Fall 12-13-2019

# The Best Management Practices for Addressing Human-Caused Riparian and Wetland Degradation

Aldo Lopez
*University of San Francisco*, alopez27@dons.usfca.edu

## Table of Contents

## List of Figures



## List of Tables

## Abstract
Riparian and wetland ecosystems accomplish a variety of significant ecological purposes, especially in the State of California where a majority of these ecosystems have been removed, degraded, or altered due to human interferences. A large portion of this interference comes from a strong agricultural presence throughout the state. In order to combat further ecological loss, private and public entities have begun strong restorative and managerial efforts. This project reviews the effects of agriculture in riparian and wetland areas, and what are the best management practices focusing on the Santa Clara River Watershed and the Elkhorn Slough found in Monterey Bay. Two methods of evaluating restoration projects are discussed, the Society for Ecological Restoration International Primer(SER Primer), which gives details on how to include different types of wetland and riparian zones into a restoration project regardless of ecological and economic complexity; and the California Rapid Assessment Method (CRAM), which gives practitioners a cost-effective and swift assessment protocol for all types of wetlands and riparian zones. The results call for a combination of the SER Primer and CRAM which will focus on developing a centralized database that allows for different restoration techniques and data to be shared and studied. With the aid from the results, recommendations were developed in order to help aid future restoration efforts in the Watsonville Slough system.

## 1. Introduction
California's wetland and riparian zones have proven to be immensely important and popular for its residents by providing recreational areas to enjoy activities such as hiking, fishing, and camping to name a few (Zavaleta et al. 2016). These ecosystems also provide benefits for both humans and wildlife, by providing habitat, flood control, migration corridors especially for migrating birds, and nutrient cycling (Svejcar 1997: Stein et al. 2000: EPA 2002: Propato et al. 2018). Due to the dry Mediterranean climate found in the Western United States including California, most of the riparian and wetland zones are shaped as narrow strips and are also found to be highly productive compared to their neighboring ecosystems. Since these areas are highly productive, a great amount of species highly depends on both wetland and riparian zones, approximately 51-82% of all species in the Southwestern United States are dependent on these zones Wetlands are not only important in the Western United States, but also throughout all of the United States. 50% of protected migratory bird species, approximately 95% of commercially harvested fish, and 80% of birds that breed in the US rely on wetland and riparian habitats.

In a global aspect, wetlands cover roughly 12.8 million km$^2$ or 8.5% of land surface (Merriman et al. 2018: Finlayson et al. 1999: Barendregt, Swarth, 2013: United States Department of Agriculture 2019). Even with such a small percentage of wetland cover, many densely human populated hubs are found near wetlands. Due to constant and heavy human land development, approximately a half of the world's wetland zones in the past century alone, and 85% of that loss is caused by agricultural (Figures 1 and 2) Despite the massive importance wetlands provide, only 15% of the earth's wetlands are considered to be protected and 10% of coastal and marine areas fall under some sort of national jurisdiction.

Figure 1. Amount of wetland area lost in the lower 48 states of the US by 1980 (United States Department of Agriculture 2019).

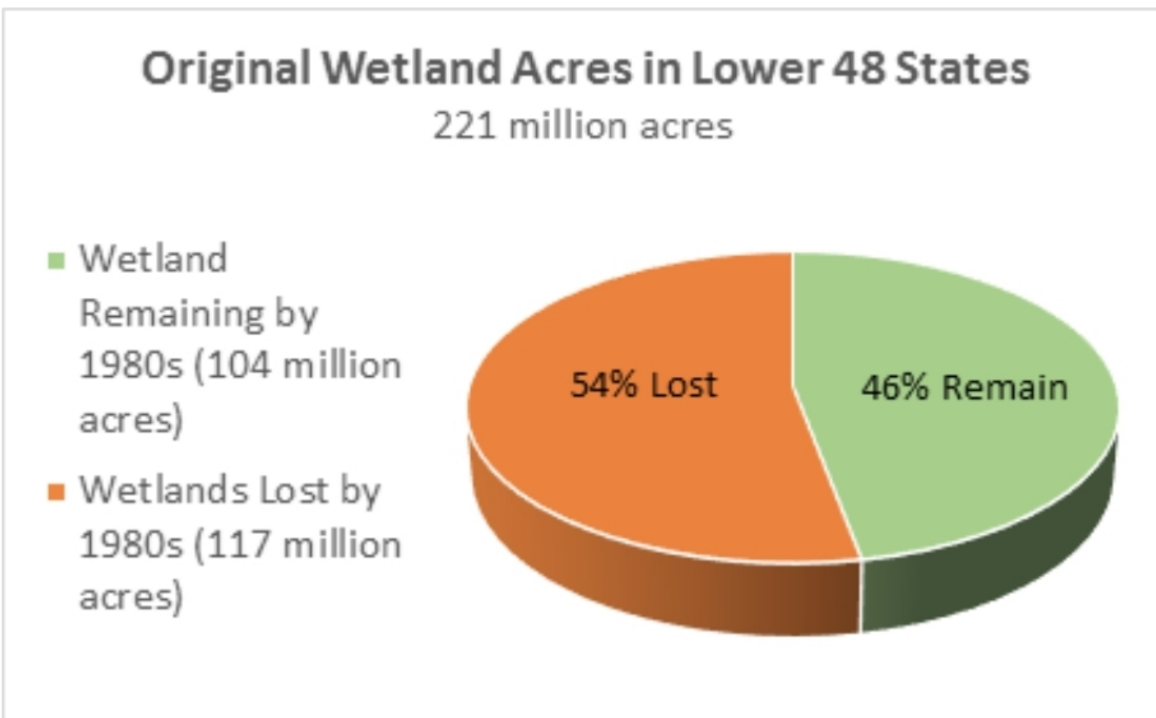
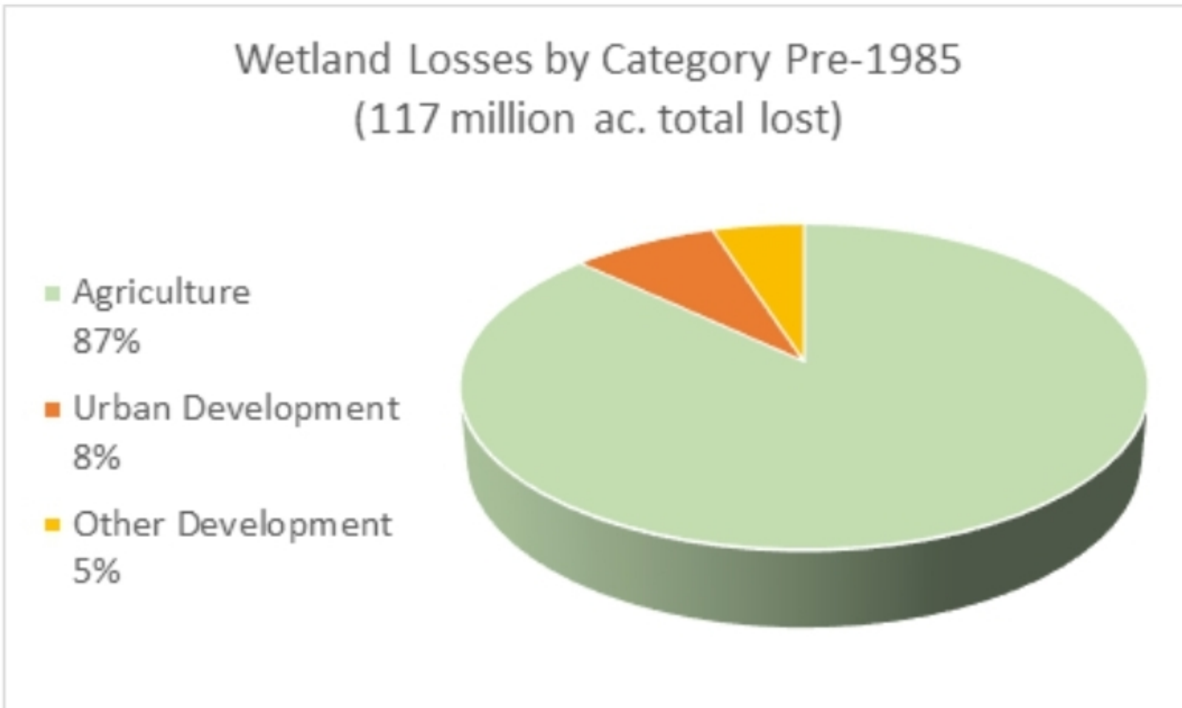


Figure 2. Primary wetland loss prior to 1985 (United States Department of Agriculture 2019).




Wetlands and riparian areas are also very important for the safety of humans throughout the US. These ecosystems act as a natural flood protection and also act as a buffer between wave action and shoreline erosion throughout their corresponding communities (EPA 2002: Propato et al. 2018: Tiner et al. 2013). Economists have revealed that wetlands located in the United States, have provided approximately 23.2 billion dollars of protection per year. Due to the removal of the natural forested wetland near the Mississippi River, the area has lost as much as 80% of the historical water and flood storage capacity. Prior to Hurricane Katrina (2005), Louisiana alone was spending approximately 816 million dollars towards storm protection per year due to the loss of wetland habitat. Since Hurricane Katrina occurred, an added loss of 34 million dollars has accrued annually. Wetlands and ecosystems also act as a natural filtration system for potential drinking water and water being released to our oceans and seas.

California's agriculture sector is a great contributor to the state's economy, but it has also contributed a large amount of damage to the state's riparian and wetland ecosystems (Carpenter et al. 1998: Elkhorn Slough Reserve 2019). Land development is at the forefront of wetland and ecosystem disturbance, due to the nutrient rich and relatively easy to maneuver soils. After an area has been developed for agricultural use, excessive run-off and lack of biodiversity also lead to long term wetland and riparian degradation. Wetland and riparian zones natural filtration systems have been altered and damaged throughout all of California, allowing for all of the harmful agricultural runoff to be essentially transported out to sea untreated (Dowd et al 2008: Palaima 2013).

Organizations throughout California have developed their own restoration and management practices in order to combat the harms of agriculture in wetlands. Even though the intentions of each organization are to facilitate the well-being of their local wetland and riparian area, but very little collaboration has been accomplished throughout the state when it comes to sharing data and techniques. Some techniques also have the potential to be contradictory or biased towards their specific goals (Bruggeman, Jones 2008). Restoration bias is also shown when it comes to selecting a restoration site (Stanford et al. 2018). Restoration specialists tend to select restoration sites where the ecosystem is ecologically complex, recreationally popular, and relatively fit. As a consequence, restoration efforts tend to be located in upper to middle class mostly white communities. While restoration efforts tend to be generally ignored in the lower class mostly Latino and African American communities.

For all the reasons details mentioned previously, the goal of this study is to provide a wetland and riparian zone restoration template for the state of California. The goal of the template will be to allow for any organization or institution to use this template and be able to create a restoration plan that will allow for the desired ecological result while still permitting for the historically ignored sections of wetland and riparian zones regardless of community wealth and ecological health and complexity. Two restoration projects found in the Santa Clara Watershed and Elkhorn

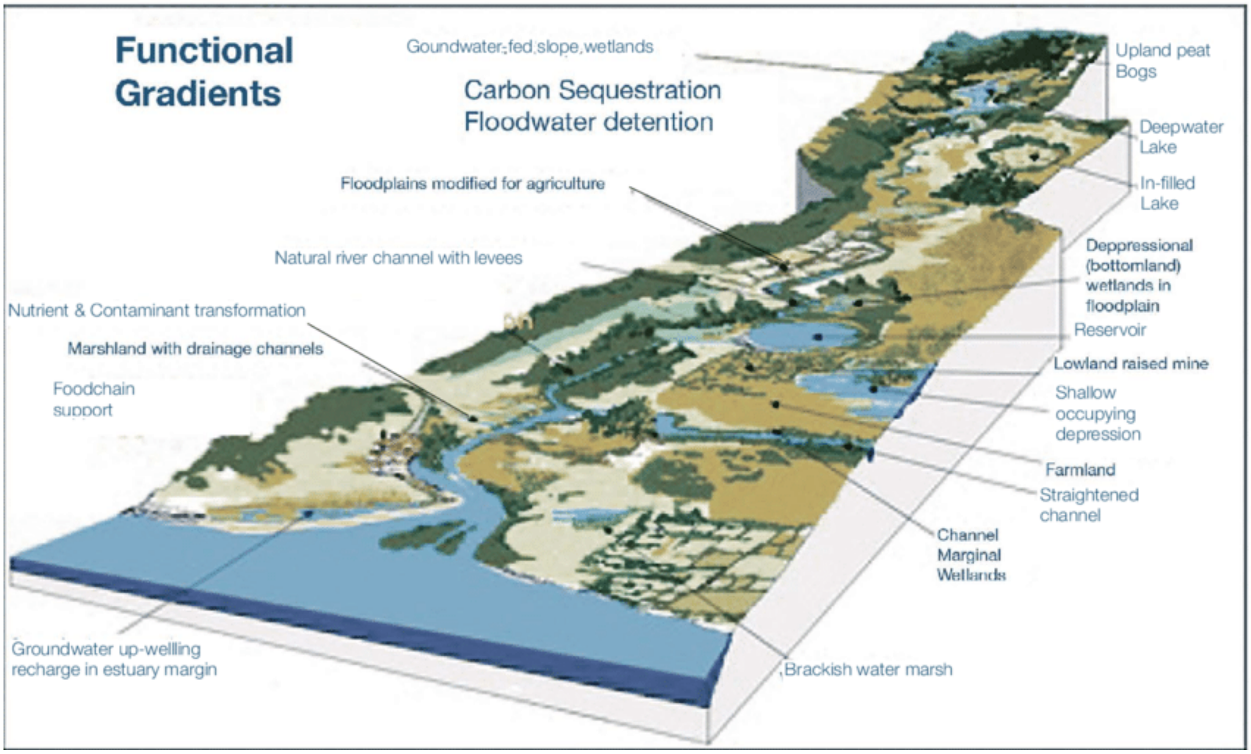
Slough, respectively, will be reviewed and critiqued on the grounds of method and collaboration. Based on the findings, recommendations will be developed and displayed.

# 2.0 Background

## 2.1 What is a Wetland and a Riparian Zone?

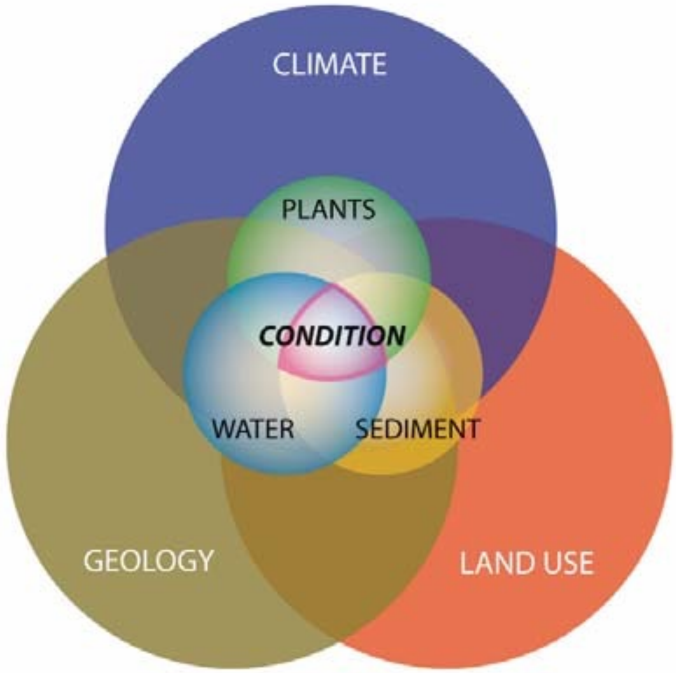
Both wetlands and riparian zones can be viewed as a transition between terrestrial and aquatic systems (Tiner et al. 2013: Baldwin et al. 2009: Chabreck 1988: Committee on Characterization of Wetlands. 1995: Keddy 1999: Dahl, Allord 1996). A riparian zone is a mass of water which acts as a connection between wetlands and upland areas (Bureau of Land Management 2019)
A wetland is an area which is seasonally or perennially flooded and contains adapted aquatic flora (NOAA 2019). Many things contribute to the character of a wetland and riparian zone including geology and hydrology, gradient, size of watershed, and local climate patterns. The positioning of both wetlands and riparian zones have allowed for distinctive properties that other landforms and ecosystems do not and cannot possess (Figure 3) . The constant freshwater flow towards seawater has allowed for some of the greatest levels of productivity found in the world. Created within these soils are primary producers that are the lifeline for the massive food web. The soils in a wetland also help with carbon sequestration (Brevik and Homburg, 2004). Some vegetation and wildlife have evolved to be able to succeed in both wet and dry conditions, allowing for a great amount of biodiversity.

Figure 3. Physical and hydrological contributions to wetland and riparian zones (Magsig et al. 2012)




Fresh and saltwater marshes, swamps, and shores exposed to flooding by tidal activities can all be classified as wetlands (Svejcar 1997). They are normally found in relatively flat terrains but can also be found in gently sloping beaches. The U.S Fish and Wildlife Service has classified most wetlands into three different categories marine (open ocean and shorelines), estuarine (fresh and salt-water mixing areas), and palustrine (freshwater areas). Positive wetland conditions are created by climate, geology, land use, water, sediment, and plants (Figure 4) ( United States Department of Agriculture, 2019)

Figure 4. Positive Wetland Conditions (Unites States Department of Agriculture 2019)




Riparian zones act not only as habitats but also as passages for flora and fauna communities (Bureau of Land Management 2019). They are the connection between streams, wetlands, and upland areas. The water itself found in riparian zones support the existence of life in the area, especially in the arid west climate that the state of California is found in. Californian riparian zones have a distinct forests, that include valley oak (*Quercus lobata)*, cottonwoods (*Populus* sp*.)*, western sycamore (*Platanus racemose)*, and ash trees (*Fraxinus* sp.).

## 2.2 Areas of Interest

For the purpose of this study, I have chosen to focus my efforts in two different regions of California, the Santa Clara River Watershed located mostly in Ventura County, and sloughs found in the Monterey Bay mainly focused on the Elkhorn Slough (Figure 5).

Figure 5. Map of Areas of Interest


## 2.3 Santa Clara River Watershed

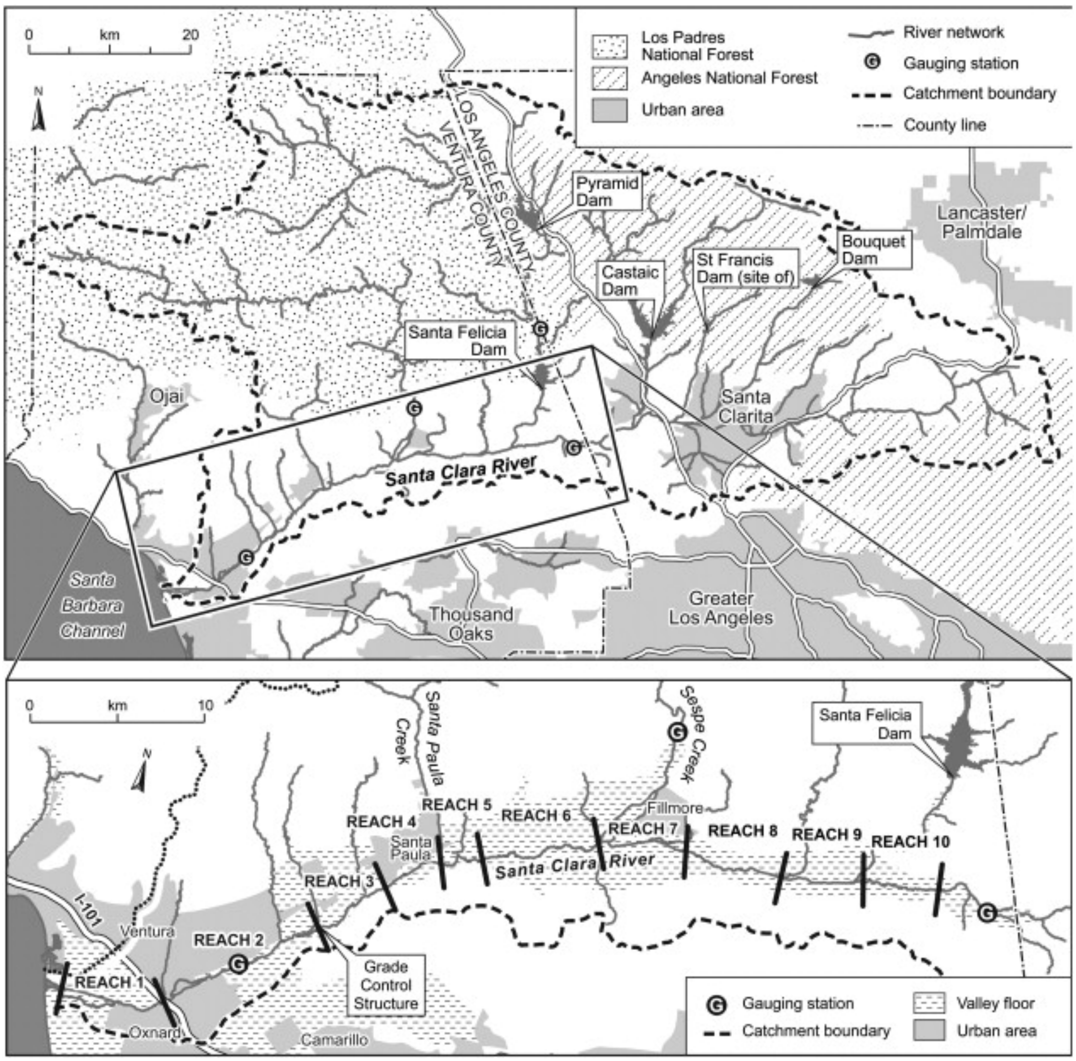
The Santa Clara River Watershed is located in both Los Angeles and Ventura counties in southern California (Figure 6). Starting in the San Gabriel Mountains and running approximately 132 km through the Oxnard Plains into the Pacific Ocean, makes it one of the largest water systems in the region (Beller et al. 2015: The Nature Conservancy 2008: Thompson 1961). The watershed supports 18 state and federally threatened or endangered species. The Santa Clara River (SCR) is an intermittent alluvial river system located in a semi-arid Mediterranean zone. A two-season Mediterranean climate limits its streamflow to peaks during the rainy season between November and March. Approximately 90% of the basin's topography is categorized as rugged; the remaining 10% of the topography is comprised of a coastal plain and a valley floor composed of a set of northeast trending mountains and Transverse Ranges (Hanson et al. 2003: Martin 1986).

Early settlers in the 18th century were the first people to begin large scale field modifications in the watershed to accommodate for stock grazing and small agricultural plots (Beller et al. 2015). More extensive land conversions to the watershed began between the late 19th and early 20th centuries in order to meet growing agricultural needs. Growing surrounding urbanization called for the construction of several dams like the Santa Felicia Dam built in 1955 and the Castaic Dam built in 1971. Due to all the of the human land use needs built in and around the riverbeds and floodplains, extensive construction of embankments and flood protection has been built all throughout the SCR.

Due to extensive human development in the SCR watershed, groundwater supplies have been steadily decreasing in past one-hundred years (Hanson et al. 2003). Before developers arrived and began to alter the area, the greatest groundwater discharge was from natural outflow towards coastal drainage systems and evapotranspiration. Thousands of water-supply wells drastically reduced the amount of outflow and have now become the main cause of groundwater outflow. Between 1984 and 1993 37% of well pumpage in the watershed was located in the upper Santa Clara River Valley area and the Oxnard Plain subareas.

Due to the large amount of groundwater lost in the watershed, land subsidence has been recorded (Hanson et al. 2003: Galloway, Burbey 2011). The first record of water level decline land subsidence was calculated in 1939, resulting in 82.33cm of total land subsidence located in the southern section of the watershed. Further study of the models suggests that most of the subsidence occurred after a long drought in the late 1920s. Additional subsidence also occurred during the 1950s and 60s when large scale agricultural expansion was developed in the basin primarily in the Oxnard Plains. Due to the culmination of land subsidence, saltwater intrusion began to occur. The first record of suspected saltwater intrusion was recorded in 1931. Simulations created for the region show that saltwater intrusion first appeared in 1927 and was present all the way until the end of the simulation in 1993.

Figure 6. Map of the Santa Clara Watershed (Downs et al. 2013)




## 2.4 The Santa Clara Watershed Restoration Project Overview

The SCR lies along the South Coast of California culminating at the Pacific Ocean in the county of Ventura (Myers et al. 2000: The Nature Conservancy 2008: Thompson 1961). The SCR is one of the few remaining non-channelized, least ecologically altered, river systems in Southern

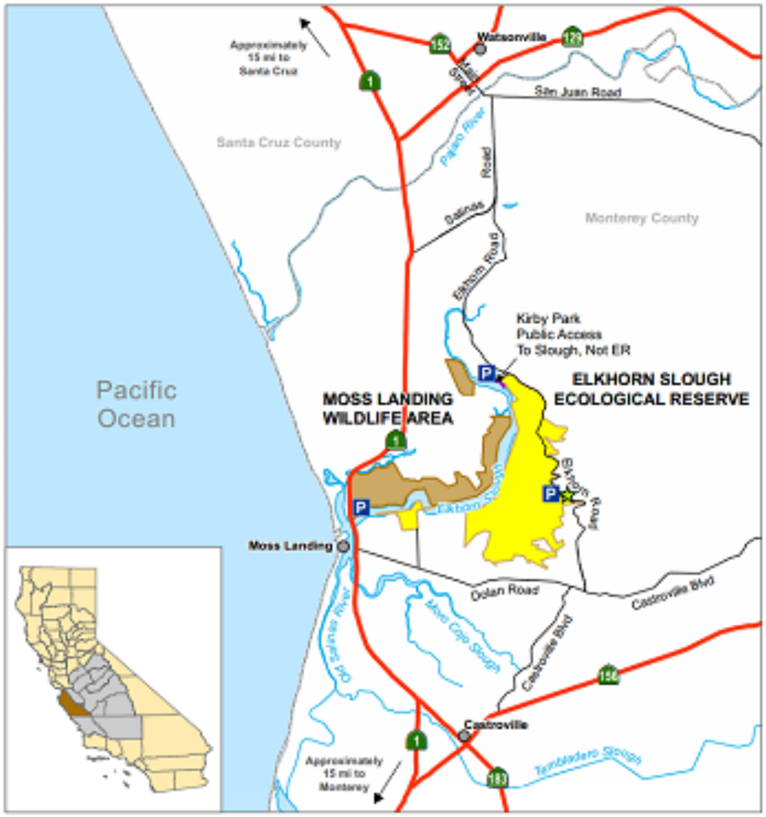
California. Due to its Mediterranean-type climate, the watershed has a variable flow, and can have dry sections during the prolonged arid times especially during hot summer months. The SCR's valuable resources have been progressively exposed to land use conversion and modifications to its hydrology, causing for the land parcels along the river to substantially increase in size and disturbance throughout time.

The Nature Conservancy (The Conservancy) partnered with other local groups and has been working for approximately 15 years to uphold and improve the biodiversity of the SCR by directly acquiring private property along the watershed from willing sellers (Parker et al. 2016). Once a property has been acquired, it is then assessed for restoration potential. This work has been conducted by the essential principle that the riparian and natural floodplains will reinforce native biodiversity using larger sections of restoration and contiguous habitat.  Project planners do realize smaller portions of landscapes might have higher priority features than those of larger landscapes. For this reason, all conservation and restoration efforts have been categorized into five pre-selected, "high-value conservation nodes" throughout the SCR.

### 2.5 Monterey Bay Slough Systems

Monterey Bay is home to several slough systems. For the purposes of this study, the Elkhorn Slough (ES) watershed system located in Monterey County, and the several sloughs found in the city of Watsonville located in Santa Cruz County will be the main area of focus (Elkhorn Slough Reserve: Watsonville Wetlands Watch: Caffrey et al. 2002) (Figure 7). Elkhorn Slough is home to the largest tract of tidal salt marsh in California outside of San Francisco Bay. Its great size delivers an abundant amount of habitat for land and marine mammals, fish, migratory birds, and plants species. (Elkhorn Slough Reserve 2019).

Figure 7. Map of Elkhorn Slough (Department of Fish and Wildlife 2019)




Elkhorn Slough was a seasonal estuary and coastal lagoon up until 1946, the estuary had a natural sand berm dividing it from the ocean only breaching during strong winter storms (Barry et al. 1996). According to archaeological studies, the slough was covered in freshwater animal and plant life. In 1946 construction of jetties located in neighboring Moss Landing caused ES to be subject to daily tidal exchange, causing extensive erosion throughout the slough. The current habitats found in ES main channel and creeks are salt evaporation ponds, salt marsh, and mudflats. The upper slough has the most salinity and temperature variability. The main channel runs 7km inland and is comprised of 141.1 hectares.  Due to the constant tidal exchange throughout the slough depth and width fluctuate; with an average width of 15m and average depth of 1.5m at the head of the slough, and an average width of 100m and 5m deep at the mouth of the slough.

The city of Watsonville has neighboring slough systems that encompasses approximately 800 acres. In total the Watsonville Slough systems (WSS) are made up of six mostly freshwater slough all being fed by the Pajaro Valley watershed (Watsonville Wetlands Watch 2019). The WS is one of the last major freshwater marshlands in California's coastal zone, giving habitat to 23 species of native flora and fauna listed as threatened and/or endangered. WSS is one of the eleven major watersheds that drain into the Monterey Bay (Powers 2006). Both ES and WSS watersheds have been greatly affected by the largescale farming industries that mainly focus on berry and artichoke production. Largescale runoff and land development have been the main causes of land and water degradation. The EPA approved the WS systems to be listed under Section 303(d) of the Clean Water Act for contaminations via pathogens, pesticides, and sedimentation. Under section 303(d) of the Clean Water Act, all states must list all surface waters that are not able to meet proper water quality standards after best management practices have been implemented.

### 2.6 Elkhorn Slough Restoration Project Overview

ES was being degraded due to large amounts of soil loss from fast moving water through the construction of the manmade channel in 1946. (Wasson et al. 2015). The soil loss also caused large amounts of salt marsh habitat. The Elkhorn Slough Foundation and other organizations began a large scale collaboration with other local organizations that have ties to the slough. The reason why a large-scale collaboration was brought into effect was due to the popularity of the slough area. A lot of fisherman, birders, kayakers, other recreational groups, and scientific groups have a lot invested in the well-being of the slough and were included in the decision-making process.

### 2.7 State and Federal Protection of Wetlands and Riparian Zones

Both the state of California and the US federal government have recognized the importance of wetlands and riparian zones and have either assigned agencies or put laws and/or ordnances in order to protect them. California's agency with the most contributions is the California Department of Fish and Wildlife (CDFW) mainly with their 1600 permit also known as the Lake and Streambed Alteration Agreement.

The 1600 permit requires that any person, state, local government, or public utility to notify the CDFW for any of the following activities (CDFW 2019):

- Divert or obstruct the natural flow of any lake, river, or stream
- Deposit, dispose, or use of material into any lake, river, or stream
- Change the bed, channel, or bank of any lake, river, or stream

There is also the State Water Resource Control Board (SWRCB) which gets its jurisdiction from their 401 permits through the Clean Water Act (CWA)(EPA 2019). The 401 permit provides states with the authority to make sure that any person or organization will not violate water quality standards

As for federal resources that have the most contributions, these are the United States Fish and Wildlife Service (USFWS) and the United States Army Corps of Engineers (USACE). The USFWS has authority over federally endangered species and their habitats. While the USACE oversees section 404 of the CWA which manages discharge of fill or dredge material affecting water resources, including wetlands and riparian zones.

## 2.8 Key Effects of Agriculture Pollution on Wetland and Riparian Zones

Since the enactment of the CWA in 1972, point source pollution has been for the most part been eliminated as a major threat to waterways and the surrounding ecosystems. Nonpoint source pollution (NPS) has now became the greatest source of pollution of waterways throughout the US (Dowd et al. 2008). Fertilizers, manures, and pesticides make up the top three most common agricultural nonpoint source pollutants that can make their way to surface waters through direct runoff towards drainage ditches and streams, and/or percolation into groundwater that will later be exposed through springs or connecting streams and sloughs (Dowd et al 2008). Phosphorous (P) and nitrogen (N) are the most common elements found in NPS that causes the harmful reaction in waterways (Carpenter et al 1998).

Excess levels of P and N can cause eutrophication, making surface water not suitable for drinking water, irrigation, recreation, and fishing. Eutrophication is credited for impairing roughly about 60% of riparian areas and 50% of lake areas throughout the United States

(Carpenter et al. 1998). Eutrophication can also be created by excess logging and construction near waterways causing siltation.  Algae blooms are the most common side effects of eutrophication near marine or saltwater ecosystems, which then release harmful toxins and cause anoxia when the algae start to decompose (Carpenter et al. 1998). As for freshwater ecosystems, cyanobacteria blooms are the results of eutrophication in freshwater zones. Cyanobacteria blooms can cause large fish kills, unsafe drinking water, and serious harm to livestock and humans (Carpenter et al. 1998).

With excessive amounts of N making its way to surface water, nitrate pollution is another harmful outcome. Nitrate pollution is very harmful for humans and large numbers of mammals (Carpenter et al. 1998. If nitrates in water are somehow consumed by humans especially infants, they can cause methemoglobinemia a condition that disrupts oxygen levels in the body. Due to its severity, the Environmental Protection Agency (EPA) has set a maximum contaminant level of nitrates in drinking water at 10 mg/L in order to safeguard infants between the ages of 3 to 6 months. This limit on nitrate pollution forces the agriculture industry in the US to monitor and limit nitrate runoff levels around waterways. Since direct exposure with P in not harmful to humans the EPA has not set any restrictions towards the exposure of P in waterways.

Lack of stakeholder and landholder participation is also a major issue when it comes to the effects of agriculture on the environment. Landholders and farmers in general tend to see restoration efforts as a threat to their overall profits (Couix and Gonzalo-Turpin 2018). So, when it comes to cooperating to any restoration efforts in or near their property, most landholders tend to not allow access or provide any useful information about the site. Trust issues can also be found for livestock landholders not just the agriculture industry. Livestock landholders tend to worry about lost or degraded supplies of fodder for their livestock (Couix and Gonzalo-Turpin 2018).

The only real environmental legislation a landholder or stakeholder needs to follow is the CWA. But if they are not dumping excessive amounts of nitrates near waterways, there is no other real incentive for a landholder to comply or cooperate with any restoration efforts in their property. (Couix and Gonzalo-Turpin 2018). Which is why it is very important for a restoration project to have a healthy and positive relationship with the local stakeholders. Having a positive educational program can significantly help provide a successful restoration project.

## 2.9 Ways to Evaluate Restoration Success

It is very important to determine what a successful rubric must include in order to conclude if a restoration project is successful or needs improvement. Most project managers in the US tend to derive mitigation ratios based on professional and personal judgements (Bruggeman and Jones 2008: EPA 2004). However, the lack of continuity and project stability can be cause for concern, especially when it comes to dealing with state and federally endangered or special interest species. The use of different restoration techniques and/or project requirements makes it problematic for different agencies and entities to duplicate, enhance, or collaborate with one another. Another challenge facing restoration managers and biologists, is how to come up with practical ways to measure conditions throughout the sites. It is difficult due to the high demand of funding and time to determine the health of all biological entities and it what way human activity has harmed these ecosystems. Human activity is not limited to how human physically disturbed a site using modern tools to build housing or other structures. But it also includes ways humans accidently interrupted the ecosystems by either introducing invasive species or livestock. The long-lasting effects of some chemicals introduced by humans to the environment can also be difficult to pinpoint the origins of such chemicals and how to halt such exposure.

Choosing which method to utilize for an individual restoration project must include the best management practices. Each project will and must have its own restoration method and success criteria, however there should still try to be some level of consistency to reduce any conflicting results towards a similar project. An urban restoration project might have different goals than that of a secluded more natural restoration project. An urban project might put into higher regard the aesthetics of the project due to its close proximity to human interactions. It might also be more focused towards developing structural integrity for local urban structures. While a secluded project will only need to worry about meeting its biodiversity or wildlife habitat area. These are a few factors that must be considered in the planning stages.

In order to combat any disconnection between projects, the Society for Ecological Restoration has produced procedures for restoration projects and implemented The Society for Ecological Restoration (SER) International Primer on Ecological Restoration (SER 2004). The CDFW issued provisions in their riparian restoration requirements found in the 1600 permit, however they have proven to be inconsistent at best all through the state since each state region follows the requirements as they see fit (Stein et al. 2000). Another rating method that has been developed in the state is the California Rapid Assessment Method in order to establish satisfactory mitigation for water resources. This method allows for a cost-effective and uniform evaluation of field conditions (Collins et al. 2008). Another popular model for coastal resource management is the ecosystem-based management (EBM), but as mention before this management plan has also seen very few examples of it showing success of the application (Wasson et al. 2015).

Figuring out what makes a successful restoration site should not be the sole focus of a restoration plan. We must also take into consideration where and why a restoration site has been chosen. It is known that human interaction with a healthy natural environment leads to enhanced quality of life and creates for opportunity for outdoor recreation, making it vital for restoration sites to be inclusive to all communities not just sites next to wealthy predominately white communities. Restoration sites also tend to be found in ecosystems with resources deems high in popularity, economic, and/or ecologically value (Stanford et al. 2018). Since funding for restoration sites tend to be limited both in money and time, managers tend to pick sites that will maximize benefits for the environment but mainly have the most positive human impact. If a site is found to have minimal benefits for humans, it is due to an agencies responsibility to protect endangered and endemic species. Sites might also be chosen for their minimal human assistance, by either simply fencing off site from harmful entity. And ignoring a high cost time consuming site that needs a lot of attention to eradicate a very invasive harmful species that has no feasibility to recover with no assistance (Stanford et al. 2018: Acuña et al. 2017). It is understandable why a restoration site must be implemented in the highest area of success, but that does not mean we are allowed to ignore or disvalue other remote or extensive potential restoration areas. Us as humans have the responsibility to try and repair all of our past environmental mistakes. It is also the responsibility of the project manager to find the balance of choosing realistic goals, while still pushing the envelope towards the most positive outcome as possible (Hilderbrand et al. 2005).

.

Public endorsements and participation should be a key factor in deciding what makes a restoration project a success. One of the main challenges of restoration is the need for the project to take a long period of time due to constant monitoring and updates, and in order to have long standing success it is important to have the backing of the local community (Patorok et al. 1997)

### 2.10 Investigation Review

Despite large amounts of funding being given to wetland and riparian restoration and conservation projects, and the constant aid from state and federal mandates, there continues to be a lot of room for improvement in most aspects of a restoration or conservation project. Agency permits are vague and lack continuity, and most of the research being done is left open for interpretation. Causing any attempts for guidance to be inconsistent, lacking, and at times contradictory. Wetland and riparian ecosystems are complicated and in turn so are their restoration efforts. Which is why the goal of this study is to determine what are the most effective restoration techniques and management practices if any.

## 3. Methodology

### 3.1 Data Literature Acquisition

To properly examine the best management practices for restoring wetland and riparian areas, an analysis and historical background on wetlands and riparian degradation on native flora and fauna, past restoration techniques, and restoration success were considered. Peer reviewed articles were gathered using a variety of reference databases such as FUSION, SCOPUS, and Google Scholar: and from professional connections. The data collected were reviewed and synthesized to compare and contrast two modern restoration management plans. The management plans will then be displayed in a sequence of tables and graphs to be further studied. Concluding with restoration management strategies will be applied to the future management of the Watsonville Slough systems, located in the city of Watsonville CA.

In order to complete the analysis on best management practices for wetland and riparian zones are, approximately 50 resources including research articles have been referred. Approximately

42 of the 50 were scientific articles while the rest were organizational websites. A significant amount of the references gave a large amount of the background needed to allow for the creation of modern restoration techniques.

## 3.2 Interviews

As part of this study, professional connections were used to interview some of the local leaders and experts of restoration in the Monterey Bay area. The goal was also to receive further insight on the ES restoration project that is a key subject for this study, since the interviewees were the individuals in charge of the developing and performing the restoration plan.

The first interview was conducted with Mark Silberstein, Elkhorn Slough Foundation Executive Director. The interview questions are as follows:

1. How important is it to own or have primary control over the property you are attempting to restore?
2. Is it imperative to have a positive relationship with neighboring landholders? If so, what are the best ways to obtaining that relationship and sustaining it without compromising your project goals?
3. Do you believe that a large parcel size of a restoration project hinders or helps the overall success of the project?

The second interview was conducted with Kerstin Wasson, Elkhorn Slough National Estuarine Research Coordinator. The interview questions are as follows:

1. How do you go about deciding what makes a successful restoration project?
2. Do you believe that a large parcel size of a restoration project hinders or helps the overall success of the project?
3. Have you used a reference site on any of your past restoration projects? Also, if a reference site is not possible, what are options could you use?

# 4.0 Results

## 4.1 Society for Ecological Restoration

One of the approaches to monitor and evaluate ecological restoration projects is the Society for Ecological Restoration (SER) International Primer on Ecological Restoration (SER Primer) (SER 2004). According to the SER Primer, ecological restoration is the practice of aiding the recovery of an ecosystem that has been reduced or destroyed. The majority of ecosystem functions should be evaluated distinctly and demand extensive research, but SER Primer states nine attributes that can aid and conclude when a restoration effort has been conducted successfully. Since every ecosystem is unique, restoration projects do not need to precisely follow the full definition of each individual attribute, but it should demonstrate the proper progression of ecosystem development are on track to meet all goals and objectives; making it easier to measure some attributes than others.

The SER nine attributes of restored ecosystems are as follows (SER 2004):

1. "The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure.
2. The restored ecosystem consists of indigenous species to the greatest practicable extent. In restored cultural ecosystems, allowances can be made for exotic domesticated species and for non-invasive ruderal and segetal species that presumably co-evolved with them. Ruderals are plants that colonize disturbed sites, whereas segetals typically grow inter-mixed with crop species.
3. All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or, if they are not, the missing groups have the potential to colonize by natural means.
4. The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory.
5. The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent.

6. The restored ecosystem is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges.
7. Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible.
8. The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem.
9. The restored ecosystem is self-sustaining to the same degree as its reference ecosystem and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure and function may change as part of normal ecosystem development and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change."

Additional attributes should be included in this list if they are recognized as goals or objectives of the restoration project (SER 2004). For example, restoration goals could include ecosystem services that provide a benefit to society, such as improved water quality, recreational fishing, and aesthetic beauty. Another goal could be to restore habitat for a specific special-status species. Goals can also focus on social outcomes, such as educating the community about the environment and bringing them together to collectively work on a restoration project.

The use of multiple reference ecosystems is stated to be significant towards planning and evaluating a restoration project. Different reference sites can provide many sources of data material towards different restoration projects. The sources include but are not limited to:

- Historic and modern aerial photos that depict restoration capacity
- Historical species lists, maps, and ecological records
- Herbarium and other museum quality specimens
- Paleoecological evidence

Comparing a reference site to a restoration site can be complex, it is important to identify and understand what these complex factors are before work is started (SER 2004). Usually a reference site is chosen for having for biodiversity and being more established, a restoration site is obviously lacking in those regards and is found in the initial stages of an ecological process. It is easier to compare sites when the restoration site has had time to develop. Another obstacle is dealing with a reference site that itself has been tainted by human impact, it should be made a priority to try and avoid copying the same human impacts at the restoration site.

According to the SER Primer, it is important to have all reference site details and the restoration goals in writing (SER 2004). The goals should be realistic and should reflect the capacity and the size of the restoration project. Overall general goals are set for the large-scale restoration projects, including landscape restoration and also the reference site can be placed under general goals. Aerial photographs are a good source of information when it comes to general goals. Some restoration projects might involve more specific goals, these tend to be for more small-scale restoration projects. This will require more detailed information like on-site data throughout the restoration site. When evaluating the success of a restoration site, the objectives and goals should be easily established and answered. If not, the goals and objectives were not easily specified or established before the project began.

The removal of non-native invasive species is most often a restoration project goal, but it is important to identify which exact non-native species should be chosen for eradication (SER 2004). Non-native species eradication tends to be both monetary and time expensive, which forces project managers to be practical. Each non-native species should be evaluated by ecological professionals for its threat level and policies should be applied accordingly. Not all non-native plant species are disruptive or harmful to an ecosystem, some can actually be helpful and provide cover crop and nitrogen fixers to the area. While other non-native species do cause some ecological harm but can be too expensive to control throughout a project.

Prior to the implementation of a restoration project, the success criteria, monitoring protocols, data evaluation, and objectives should be implemented in the original restoration plan (SER 2004). Success criteria are designed from knowledge gained from the reference sites and provide concrete data on whether a restoration site has been successful or not. If the data shows a successful criteria, then that means that the project objectives were a success. Successful project objectives in return usually mean that the project site will most likely be strong enough to survive on its own without any future human intervention. It is important to identify the possibility and exemption of a successful criteria that will lead to successful project goals. Unforeseen environmental factors and/or insufficient criteria can lead to a lacking restoration site. The only real way to deal with these issues is to use professional judgement, but in doing so some bias will be unavoidable.

According to the SER Primer, there are three available strategies that allow for restoration evaluations: direct comparison, attribute analysis and trajectory analysis (SER 2004). In direct comparison, particular structures representing biotic and abiotic factors are chosen to be compared between a reference and a restoration. When data of direct comparisons are similar and others are dissimilar, it can lead to the results being doubted. One of the most suitable methods to combat direct comparison uncertainty, is to carefully choose a variety of characteristics that completely characterize the entire ecosystem.

Attribute analysis uses attributes to be evaluated, quantifiable and semi-quantifiable data gathered from monitoring, and additional data and recordings are used to conclude if each of the determined goals have been met (SER 2004). In trajectory analysis, data from a restoration site is regularly taken in order to establish if trends can be found. A restoration site trend should move towards that of the reference site conditions, once that is shown then it is safe to say the restoration site is successful.  No timeframe is given in the hopes of allowing for sufficient time to properly gather and analyze data.

The SER Primer covers everything from planning to evaluation of a restoration project. It allows for data analysis in order to determine success, but also allows for professional judgement to evaluate restoration projects.  The SER Primer underlines the fact that both the restoration and reference sites are unique to each other and between different projects. The SER Primer does not provide any type of standardized record keeping, nor does it provide a consolidated information hub to help track and share data from different restoration projects.

## 4.2 California Rapid Assessment Method

The California Rapid Assessment Method for Wetlands User's Manual (CRAM), was developed to deliver swift, uniform, "scientifically defensible", cost-effective assessments of the status and trends in the settings of a wetland and the execution of related policies, and projects all over California (Collins et al. 2008; Kilmas, Coastal 2008). CRAM was created by resource managers, agencies like such as California State Water Resources Control Board, CDFW, United States Army Corps of Engineers (USACE), California Coastal Commission (CCC), Regional Water Quality Control Boards, United States Environmental Protection Agency, several science-based NGOs, in-state academic institutions, and private consultants. Plenty of conservation, restoration, and management programs for California's wetland ecosystems have been well funded throughout the years; but success evaluations between all state wetland entities were varying and questionable when it came to data quality. Data distribution throughout management entities was also not readily available. To address the above-mentioned issues, CRAM was developed.

CRAM makes the assumption that ecological circumstances differ predictably along gradients of stress and can be divided into a set of distinct indicators. CRAM's three distinct criteria are as follows (Collins et al. 2008):

- the method should assess existing conditions, without regard for past, planned, or anticipated future conditions;
- the method should be truly rapid, meaning that it requires two people no more than one half day of fieldwork plus one half day of subsequent data analysis to complete; and
- the method is a site assessment based on field conditions and does not depend largely on inference from data, existing reports, opinions of site managers, etc.

CRAM is hindered by a sequence of presumptions about the interactions between hydrologic, biotic, and abiotic processes (Collins et al. 2008). CRAM assumes that the main factors of a wetland condition are both the quantity and quality of sediment and water. CRAM also assumes that geology, land use, and climate dictate the amount of water and sediment found in the wetland system.

Before field professionals arrive to a restoration site to perform a CRAM assessment, specialists should assess background material about the history and ecology of the wetland, human-caused and natural stressors (Collins et al. 2008; California Wetlands Monitoring Workgroup 2013). Relevant reports on mitigation, restoration, environmental impacts, hydrology, soils, geology, cultural and historic documents can all be very instructive and helpful.

The next step in a CRAM report will be to categorize what kind of wetland is found using the CRAM manual (Collins et al. 2008; California Wetlands Monitoring Workgroup 2013). Specialists decide on the best group of descriptions for conditions they have examined in the field, all the way from the least distinguished to the most achievable for the kind of wetland being examined. The CRAM manual acknowledges six main types of wetlands, which estuarine, depressional, riverine, slope, playas, and lacustrine wetlands (Table 1). Four of the six main wetlands also contain sub-types. The sub-types of a depressional wetland include: vernal pools and vernal pool systems, and other depressional wetlands. Sub-types for a riverine wetland include: confined and non-confined riverine wetlands. Sub-types for an estuarine wetland include: perennial saline and non-saline estuarine wetlands, and seasonal estuarine wetlands. Finally, the sub-types for a slope wetland include: seeps, springs, and wet meadows.

Table 1. Preferred AA sizes according to wetland type (California Wetlands Monitoring Workgroup 2013).

| **Wetland Type** | **Recommended AA Size** |
|---|---|
| **Slope** | |
| Spring or Seep | Preferred size is 0.50 ha (about 75m x 75m, but shape can vary); there is no minimum size (least examples can be mapped as dots). |
| Wet Meadow | Preferred size is 1.0 ha (about 140m x 140m, but shape can vary); Maximum size is 2.0 ha; minimum size is 0.1 ha (about 30m x 30m). |
| **Depressional** | |
| Vernal Pool | There are no size limits. |
| Vernal Pool System | Preferred size is <10 ha (about 300m x 300m; shape can vary); there is no minimum size so long as there are between 3 and 6 pools. If the system has between 3 and 6 pools, assess all of them. If there are more than 6 pools, select 6 that represent the range in size of pools present on the site. |
| Other Depressional | Preferred size is 1.0 ha (a 56 m radius circle or about 100m x 100m, but shape can vary); Maximum size is 2.0 ha (an 80 m radius circle or about 140m x 140m, but shape can vary); There is no minimum size. |
| **Riverine** | |
| Confined and Non- confined | Recommended length is 10x average bankfull channel width; maximum length is 200 m; minimum length is 100 m.<br><br>AA should extend laterally (landward) from the bankfull contour to encompass all the vegetation (trees, shrubs vines, etc.) that probably provide woody debris, leaves, insects, etc. to the channel and its immediate floodplain; minimum width is 2 m. |
| **Lacustrine** | Preferred size is 2.0 ha (about 140m x 140m, but shape can vary); Minimum size is 0.5 ha (about 75m x 75m). |
| **Playa** | Preferred size is 2.0 ha (about 140m x 140m, but shape can vary); Minimum size is 0.5 ha (about 75m x 75m). |
| **Estuarine** | |
| Perennial Saline | Preferred size and shape for estuarine wetlands is a 1.0 ha circle (radius about 55m), but the shape can be non-circular if necessary, to fit the wetland and to meet hydro-geomorphic and other criteria. The minimum size is 0.1 ha (about 30m x 30m). |
| Perennial Non-saline | |
| Bar-Built | Maximum size is 2.25 ha (about 150 m x 150 m, but shape can vary), The minimum size is 0.1 ha (about 30m x 30m). |

There are four key traits defining the conditions of each wetland type, which comprise of physical and biotic structure, hydrology, buffer, and landscape context (Table ) (Collins et al. 2008; California Wetlands Monitoring Workgroup 2013). There are metrics and sub-metrics within each attribute. Some metrics within buffer and landscape context include: buffer conditions and Aquatic Area Abundance or Steam Corridor Continuity. The metrics for hydrology is as follows: hydrologic connectivity, hydroperiod or channel stability, and water source. Structure is split into two sections, physical and biotic and the metrics for physical structure are as follows: structural patch richness and topographic complexity. And as for biotic, some of the metrics include vertical biotic structure and number of co-dominant species.

Table 2. Various types of wetland and riparian attributes (California Wetlands Monitoring Workgroup 2013)

| **Attributes** | | Metrics and Submetrics |
|---|---|---|
| Buffer and Landscape Context | | Aquatic Area Abundance or Steam Corridor Continuity |
| | | Stream Corridor Continuity (Bar-built estuaries only) |
| | | Aquatic Area in Adjacent Landscape (Bar-built estuaries only) |
| | | Marine Connectivity (Bar-built estuaries only) |
| | | Buffer: |
| | | Percent of AA with Buffer |
| | | Average Buffer Width |
| | | Buffer Condition |
| Hydrology | | Water Source |
| | | Hydroperiod or Channel Stability |
| | | Hydrologic Connectivity |
| Structure | Physical | Structural Patch Richness |
| | | Topographic Complexity |
| | Biotic | Plant Community: |
| | | Number of Plant Layers Present<br>or Endemic Species Richness (vernal pools only) |
| | | Number of Co-dominant Species |
| | | Percent Invasion |
| | | Horizontal Interspersion |
| | | Vertical Biotic Structure |

The following step in the CRAM procedure is to confirm the appropriate evaluation window and factors for the site assessment (Collins et al. 2008; California Wetlands Monitoring Workgroup 2013). Usually, the evaluation window for a specific wetland community depends on the growing season for the region and the distinctive traits for the local vegetation community. These windows usually lie between the months of March and September, unless the region is affected by tidal impacts or the presence of snow. In areas where snow is found, propagation might not start until May or June depending on altitude, latitude and how much snow fell during the winter months. As for areas affected by tidal forces and overall seasonal wetlands like vernal pools, the growing season is often found between the months of March and June; but vernal pools can have drastically shorter growing seasons depending on temperature and recent rainfall. CRAM explicitly states that riverine wetlands should be assessed during the late growing season not during high water marks, due to some key indicators can be hidden under water, and high danger potential for an expert to gather data in high flow areas.

The fourth step of the CRAM assessment is to determine the assessment area (AA), which is consists of the wetland that is being assessed (Collins et al. 2008; California Wetlands Monitoring Workgroup 2013). It is important to correctly to establish the most suitable AA, in order to do so the result must include stressors and management measures. Guidelines were created in order to aid practitioners; the guidelines are as follows:

- Each AA must only include one wetland and cannot include bordering wetland
- Every AA can only be composed of one wetland type
- Each AA must be classified using the CRAM wetland type and assessed using the corresponding metrics
- Individualized guidelines for riparian areas have also been defined

An added critical guideline is the size and the hydro-geomorphic integrity of a potential site no matter the wetland type (California Wetlands Monitoring Workgroup 2013). CRAM tends to be sensitive towards wetland structural complexity, giving larger AAs more of an opportunity to meet variability in configuration. Essentially, the larger the AA, the higher the CRAM score tends to be. The boundaries of any AA should be delineated based on hydrology, geomorphology, and sediment supply. With the combination of the two previously mentioned critical guidelines with the wetland type, an appropriate AA size could be established (Table 1)

The following steps of CRAM are to conduct both an initial office and field site evaluation of conditions metrics and stressors (Collins et al. 2008; California Wetlands Monitoring Workgroup 2013). Office evaluations include gathering and reviewing site management information, maps, aerial imagery, and logistically developing for site evaluations including anthropogenic stressors. Once all background information is gathered, professionals are now able to go out to the field and perform a field site evaluation. Once out on the field, AA boundaries will be established.

The final two steps in performing a CRAM assessment is to complete scoring and upload results into regional and statewide databases (Collins et al. 2008; California Wetlands Monitoring Workgroup 2013). Constructed on the component scores for the attributes and their metrics, the total score is yielded for the area evaluated. The highest scores indicate the ideal state that is expected to be reached for the wetland type. It should be known that land uses can restrict local conditions and should be put into consideration when examining CRAM scores. CRAM has developed a helpful website (wwww.cramwetlands.org) which allows for organizations to upload data entry for others to examine. The website also provides the user manual, training materials, and an electronical version of CRAM. The database can only be view by registered users, and data can only be edited by the original owners of the data.

Although CRAM has was developed to save time and effort by allowing cooperation and a list of rules and steps, CRAM still has proven to have some limitations (Collins et al. 2008). It seems that CRAM scores tend to favor wetlands that are structurally more complex. Low scores are given to more structurally damaged wetlands, which in theory can cause certain highly impacted wetlands and riparian zones to be ignored or taken out of contention for aid. This can be problematic in California, due to the lack of pristine and low complexity wetlands and riparian zones.

Overall, CRAM allows for rapid evaluation of restoration projects by providing standardized forms and guidelines (Collins et al. 2008). The standardized forms and guidelines also allow for consistency and swift assessment, which in return would allow for the field practitioners to not spend a long period of time out on the field. With its consistency, CRAM allows for organizations to become cost-effective. CRAM also cuts back the amount of dependency on site managers which might have the capability to skew or favor certain results. Possibly the most important tool that CRAM provides is a website that allows for a centralized source for the most up to date restoration results and techniques.

## 4.3 Prioritizing Riparian Conservation: A Methodology Developed for the Santa Clara River

There were a total of 68 parcels being analyzed by The Conservancy along the SCR (Parker et al. 2016). Out of the 68 parcels, only 24 of them were directly managed by The Conservancy, 1 parcel was owned by partnering local non-profit organization, and the remaining parcels were owned by private landholders. All parcels required to be within the 100-year floodplain of SCR, had not been developed for urban uses, and contain at riparian habitat. The total average size of the 68 parcels was 53.13 hectares. Out of the 68 parcels included in the analysis 42 parcels were measured to be less than 40.47 hectares in size, while only 5 parcels were greater in than 161.87 hectares in size. All plots of land hold some riparian habitat, which vary between 0.611 to 153.601 hectares and covered between 3.3 and 100% of land parcel area. The average riparian area cover per parcel was calculated to be 46.2% coverage. The average size of a riparian zone within the parcels was calculated at 21.97 hectares. According to The Conservancy, the larger plots of land tended to have smaller percentages of total riparian area. Statistical analysis determined that the correlation between the land size and riparian habitat was not significant.

Table 3. Ranking the nodes developed in the Santa Clara Watershed (Parker et al. 2016)

| Criteria | Ranking 0 | Ranking 1 (> 0–20% of max.) | Ranking 2 (> 20–40% of max.) | Ranking 3 (> 40–60% of max.) | Ranking 4 (> 60–80% of max.) | Ranking 5 (> 80–100% of max.) |
|---|---|---|---|---|---|---|
| Total Acreage | N/A | > 0–155 acres | > 155–309 acres | > 309–464 acres | > 464–618 acres | > 618–773 acres |
| Acres of Riparian Habitat | N/A (all parcels have some riparian habitat) | > 0–76 acres | > 76–152 acres | > 152–228 acres | > 228–304 acres | > 304–380 acres |
| Acres of Unique Habitat | 0 (parcels containing no unique habitat) | > 0–15 acres | > 15–30 acres | > 30–44 acres | > 44–59 acres | > 59–74 acres |

| Criteria | Ranking 0 | Ranking 2.5 | Ranking 5 |
|---|---|---|---|
| Restoration Potential | N/A | Lower restoration potential (parcel is currently in agriculture) | Higher restoration potential (parcel is not currently in agriculture) |
| Restoration Intensity | Land conversion: agricultural parcel, requires creation of new habitat | Active restoration: requires some enhancement of existing habitat, but not creation of completely new habitat | Passive restoration: no or very little action required to restore parcel |

According to The Conservancy, land acquisition and habitat restoration are their two most important methods when it comes to achieving riparian habitat protection and improvement (Parker et al. 2016). By then developing a ranking system and dividing the land parcels into nodes will allow for the best potential restoration outcome. The Conservancy also wanted to develop other science-based approaches when it comes to aiding restoration efforts. They are also very committed to the contributing resources towards completing their goals. The Conservancy believe that their approach outlined with the development of the nodes will provide future guidance for The Conservancy and outside agencies.

## 4.2 Assessing the SCR Criteria

Comparing the SCR restoration project to both the SER Primer and CRAM restoration methods will allow for the project to be analyzed for its overall success. Beginning with the criteria established by both the SER Primer and CRAM, the first step is to gather the background information needed to have a strong understanding of the area being restored. The Conservancy did state and display adequate background information in order to meet the criteria. Both methods state the importance of setting the restoration goals before beginning field work. The Conservancy stated that their goals for all restoration projects are to maintain and enhance biodiversity and acquire as much property to restore as possible (Parker et al. 2016). Even though it would have been more beneficial for future restoration projects within and outside of the organization to develop more precise goals like how much land and biodiversity should be accomplished: technically goals were set and met when it came to increasing biodiversity and land acquisition.

The SER Primer also stated criteria that are specific to the SER Primer itself and not found in CRAM. The first being the establishment of a reference site in order to compare the progress of the restoration site (Parker et al. 2016). The Conservancy did not mention the use of any reference site. Consequently, without the presence of a reference site, the use of three available strategies that allow for restoration evaluations: direct comparison, attribute analysis and trajectory analysis are also not able to be performed. Even though background information acquisition was met, the SER Primer also states the importance of gathering historic and modern aerial photos, historical species lists, herbarium and museum quality specimens, and other paleoecological evidence in to be able and depict restoration capacity, none of which were conducted by The Conservancy.

As for the criteria created by CRAM, the most important is the use of centralized database to upload all data and restoration techniques used in the project. The Conservancy did not create or upload any data to a centralized database besides the peer reviewed article by Parker et al. (2016). The Conservancy did determine and acquire large restoration areas; however, they did not use the overall techniques developed by CRAM (Table 4). The Conservancy also did develop their own scoring system, but it was not the same as the one used by CRAM (Table 3). CRAM requires the practitioners to identify what type of wetland or riparian area is being restored. The Conservancy did state that all the restoration areas in focus are in riparian zones, but mentioned areas with special traits that were never clarified if they were different wetland types. Finally, CRAM also states the importance of assessing and restoring the habitat at the best time and season, which The Conservancy did not state they did or considered (Tables 4).

### 4.3 Lessons Learned from an Ecosystem-Based Management Approach to Restoration of a California Estuary, Results

Due to the artificially deep mouth of the ES estuary, tidal amplitude and current speeds were increased leading to considerable tidal scour to the main channel causing salt marsh habitat loss (Wasson et al. 2015). Since 1870 approximately 50% of the salt marsh has been lost with an annual channel banks erosion rate of 0.3–0.6 m/year, causing sediment export from the estuary estimated at >50,000 $m^3$/year.

In order to combat the erosion problem, a collaboration of local decision makers approved 10 recommendations, followed by a phase of open comment and project modifications. After the open discussion none of the 10 recommendations were approved due to the lack of certainty that the work would not negatively impact biodiversity and water quality in the slough. As a result, the overall project was turned into a small to medium sized project, to allow for biodiversity and water quality to not be negatively affected.

## 4.4 Assessing the Elkhorn Slough Criteria

Comparing the ES restoration project to both the SER Primer and CRAM restoration methods will allow for the project to be analyzed for its overall success potential. Both the SER Primer and CRAM emphasize the importance of gathering as much site background information as possible. The ES leadership has done extensive research when it comes to historical background throughout the ES foundation's history, so it is safe to say the project had sufficient background information available. Both methods state the importance of having concrete goals in writing before field work begins. The ES restoration project did have the goals of reducing soil erosion and promoting better salt marsh habitat prior to beginning work, but it also wanted to have the flexibility of changing its techniques to ensure that biodiversity and water wellness were not negatively affected (Wasson et al. 2015).

As for the criteria developed by the SER Primer, a restoration project must develop a reference site in order to compare the progress on the project. The Wasson et al. (2015) peer reviewed article did not specifically state that the restoration project used a reference site; but after interviewing Kerstin Wasson, the project coordinator, the project indeed uses a reference site within the boundaries of the reserve (pers. comm.). With the use of a reference site, the project was able to use a combination of direct comparison and trajectory analysis as restoration evaluations.

The most important criteria created by CRAM is the use of centralized database to upload all data and restoration techniques used in a project. ES did not create or upload any data to a centralized database besides the peer reviewed article by Wasson et al. (2015). The project area was owned and managed by the project practitioners, meeting the criteria of owning a large parcel of land for the use of restoration. Establishing the wetland type was determined for the project. As for developing a scoring system and determining when the best time or season to begin restoration, neither were developed nor stated in the restoration project (Table 4).

Table 4. Criteria met by both the Elkhorn Slough foundation and The Conservancy between the SER Primer and CRAM (California Wetlands Monitoring Workgroup 2013: Collins et al. 2008: Parker et al. 2016: Wasson et al. 2015).

| Criteria | Santa Clara River | Elkhorn Slough |
| --- | --- | --- |
| **SER Primer** | | |
| Historical and Modern Aerial Photography | | X |
| Site background | X | X |
| Goals in writing | X | X |
| Monitoring criteria | | X |
| Reference site | | X |
| Restoration evaluations | | X |
| Museum quality evidence | | X |
| Paleo-ecological evidence | | X |
| **CRAM** | | |
| Background | X | X |
| Identify wetland type | X | X |
| Appropriate restoration window | | |
| Determine assessment area | X | X |
| Scoring system | X | |
| Upload data and techniques to database | | |

As for the interviews conducted with ES leadership. Real world restoration aspects were discussed and clarification of what kind of issues were able to be examined. The answers to interview questions are as follows:

Mark Silberstein Elkhorn Slough Foundation Executive Director

1. How important is it to own or have primary control over the property you are attempting to restore?
   "Here in Elkhorn Slough, we've used a combination of fee ownership and conservation easements. In addition, we've worked with the Central Coast Wetlands Group who have restored wetlands on property owned by the Foundation. Direct ownership is not an absolute goal or need. For the work we've done, it has been useful and easier to work on lands that are owned by the Foundation. The trade-off is that owning land is costly, both for the acquisition costs and for the long-term maintenance and management. So, the answer to your question is "it depends". It is clearly possible to do significant restoration actions w/o full ownership of the land being restored. Ownership comes with both benefits and responsibilities."
2. Is it imperative to have a positive relationship with neighboring landholders? If so, what are the best ways to obtaining that relationship and sustaining it without compromising your project goals?
   "It seems to me that positive relationships are important no matter the arena you work in. We do work hard to maintain good relations with neighbors and work to care for our lands in responsible ways. That said, we've had to resolve conflicts through the legal process in a few instances – all related to boundary encroachments. In one case, an adjoining landowner built his house across the property line! We went to mediation and have a lien on title, so that when he sells the property, we will recoup the costs we sunk into resolution and the property values.
   We work on maintaining property edges where we butt up against neighbors' land uses. Mowing fire breaks, tackling weeds, keeping properties clean all help demonstrate our respect. We try to be responsive to concerns raised by neighbors."
3. Do you believe that a large parcel size of a restoration project hinders or helps the overall success of the project?
   "The scale of a project is important – typically, the bigger the better, but scope and size is affected by the goals and funding. While a larger project can likely produce a larger

positive ecological impact, if it is under-resourced or poorly designed, it can lead to falling short of the objectives and be frustrating. Success criteria have to fit the project."

Kerstin Wasson Elkhorn Slough National Estuarine Research Coordinator

1. How do you go about deciding what makes a successful restoration project?
   "Work with stakeholders to determine what the objectives are and define quantitative success criteria based on that. Varies for every project, of course, so this is a general answer."
2. Do you believe that a large parcel size of a restoration project hinders or helps the overall success of the project?
   "Helps – the bigger the better, in terms of likelihood of success. However, you of course need more funding/resources/staffing for larger projects."
3. Have you used a reference site on any of your past restoration projects? Also, if a reference site is not possible, what are options could you use?
   "Yes, we monitor the restoration site in a few ways:
   Before vs. after just to track changes at the restoration site
   Restoration vs. control (to compare how restored site does compared to similar degraded unrestored site)
   Restoration vs. reference (to compare how restored site does compared to intact, high quality site)"

The interview questions aided in understanding that each restoration project should be uniquely developed and planned. A set of guidelines should be used under the discretion of the project leaders. It became evident that owning and managing a large parcel of land can be beneficial and detrimental to a restoration site due to the amount of maintenance and monetary needs. Also important is to find the line between working on having a positive relationship with neighboring property owners and not losing sight on what your organization's goals are.

# 5.0 Discussion

Wetland and riparian restoration is a complex, inter-disciplinary field that has proven to be open to interpretation by different organizations. Many factors play into the considerations of planning a restoration project, including surrounding land use, adjacent habitat, the watershed as a whole, and riparian buffers (Honey-Roses et al. 2013: Anderson and Poage 2014). Many methods already exist that develop and evaluate restoration projects. With so many different methods, inconsistent and conflicting direction can become an issue. Which is why it is important to develop a restoration method that will minimize these issues.

Both The Conservancy and ES foundation developed restoration methods that they believed would create the most positive outcome to their respective areas. The Conservancy has been able to acquire access to plenty of land along the SCR by either purchasing or managing the land. They were able to develop their own ranking system in order to restore the parcels they saw best fit to aid. However, The Conservancy developed a restoration method that seemed to favor more developed and complex parcels and ignored areas that are in need of more help. They seemed to lack a detailed historical data that would allow them to determine what are the potential habitat and biodiversity goals of each parcel of land.

As for the ES foundation, the data seems to support the notion that they developed a far more thorough management plan than that conducted by The Conservancy (Table 4). The main criteria that was not met by ES was the lack of a centralized database. Otherwise, the lack of a scoring system can be implemented for the following project.

# 6.0 Recommendations/ Conclusion

## 6.1 Overall Restoration Recommendations

Restoration managers should begin to use a combination of the SER Primer and CRAM in order to develop the best overall outcomes to a restoration project. With this kind of combination, practitioners will be allowed to save time and be cost effective: but most importantly develop a restoration plan that will aid all types of wetland and riparian areas, not just the ones near ecologically superior and economically wealthy. Throughout the development of environmental restoration low income areas and highly disturb ecosystems have been relatively ignored (Stanford et al. 2018). It is time a restoration method is developed to combat this issue.

## 6.2 Future Restoration Projects

Combining the SER Primer with CRAM methods, will allow for the development of future restoration project. One being the restoration efforts of the Watsonville Slough systems, mainly in the parcels found in agricultural zones. My non-profit organization, Watsonville Wetlands Watch, takes on the efforts of managing and restoring highly degraded wetland areas throughout the slough systems. Since Watsonville Wetlands Watch is a small non-profit organization, overall costs and time must be kept as low as possible, which is why it is important to have a restoration method that will allow for thorough and cost-effective assessment.

With Watsonville Wetlands Watch not having as big of a budget as some of the other bigger organizations like ES foundation, it will be harder for them to purchase large parcels of property in order to restore. Instead, Watsonville Wetlands Watch has to rely on the partnership they have developed with the Land Trust of Santa Cruz County to acquire property and allow for Watsonville Wetlands Watch to manage most aspects of the restoration efforts, which would be beneficial for Watsonville Wetlands Watch, in regard to not being financially responsible for property maintenance as mentioned by Mark Silberstein.

## 6.3 Developing a Centralized Database

It is important to develop a centralized database that all restoration organizations will be able to upload and access data and techniques throughout the state of California and potentially the United States. This responsibility should not be held by just one organization, but it must be a collaborative effort between restoration leaders throughout the state of California. The database will not be effective if all restoration organizations and government entities do not buy in and input all their data to share with all. A state government agency like the California Department of Fish and Wildlife, will have the be the agency to begin the collaborative process by forming a conference to invite all restoration experts.

## 6.4 Conclusion

California's agricultural sector has provided both benefits and detriments to the state. Throughout the development of agricultural technology, wetland and riparian zones have been removed and damaged. Restoration experts have developed different types of restoration techniques but have caused bias and conflict between the different techniques, which is why a new method in which the SER Primer and CRAM were combined to combat these issues.

## Acknowledgements

I would like to acknowledge all the people who have helped me throughout this long process. I would like to begin by thanking my parents Rosa and Jesus Lopez for always supporting my goals and moving to this country to give my siblings and I the opportunity to succeed in life. I would also like to thank my siblings Rocio, Guillermo, and Diego for providing me with guidance throughout my life and always making sure I had the resources to continue my education. I would also like to thank my partner Jasmine Aispuro for being my constant support during my master's program, I could have not achieve this without her. I would also like to thank all my professors throughout the program especially Dr. Coffman and Dr. Karentz for all the guidance they gave me. I would like to give my final thanks to Jonathan Pilch, Kerstin Wasson, Mark Silberstein for providing valuable resources for this project.

## Work Cited


1. Acuña V, Hunter M, Ruhí A. 2017. Managing temporary streams and rivers as unique rather than second-class ecosystems. Biol. Conserv., 211:12-19
2. Anderson, S., & Ambrose, R. 2011. Estuary Subwatershed Study Assessment of the Physical and Biological Condition of the Santa Clara River Estuary, Ventura County, California. Final Synthesis Report and the Environmental Effects of the City of Ventura Wastewater Reclamation Facility Discharge to the Santa Clara River Estuary.
3. Anderson, P.D. and N.J. Poage. 2014. The density management and riparian buffer study: a large-scale silviculture experiment informing riparian management in the Pacific Northwest, USA. Forest Ecology and Management 316: 90-99.
4. Baldwin, A. H, Barendregt, A, Whigham D.F. 2009. Tidal freshwater wetlands—an introduction to the ecosystem. In: A. Barendregt, D. F. Whigham, and A. H. Baldwin (eds.). Tidal Freshwater Wetlands.Backhuys Publishers, Leiden, The Nether-lands. Chapter 1; 1–10
5. Barendregt, A., & Swarth, C. 2013. Tidal Freshwater Wetlands: Variation and Changes. Estuaries & Coasts, 36(3), 445–456.
6. Barry, J. P., Yoklavich, M. M., Cailliet, G. M., Ambrose, D. A., & Antrim, B. S. 1996. Trophic ecology of the dominant fishes in Elkhorn Slough, California, 1974-1980. Estuaries, (1), 115.
7. Beller, E. E., Downs, P. W., Grossinger, R. M., Orr, B. K., & Salomon, M. N. 2016. From past patterns to future potential: using historical ecology to inform river restoration on an intermittent California river. Landscape Ecology, 31(3), 581.
8. Browning, B. M. 1972. The natural resources of Elkhorn Slough: Their present and future use. California Department of Fish and Game, Coastal Wetlands Series 4.
9. Brevik, E. C., Homburg. J.A. 2004. A 500 year record of carbon sequestration from a coastal lagoon and wetland complex, South-ern California, USA. Catena 57:221–32.
10. Bruggeman, D.J, Jones, M.L. Environmental Management 2008 42: 591.
11. Caffrey. J.M., Brown M.,Tyler W.B., Silberstein M (Eds.) 2002, Changes in a California estuary: a profile of Elkhorn Slough, vol. 280, Elkhorn Slough Foundation, Moss Landing
12. California Wetlands Monitoring Workgroup (CWMW). 2013. California Rapid Assessment Method (CRAM) for Wetlands, Version 6.1 pp. 67
13. Carpenter, N. F. Caraco, D. L. Correll, R. W. Howarth, A. N. Sharpley, & V. H. Smith. 1998. Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. Ecological Applications, 8(3), 559.
14. Chabreck, R. H. 1988. Coastal Marshes: Ecol-ogy and Wildlife Management. University of Minnesota Press, Minneapolis, MN.
15. Committee on Characterization of Wetlands. 1995. Wetlands: Characteristics and Boundaries. National Academy Press, Washington, DC

16. Couix, N., Gonzalo-Turpin, H. 2015. Towards a land management approach to ecological restoration to encourage stakeholder participation. Land Use Policy, 46, 155–162.
17. Dahl, T. E., and G. J. Allord. 1996. History of wetlands in the conterminous United States. Pages 19–26 in J. D. Fretwell, J. S. Williams, and P. J. Redman, editors. National water summary on wetland resources. United States Geological Survey. Water Supply Paper 2425. Reston, Virginia, USA.
18. Dowd, B. M., Press, D., & Huertos, M. L. 2008. Agricultural nonpoint source water pollution policy: The case of California's Central Coast. Agriculture, Ecosystems and Environment, 128(3), 151–161.
19. Downs, P.W., Dusterhoff, S.R., & Sears, W.A. 2013.Reach-scale channel sensitivity to multiple human activities and natural events: Lower santa clara, California, USA
20. Elkhorn Slough National Estuarine Research Reserve, http://www.elkhornslough.org/esnerr/
21. Environmental Protection Agency, (2019) https://www.epa.gov/cwa-401/clean-water-act-section-401-state-certification-water-quality
22. Finlayson CM, Davidson NC, Spiers AG, Stevenson NJ. 1999 Global wetland inventory—current status and future priorities, Mar Freshw Res, 50, 8, 717, 727, 10.1071
23. Fong, L., Stein, E., & Ambrose, R. 2017. Development of Restoration Performance Curves for Streams in Southern California Using an Integrative Condition Index.
24. Foxgrover, A. C., Marvin-DiPasquale, M., Jaffe, B. E., & Fregoso, T. A. 2019. Slough evolution and legacy mercury remobilization induced by wetland restoration in South San Francisco Bay. Estuarine, Coastal and Shelf Science, 220, 1–12.
25. Galloway, D. L., & Burbey, T. J. 2011. Review: Regional land subsidence accompanying groundwater extraction. Hydrogeology Journal: Official Journal of the International Association of Hydrogeologists, 19(8), 1459.
26. Garbach, K., & Long, R. F. 2017. Determinants of field edge habitat restoration on farms in California's Sacramento Valley. Journal of Environmental Management, 189, 134–141.
27. Hanson, R. T., Martin, P., & Koczot, K. M. 2003. Simulation of ground-water/surface-water flow in the Santa Clara-Calleguas ground-water basin, Ventura County, California. U.S. Department of the Interior, U.S. Geological Survey.
28. Hilderbrand, R.H., A.C. Watts, and A.M. Randle. 2005. The myths of restoration ecology. Ecology and Society 10: 19-29.
29. Honey-Roses, J., V. Acuna, M. Bardina, N. Brozovic, R. Marce, A. Munne, S. Sabater, M. Termes, F. Valero, A. Vega, and D. Schneider. 2013. Examining the demand for ecosystem services: the value of stream restoration for drinking water treatment managers in the Llobregat River, Spain. Ecological Economics 90: 196-205.
30. Keddy, P. 1999. Wetland restoration: the potential for assembly rules in the service of conservation. Wetlands 19:716–732.

31. Lowrance, R., Todd, R., Fail, J., Hendrickson, O., Leonard, R., & Asmussen, L. 1984. Riparian Forests as Nutrient Filters in Agricultural Watersheds. BioScience, 34(6), 374-377.
32. Magsig, B.O. Moynihan, R. Rieu-Clarke. A. 2012. UN Watercourses Convention: User Guide.
33. Martin, P, 1986, Southern California alluvial basins regional aquifer-system study, in Sun, R.L. (ed.), Regional Aquifer-System Analysis Program of the U.S. Geological Survey— summary of projects, 1978–84, U.S. Geological Survey Circular 1002, p. 245–247
34. United States Environmental Protection Agency, Office of Water 2002 Methods for evaluating wetland condition : 1 introduction to wetland biological assessment.
35. Meyer, J.L., M.J. Paul, W.K. Taulbee. 2005. Stream ecosystem function in urbanizing landscapes. Journal of North American Benthological Society 24: 602-612.
36. Myers, N., Mittermeier, R.A, Mittermeier, C.G, da Fonseca G.A.B, Kent. J 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858. National Oceanic and Atmospheric Administration. 2019 https://oceanservice.noaa.gov/facts/wetland.html
37. Palaima, A. 2013. Ecology, Conservation, and Restoration of Tidal Marshes : The San Francisco Estuary. Berkeley: University of California Press.
38. Parker, S. S., Verdone, L. N., Remson, E. J., & Cohen, B. S. 2016. Prioritizing Riparian Conservation: A Methodology Developed for the Santa Clara River, California. Ecological Restoration, 34(1), 61–67.
39. Pastorok, R.A., MacDonald A, Sampson J.R, Wilber P, Yozzo D.J, Titre J.P. 1997. An ecological decision framework for environmental restoration projects. Ecological Engineering 9: 89-107.
40. Powers, M. A. (2006). Restoring a native grass to reduce farm runoff in the watsonville sloughs (Order No. 1436945).
41. Propato, M., Clough, J. S., Polaczyk, A. 2018. Evaluating the costs and benefits of marsh-management strategies while accounting for uncertain sea-level rise and ecosystem response. Plos One
42. Queheillalt, D.M. and M.L. Morrison. 2006. Vertebrate use of a restored riparian site: a case study on the Central Coast of California. Journal of Wildlife Management 70: 859-866.
43. Stanford, B., Zavaleta, E., & Millard-Ball, A. 2018. Where and why does restoration happen? Ecological and sociopolitical influences on stream restoration in coastal California. Biological Conservation, 221, 219–227.
44. Stein, E., Tabatabai F, Ambrose R. 2000. Wetland mitigation banking: a framework for crediting and debiting. Environmental Management 26: 233-250.
45. Svejcar, T. 1997. Riparian zones: 1) what are they and how do they work? Rangelands 4-7.

46. Tiner, R. W. 2013. Tidal wetlands primer : an introduction to their ecology, natural history, status, and conservation. University of Massachusetts Press.
47. The Nature Conservancy (TNC). 2008 Conservation plan for the lower Santa Clara River watershed and surrounding areas.
48. Thompson TH, West AA ([1883]1961) History of Santa Barbara and Ventura Counties. Howell-North, Berkeley
49. United States Department of Agriculture, National Resources Coservation Service. 2019 https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/wetlands/?cid=stelprdb1043483
50. Wasson, K., Suarez, B., Akhavan, A., McCarthy, E., Kildow, J., Johnson, K. S., … Feliz, D. (2015). Lessons learned from an ecosystem-based management approach to restoration of a California estuary. Marine Policy, 58, 60–70. https://doi.org/10.1016/j.marpol.2015.04.002
51. Watsonville Wetlands Watch, Watsonvillewetlandswatch.org
52. Zavaleta, E., & Mooney, H. A. 2016. Ecosystems of California. Oakland, California: University of California Press