhea remedy made from water taken from acorn leaching; bark used for tinder; wood used to make various tools and utensils (Bocek, 1984)
- *Rubus ursinus* - ’Enésmin - California blackberry	Berries eaten; Used to make a purple dye for plant material used in basketry (Peralto et al., 2008); roots used in a tea remedy for diarrhea and dysentery and as a treatment for infected sores (Bocek, 1984)
- *Salix* spp. - N/A - willow	Shoots of *S. lasiolepis* Benth. and *S. exigua* Nutt. used in basketry; various parts of *S. lasiolepis* used for cold remedies; *S. laevigata* Bebb bark made into fever remedy; *S. exigua* twigs used for kindling; leaves from various species used as a scalp treatment for falling hair and as hair rinse; rope made from braided bark; willows poles used in construction (Bocek, 1984); shredded bark used to make clothing (Lightfoot & Parrish, 2009)

• *Schoenoplectus acutus* var. *occidentalis* • N/A • common tule	Sometimes used in basketry; more often used in building and boat construction; used in making sanitary napkins, clothing, and boats; some Ohlone groups ate roots and baked pollen (Lightfoot & Parrish, 2009)
• *Scrophularia californica* • N/A • California bee plant	Poultices for sore eyes, boils, and swellings made from leaves; twigs used in decoctions to wash infections and were tied over swollen sores; eyewash from plant juice used to treat poor vision (Bocek, 1984)
• *Symphoricarpos albus* • N/A • common snowberry	Brooms made of brushy stems (Bocek, 1984)
• *Toxicodendron diversilobum* • N/A • poison oak	Bread wrapped in leaves; shoots used in basketry (Bocek, 1984); used by Kashaya Pomo and Coast Miwok for tattooing; eaten by Esselen children to develop immunity to rashes (Lightfoot & Parrish, 2009)
• *Typha* spp. • N/A • cattail	*T. latifolia* L. shoots, and pollen eaten (Bocek, 1984); some claim *T. latifolia* roots were eaten, but most likely rhizome was eaten (Bocek, 1984; Lightfoot & Parrish, 2009); various species used to make cordage (Anderson, 2005)
• *Umbellularia californica* • Sokóote • California bay laurel	Fruits eaten; kernels roasted or ground in flour; leaves used as air fresheners; burned leaves to get rid of fleas or drive out squirrels from ground burrows; damp leaves put on head for headaches; used to make poison oak dermatitis wash (Bocek, 1984); leaves used to spice food; used to treat afterbirth pains; poultice made from seeds to treat sores; leaves put in steam bath to clear out sickness (Peralto et al., 2008); wood was used to make split-stick clapper instruments and fences for dance circles (Lightfoot & Parrish, 2009)

NON-NATIVE HISTORIC RESOURCES	
• *Brassicaceae* • N/A • mustard	Leaves of many native and non-native species eaten by different groups in central California; Ohlone groups specifically collected tansy mustards (*Descurainia* spp.) (Lightfoot & Parrish, 2009)
• *Erodium cicutarium* • N/A • redstem filaree	Stems eaten; leaves used to make a typhoid fever remedy tea (Bocek, 1984)
• *Nicotiana glauca* • N/A • tree tobacco	Uses unknown, however seeds dating back from the early 1800s have been found at Mission Santa Clara in a pit with ceremonial materials of mourning, suggesting the plant was adopted into Ohlone TEK, which had a history of smoking various nicotine species (Bocek, 1984; Cuthrell et al., 2016; Lightfoot & Parrish, 2009)
• *Plantago major* • N/A • broadleaf plantain	Roots used in fever and constipation remedies (Bocek, 1984)

Appendix C

Results of the Kruskal-Wallis Test Comparing Species Presence Across Land Use Types

Species Measurements	**P-Value**
Total species richness count*	0.038
Total species richness density	0.070
Resource species richness count	0.187
Resource species richness density	0.379
Resource species richness dominance	0.441
Native resource richness count*	0.019
Native resource richness density*	0.042
Native resource richness dominance	0.147
Native species richness count*	0.002
Native species richness density*	0.006
Native species richness dominance*	<0.001
Non-native species richness count	0.392
Non-native species richness density	0.191
Non-native species richness dominance*	<0.001
Total species abundance count	0.181
Total species abundance density*	0.022
Resource species abundance count	0.456
Resource species abundance density	0.086
Resource species abundance dominance	0.328
Native resource species abundance count	0.331
Native resource species abundance density	0.124
Native resource species abundance dominance	0.279
Native species abundance count*	0.025
Native species abundance density*	0.003
Native species abundance dominance*	0.008
Non-native species abundance count	0.111
Non-native species abundance density*	0.014
Non-native species abundance dominance*	0.008

Note. Measurements that varied significantly across land uses are marked with an asterisk (alpha equals 0.05).

Appendix D

Relationships between Species Presence and Environmental Characteristics

Geological Feature	**Species Measurement**	**Correlation Coefficient**	**P-Value**
Geological Transect Subsection	Total species richness density	-0.436	<0.001
	Resource species richness count	-0.219	0.047
	Resource species richness density	-0.392	<0.001
	Native resource richness density	-0.371	0.001
	Native species richness density	-0.384	<0.001
	Non-native species richness density	-0.321	0.003
	Total species abundance count	0.269	0.014
	Native resource species abundance dominance	-0.218	0.048
	Native species abundance dominance	-0.240	0.029
	Non-native species abundance count	0.275	0.012
	Non-native species abundance dominance	0.240	0.029
Canopy (%)	Total species richness count	0.216	0.050
	Total species richness density	0.336	0.002
	Resource species richness count	0.317	0.004
	Resource species richness density	0.345	0.001
	Resource species richness dominance	0.221	0.044
	Native resource species richness count	0.505	<0.001
	Native resource species richness density	0.502	<0.001
	Native resource species richness dominance	0.529	<0.001
	Native species richness count	0.497	<0.001
	Native species richness density	0.532	<0.001
	Native species richness dominance	0.588	<0.001
	Non-native species richness dominance	-0.588	<0.001
	Native resource species abundance count	0.359	0.001
	Native resource species abundance density	0.422	<0.001

	Native resource species abundance dominance	0.460	<0.001
	Native species abundance count	0.342	0.002
	Native species abundance density	0.415	<0.001
	Native species abundance dominance	0.477	<0.001
	Non-native species abundance dominance	-0.477	<0.001
Slope (°)	Total species richness density	0.335	0.002
	Resource species richness density	0.451	<0.001
	Resource species richness dominance	0.309	0.005
	Native resource species richness density	0.384	<0.001
	Native resource species richness dominance	0.240	0.029
	Native species richness density	0.332	0.002
	Non-native species richness density	0.264	0.016
	Total species abundance count	-0.395	<0.001
	Resource species abundance count	-0.264	0.016
	Non-native species abundance count	-0.379	<0.001
	Non-native species abundance density	-0.224	0.042
Ground Cover (%)	Resource species richness dominance	-0.236	0.032
	Non-native species richness count	0.219	0.046
	Total species abundance count	0.447	<0.001
	Total species abundance density	0.369	0.001
	Resource species abundance dominance	-0.485	<0.001
	Native species abundance dominance	-0.239	0.030
	Non-native species abundance count	0.465	<0.001
	Non-native species abundance density	0.379	<0.001
	Non-native species abundance dominance	0.239	0.030
Length (m)	Total species richness count	0.327	0.003
	Total species richness density	-0.672	<0.001

	Resource species richness density	-0.712	<0.001
	Resource species richness dominance	-0.314	0.004
	Native resource species richness density	-0.608	<0.001
	Native resource species richness dominance	-0.285	0.009
	Native species richness density	-0.577	<0.001
	Non-native species richness count	0.414	<0.001
	Non-native species richness density	-0.485	<0.001
	Total species abundance count	0.493	<0.001
	Resource species abundance count	0.421	<0.001
	Native species abundance count	0.313	0.004
	Non-native species abundance count	0.471	<0.001
Grass (%)	Total species richness density	-0.248	0.024
	Resource species richness density	-0.346	0.001
	Resource species richness dominance	-0.240	0.029
	Native resource species richness count	-0.264	0.016
	Native resource species richness density	-0.383	<0.001
	Native resource species richness dominance	-0.317	0.003
	Native species richness count	-0.280	0.010
	Native species richness density	-0.401	<0.001
	Native species richness dominance	-0.416	<0.001
	Non-native species richness dominance	0.416	<0.001
	Native species abundance dominance	-0.277	0.011
	Non-native species abundance dominance	0.277	0.011
Clover (%)	Non-native species richness count	0.253	0.021

Note. Only the statistically significant relationships are listed (alpha equals 0.05).

Appendix E

Relationships between Species Measurements and Non-Native Species

Non-Native Species Measurement	Species Measurement	Correlation Coefficient	P-Value
Non-native species richness count	Total species richness count*	0.842	<0.001
	Resource species richness count*	0.365	0.001
	Native resource species richness count*	0.236	0.032
	Native species richness count*	0.381	<0.001
Non-native species richness density	Total species richness density*	0.783	<0.001
	Resource species richness density*	0.532	<0.001
	Native resource species richness density*	0.429	<0.001
	Native species richness density*	0.479	<0.001
Non-native species richness dominance	Resource species richness dominance*	-0.614	<0.001
	Native resource species richness dominance*	-0.859	<0.001
Non-native species abundance count	Total species abundance count*	0.948	<0.001
	Resource species abundance count*	0.580	<0.001
	Native resource species abundance count	0.187	0.091
	Native species abundance count*	0.347	0.001
Non-native species abundance density	Total species abundance density*	0.919	<0.001
	Resource species abundance density*	0.473	<0.001
	Native resource species abundance density	0.121	0.274
	Native species abundance density*	0.248	0.024
Non-native species abundance dominance	Resource species abundance dominance*	-0.431	<0.001

	Native resource species abundance dominance*	-0.883	<0.001

Note. Statistically significant correlations are marked with an asterisk (alpha equals 0.05). For dominance comparisons, native richness and abundance were not included, as native and non-native species were disjoint sets (r = -1.000).