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A Case Study of Northern California: An Evaluation of Stream Restoration and the Success of Increasing California's Native Salmonid Stocks

Tara M. Morin
University of San Francisco, dobbey147@mac.com

This Master's Project

A Case Study of Northern California: An Evaluation of Stream Restoration and the Success of Increasing California's Native Salmonid Stocks

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Tara Marie Morin

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Abstract

Over the past decade Stream Restoration has become a management tool in helping combat the degradation of our streams. This case study compares three watersheds in Northern California, the Klamath River Basin, Russian River Basin and Lower Putah Creek. The comparison determines whether or not their implemented stream restoration projects over the years have been successful. The case study revealed gaps in information. The lack of tools for evaluation of past and current restoration projects has left the stream restoration field unable to advance. If there is no evaluation of the restoration projects then there is no way to determine if the actions and millions of dollars of grant funding is having the positive impact on habitats and increasing populations of California's Native Salmonid stocks. The case study identified the gaps in stream restoration projects as lacking standardization, and sustainable funding for the maintaining, monitoring and data collection that is needed post-implementation. The methods used were a literature review and a comparison of the watersheds using a hierarchical strategy and comparison of how watersheds handled limiting variables within stream restoration projects. There were three main findings, first finding was that for stream restoration projects to be successful a top down approach is needed to fully understand the root of degradation occurring in the steam which means doing an assessment at the watershed level and at the sub watershed levels. The second finding was the importance of a stream advocate such as a "Streamkeeper" whose purpose it to make sure the streams needs are heard while decisions are being made. The final finding was that alternate funding sources needed to be pursued for stream restoration besides state and federal grants. Such sources will allow for the continuation of projects when grant funding is no longer available and past implementation phase. All of this together tells is that the field of stream restoration has room for improvement so that we get the most out of the projects and help stabilize California Native Salmonid stock populations.

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1. Introduction

Across the United States billions of dollars every year are spent on various watersheds for restoration projects (Bernhardt et al. 2007). These projects hope to restore habitats and reverse the declining or lost salmon runs that are left in North America. As rivers continued to degrade due to increased water demands, environmental managers and policy makers have become more aware of habitat degradation and the decrease in populations of Pacific Coast salmonids (Bernhardt et al. 2005). In 2016, the Putah Creek Council saw the culmination of hard work on the Lower Putah Creek restoration projects become a reality. Stream restoration projects have taken place for many years on Lower Putah Creek. Before the current drought, small increases in returning salmon were seen, and an estimated fall-run Chinook of 200 were present in 2014 (Jasper and Hamilton 2016). However, in December 2016 the numbers hit a record high, estimations were between 1,000 to 1,600 spawning fall-run Chinook (Davis Enterprise 2016). It is imperative to evaluate the actions that Lower Putah Creek restoration plans implemented, while even in a drought, resulted in an increased the salmonid populations. Results like those in Lower Putah Creek provide a viable model for other locations where stream degradation can be reversed to help sustain local ecosystems and economies throughout the state.

Lower Putah Creek had a huge increase in returning salmon populations in 2016 for the creeks fall-run Chinook salmon. This prompted an investigation to find the “silver bullet” that could prove to be beneficial in future restoration of creeks and/or watersheds. Defining what makes a successful stream restoration plan and what makes a successful salmon run will help the restoration field advance by determining specific factors that make a stream more appealing to salmon. Discovering if the success on the Lower Putah Creek was due to one specific factor or a combination of many factors is important for advancement in the field. Several factors to consider in a restoration plan include time, funding, flow concept, relationships, and having a stream keeper. Any one or combinations of these factors may be the solution restoration plans need to incorporate to be successful in sustaining or restoring the salmon population.

Synthesizing this knowledge could allow the field of stream restoration to implement data, applicable to various restoration plans across the state. Utilization of Lower Putah Creek restoration plans as a template for the improvement of future salmon runs helps preserve the species from becoming extinct. One potential benefit from local stream restoration is a decrease in spending. The decrease in spending would allow the financial savings to be directed to other environmental issues such as pollution, loss of biodiversity, and urban sprawl to name a few.

To determine if Putah Creek should be used as a template in future restoration plans this paper will discuss what is happening with the salmon species. In addition, this paper will define Pacific Coast salmon, the concern for California’s salmon species and local stocks of salmon in our waterways. Furthermore the paper will review stream restoration and compare it to reconciliation to see if the desired goals are achievable or if the waterways are beyond repair. Evaluating the different activities that encompasses stream restoration will help determine why the Putah Creek Chinook winter-run was successful. In order to fully understand and successfully incorporate the activities of stream restoration the limitations of the restoration need to be brought to light.

Having a better knowledge of the limitations and the ability to replicate successful stream restoration activities for the various species will help increase the species populations. Observing these effects allow for comparison across different rivers in Northern California, thus gaining a better understanding of stream restoration. This knowledge will help determine if Putah Creek has found the "silver bullet" which could restore the Salmon populations to creeks that were once filled to abundance.

2. Background

2.1. Salmon Extinction

According to Robert Lackey (2015) every year an exorbitant amount of money is spent on restoration projects; the estimates are in the hundreds of millions to billions of dollar in the United States alone all to restore salmon populations (Lackey 2015). Are the whole species in peril of extinction or just particular species of salmon that have adapted to their local habitats tittering on extinction? Due to the lack of data that is available scientists do not know the definitive answer (Rumps et al. 2007). Many believe that the loss of genetic diversity is detrimental to the whole species (Nehlsen, Williams, and Lichatowich 1991). Protection of all of a species' subspecies, in all their different endemic habitats, should be a consideration, so the species as a whole stays healthy. As science has advanced over the past decades, it has been realized that a more holistic approach to ecosystem restoration is the way to proceed. The fluctuation in the population of just one species can be the result of many different human or natural impacts that over time can be compounded in a negative way. Therefore looking at the whole ecosystem for restoration is considered more effective, but tackling it from a watershed approach still leaves a very complex problem (Lackey 1999).

2.1.1. Salmon Species

California is concerned with the loss of its many salmon subspecies. In the Pacific Northwest alone 29% of historical populations are extinct already. The range of the species has decreased 40% from the historical waterways the species used to inhabit (Gustafson et al. 2007). California is home to the Pacific Coast salmon, which is on the edge of the range of viability for the species (Katz et al. 2013). With climate change and extinction of seasonal salmon runs (winter, spring, fall) California may very soon no longer be the inclusive edge of the range but the excluded edge of the Pacific Salmon range. While there are seven species that make up the Pacific Coast salmon only five of those are found in North America, they include the following; Chinook, Oncorhynchus tshawytscha; Coho, Oncorhynchus kisutch; Sockeye, Oncorhynchus nerka; Chum, Oncorhynchus keta; and Pink, Oncorhynchus gorbuscha. Trout are often considered part of this group because of their anadromous nature. The trout species that are included with the Pacific Coast Salmon are rainbow trout, Oncorhynchus mykiss; and cutthroat trout, Oncorhynchus clarkii (Lackey 1999).

There are 32 species of the salmonid fish that are native to California. Table 1 demonstrates 32 species made up of 21 anadromous and 11 that are nonanadromous. Anadromous species are born in freshwater and live part of their juvenile lives in

Table 1: Native Californian Anadromous and Nonanadromous Species

Native California Anadromous Species		
Species Common Name	**Species Scientific Name**	**Range**
Central coast coho salmon	*Oncorhynchus kisutch*	California
Pink Salmon	*O. gorbuscha*	Pacific Coast
Upper Klamath-Trinity spring Chinook salmon	*O. tshawytscha*	California

Southern Oregon Northern California coast coho salmon	*O. kisutch*	California & Oregon
Chum	*O. keta*	Pacific Coast
Central Valley late fall Chinook salmon	*O. tshawytscha*	California
Klamath Mountains Province summer steelhead	*O. mykiss*	California
Southern California steelhead	*O. mykiss*	California
Central Valley winter Chinook salmon	*O. tshawytscha*	California
Central Valley spring Chinook salmon	*O. tshawytscha*	California
Central Valley fall Chinook salmon	*O. tshawytscha*	California
Upper Klamath-Trinity fall Chinook salmon	*O. tshawytscha*	California
California Coast fall Chinook salmon	*O. tshawytscha*	California
Central Valley steelhead	*O. mykiss*	California
South Central California coast steelhead	*O. mykiss*	California
Central California coast winter steelhead	*O. mykiss*	California
Northern California coast winter steelhead	*O. mykiss*	California
Southern Oregon Northern California coast fall Chinook salmon	*O. tshawytscha*	California & Oregon
Klamath Mountains Province winter steelhead	*O. mykiss*	California & Oregon
Northern California coast summer steelhead	*O. mykiss*	California
Native California Nonanadromous Species		
Species Common Name	**Species Scientific Name**	**Range**
Bull trout	*Salvelinus confluentus*	Pacific Northwest
Paiute cutthroat trout	*O. c. seleneris*	California
McCloud River redband trout	*O. m. stonei*	California
Kern River rainbow trout	*O. m. gilberti*	California
California golden trout	*O. m. aguabonita*	California
Little Kern golden trout	*O. m. whitei*	California
Eagle Lake rainbow trout	*O. m. aquilarum*	California

Lahontan cutthroat trout	*O. c. henshawi*	Western USA
Goose Lake redband trout	*O. m. subsp.*	California
Coastal cutthroat trout	*O. clarki clarki*	Pacific Coast
Mountain whitefish	*Prosopium williamsoni*	Pacific Northwest
Coastal rainbow trout	*O. m. irideus*	Pacific Coast

Table 1: This table lists the 32 salmonid species that are native to California (Katz et al. 2012).

freshwater before migrating to the sea. In the sea the anadromous species mature for a few years in the ocean until which time they are ready to spawn. Once matured this triggers the migration from the sea to the freshwaters streams where they were born. For the anadromous trout species this cycle of migration between freshwater and the ocean can occur multiple times during a trout's life span. Unfortunately, after the anadromous salmon species spawns, they die, then a few months later the new generation of anadromous salmon are born, and the cycle begins anew. Salmon are defined as being native to California if they are known to breed in particular rivers and streams located within the California borders (Katz et al. 2012). As stated in the Katz et al. study (2012) estimates were given that by the end of this century only 25 of the native Californian salmon species will remain of the 32 species, unless there are drastic improvements to our waterways. Salmonids are unique in the way that the fish have learned to adapt to the harsh conditions, especially the subspecies of salmon that has survived in California.

There is significant variability in the habitats that can be found here in California: impending drought, Mediterranean climate, and vast fluctuating elevations. Due to the adaptations that salmonids have had to make to survive here in California, showcases how the salmon species is resilient (Katz et al. 2012). The increase in human population has caused stress on the salmonid population, in many different forms. Some stresses have triggered adaptations, others a flat out decrease in the populations of salmon. Scientists have claimed a broad array of reasons for the decline in populations such as; mining, logging, grazing, agriculture, diversion for farming, diversion for urban users, dams, road construction, recreation, overfishing, predation, alien species, fire, estuary alterations, hatcheries and most recently added to the list is climate change (Lackey 2015; and Katz et al. 2012). Some of these threats have the potential to decimate a population, while other threats compounded over time take their toll on the salmonids and other species.

2.1.2. Salmon Stocks

There are 214 native stocks that make up the grouping of Pacific Coast Salmon species that have natural spawning and can be found in a range from California, Idaho, Oregon, and Washington (Nehlsen, Williams, and Lichatowich 1991). Stocks are considered genetically special populations of salmon. The stocks are populations of salmon that have specific geographical locations in which that specific stock can be found. The stocks have modified to their habitat with varying transformations depending on local environmental conditions, and ability to co-exist with other species. Examples of stock adaptations include larger bodies, varying skin colors, and patterns based on the current habitat the fish species inhabits. Nehlsen, Williams, and Lichatowich (1991), break down the 214 stocks into groups based on the risk of extinction. The four groups identified are ranked from most severe to least severe for listing they include: listed, high risk, moderate risk, and of special concern for extinction (Nehlsen, Williams, and Lichatowich 1991). Upon closer examination of the North American region there is one stock that is threatened and listed on both the federal and state endangered species list; 101 stocks are high risk of extinction; 58 stocks are moderate risk, and 54 stocks are of special concern. The list located in Table 2 looks at the 214 stocks of Pacific Salmon and gives the breakdown by states of the stocks at risk.

Table 2: Native Stocks of Pacific Coast Salmonids at risk by state

Status	California	Idaho	Oregon	Washington	Totals
Listed as threatened or endangered	1	-	-	-	1
High risk of extinction	20	36	19	26	101
Moderate risk of extinction	12	14	24	8	58

Of Special Concern	6	26	15	7	54
Totals	39	76	58	41	214

Table 2: This table breaks down by state the native stocks that are at risk for extinction that are included in the species of the Pacific Coast Salmonids located in North America (Nehlsen, Williams, and Lichatowich, 1991).

Looking specifically at California from the table above there are 39 stocks located with in the state. Of those one is listed as and endangered species both at the federal and state level; 20 are considered high risk, 12 are moderate risk and six are of special concern. Table 3, lists the names of the different salmonid stocks and the rivers that they use as spawning grounds and rearing habitats.

Table 3: California Rivers that support Native Stocks

Species	Runs	California River
Chinook Salmon	Winter	Sacramento River
	Spring/Summer	Sacramento River
		Klamath River
		Smith River
		Yuba River
	Fall	Shasta River
		Scott River
		San Joaquin River
		Cosumnes River
		Minor Humboldt tributaries
		Lower Klamath tributaries
		Redwood Creek
		Mad River
		Smith River
		Mattole River
		Russian River
		Lower Eel River
Coho Salmon		California small coastal streams north of San Francisco
		California small coastal streams south of San Francisco

		Klamath River
Pink Salmon		Russian River
Steelhead trout	Winter	Malibu Creek
		Santa Clara River
		Ventura River
		Santa Ynez River
		Little Sur River
		Big Sur River
		Carmel River
		Salinas River
		Pajaro River
		South San Francisco Bay tributaries
		Sacramento River
		Napa River
	Summer	Eel River
		Mad River
		Redwood Creek
		Klamath River
		Smith River
Sea-run cutthroat trout		California coastal streams

Table 3: This table lists the names of the migratory and spawning rivers where the California native stocks of salmonids are located (Nehlsen, Williams, and Lichatowich 1991).

Keeping the salmonid stock populations in healthy ranges is important for a variety of reasons. The more vigorous the stock, the more diversified the gene pool. Diversified gene pools improve population selection available for re-stocking for both hatcheries and the overall health of the stream including the surrounding ecosystem (Nehlsen, Williams, and Lichatowich 1991). It has been theorized that salmon are a keystone species in the ecosystems they inhabit. Salmon bring with them nutrients that can be found in the marine system and deposit nutrients into the freshwater system and surrounding ecosystem (Hilderbrand, Farley, Schwartz and Robbins 2004). After salmon spawn and their life cycle come to an end, the carcasses decompose, and the nutrients are absorbed into the soil, which in turn provides valuable nutrients to the vegetation surrounding the creeks and rivers (Wilson, Gende, and Marston 1998). If the salmon runs are lost the vegetation that depends on the nutrients are at risk of survival (Hilderbrand, Farley, Schwartz, and Robbins 2004). Not only does the vegetation depend on the salmon to complete the cycle but also so do many predation species. Various species in the forest rely on the salmon as a beneficial source of food around reproduction time (Wilson, Gende, and Marston, 1998). The study by Wilson, Gende, and Marston (1998), shows that salmon body mass contains 8% lipids while other Pollock fish body masses only contain 3% lipids. Predators such as brown bears, minks, and eagles, instinctually know that they reap more benefits by eating salmon because of their nutritional component.

2.2. Stream Restoration

Bernhardt et al. (2007) states that " With 45% of our nation's rivers classified as endangered or impaired, we cannot be content with only protecting the remaining “supporting” rivers and streams" (Bernhardt et al. 2007). Since the environmental movement of the 1960s that focused on pollution for clean air and water; and produced the Clean Air Act of 1970 (encyclopedia.com 2017). Since then concern for the environment has swept the nation in all different venues. During the past two decades restoration practitioners and project managers have used stream restoration as an instrument in their management toolbox (Nilsson et al. 2016). However, research shows that there is little knowledge on the effectiveness of stream restoration (Bernhardt et al. 2014).

The goal of stream restoration is to improve the conditions and ecological processes of degraded rivers. Stream restoration is becoming more of a mainstream idea, and as a result, more financial resources are being utilized in an effort to protect habitats and the species found within it. Most restoration projects are intended to help with water quality and riparian management. Restoration is being done all over the country, the study by Bernhardt et al. (2014), shows that 46% of restoration is done in agricultural land and

53% of the time it was on privately owned land.

2.2.1. Restoration vs. Reconciliation

Most watersheds have a variety of ecosystems located throughout them, and as a stream makes its way from its headwaters to the ocean it travels through an array of land uses. Human population is growing in record numbers; California alone has quadrupled since the 1950s (US Census Bureau 2016). Figure 1 shows the constant increase in population here in California, the current estimated population for 2017 is 39.61 million people (US Population 2017). The increase in human population increases the pollution output and encroachment on stream habitat due to urban sprawl. These contributory factors

Figure 1: California population growth from 1910-2017

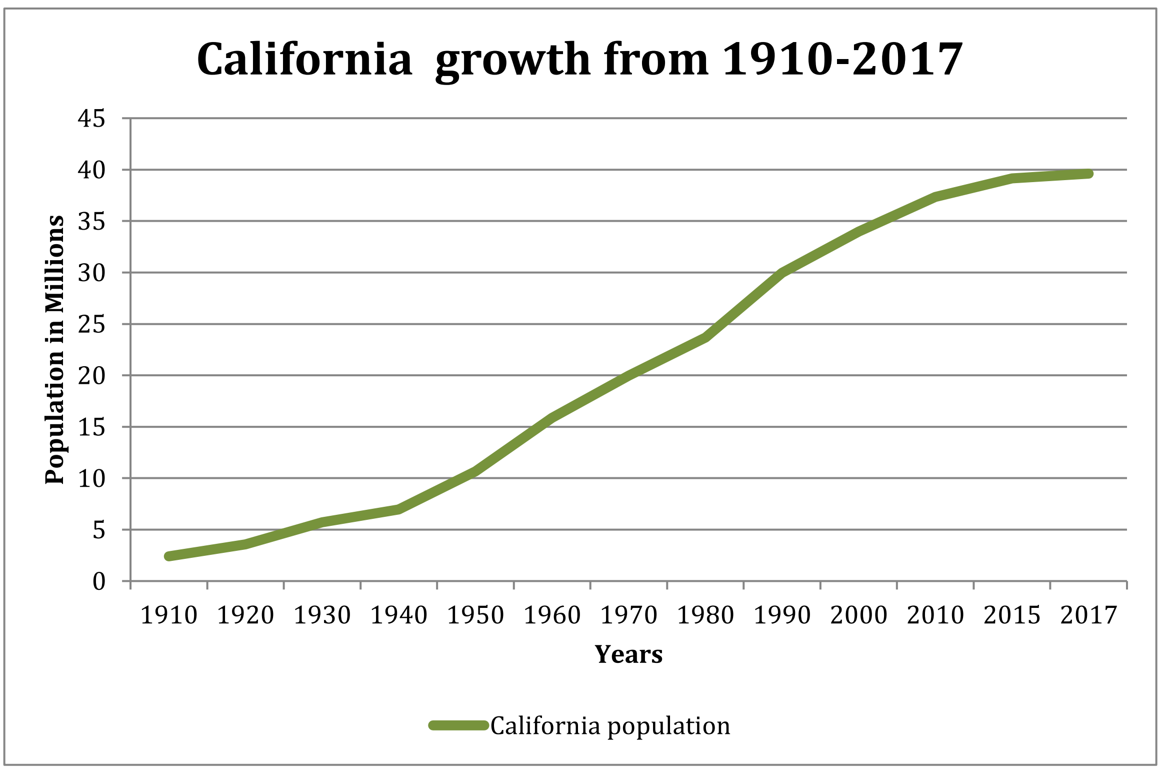


Figure 1: The graph above shows the steady increase of California's human population from 1910 to an estimated 39.61 million people in 2017 (combination from US Census Bureau 2016 and US Population 2017).

have led to the degradation of many streams across the country, and few are left that are thought to be in pristine condition (Moyle 2014). The constant degradation and the highly altered state that many ecosystems are experiencing make it difficult for successful restoration of streams (Palmer et al. 2005).

Returning a stream's ecosystem to the way it was before human interaction is becoming more challenging and harder to define as population grows and degradation increases. These human altered habitats are changing the makeup of the species that were once found within undistributed habitat (Moyle 2014). Stream restoration is defined as returning a degraded ecosystem to a stable, healthy condition (NOAA 2017). Scientists are changing their way of thinking when it comes to stream restoration. This shift in the way of thinking stems from the discussion stating ecosystems do not need to be brought back to the original pristine conditions but instead should focus on improving the current state of the habitat, so the processes are improved or restored to a more natural condition (Palmer et al. 2005).

Under this idea, the stream habitat is improved not by stream restoration but rather by stream reconciliation. Stream reconciliation allows for a melding of conservation of species with human activities (Moyle 2014). Reconciliation recognizes that a habitat has been dramatically changed as the result of human impact. These alterations to the physical environment are irreversible due to human reliance on the alterations. Rosenzweig (2003) brought this idea to light in his book *Win-Win Ecology;* it reiterates the concept that there is not enough of the planet to segregate human areas and nature areas to preserve all the biodiversity that the earth holds. A compromise needs to be found where humans, wildlife, and ecosystems can coexist (Rosenzweig 2003).

The literature review includes the techniques for stream restoration and stream reconciliation. Stream restoration has a more mature literature foundation compared to stream reconciliation. The main difference between the two is the overall outcome. Stream restoration's goal is to return the stream to its historical conditions. Due to the highly altered nature of today's streams, this is an extremely difficult task. If historical conditions are the goal, then it is hypothesized that most projects would be failures as the result of human impact on the waterways.

Stream reconciliation sets the goal at a possible standard. There is an understanding that due to the human impacts some actions cannot be reversed and as a result, historical conditions are not obtainable. This does not mean that the outcome of restoration is relaxed, but rather, there is an understanding that both humans and the habitat need to coexist together and work at finding a sustainable compromise. The idea of reconciliation allows managers to pause and take a more holistic approach. Projects can look at the whole watershed over time and analyze new threats while balancing the project expectations (Bisson, Reeves, and Dunham 2009). This paper will use the terms interchangeably.

2.2.2. Restoration Activities

Restoration activities chosen for a project should be contingent on the needs of the watersheds and the stakeholders. Watersheds have both differences and similarities when comparing damage done as a result of various human activities located within the local area. It is important to note not all similar activities require the same action to improve the streams conditions (Palmer et al. 2005). Similarly, what works in the upper watershed may not be effective in the lower watershed due to the different environments and quality of the stream, which can be found at the various reaches within a stream (Palmer et al. 2005).

Looking at the watershed in its entirety is becoming the standard as science advances, and it is realized that a piecemeal approach to protecting the environment does not work as effectively (Roni et al. 2002). Looking at the whole watershed helps with understanding those processes that have vanished or that have been severely degraded over time (Roni et al. 2002). Looking at the watershed as a whole leads to a better understanding of what problems are hindering the species from thriving; which in turn allows project goals and funds to be focused on those specific issues. In 2002, the United States General Accounting Office estimated that in the Columbian River Basin alone the federal government spent an estimated $400 million on stream and river restoration projects (Katz et al. 2007).

Some of the activities used to restore stream habitats focus on roads near the creek, riparian areas, reestablishing nearby floodplain, instream enhancements, barrier removal for improved fish passages, increases in the flow of the streams water level and nutrient enrichment (Roni, Hanson, Beechie 2005). Table 4 shows restoration projects and the pressures they hope to alleviate or restore.

Table 4: Stream Restoration Activities

Stream Restoration Activities		
Project Type	**Goal**	**Techniques**
Road Improvements/ Sediment Reduction	Reduce sediment supply; restore hydrology; improve water quality	Road closing or abandonment; resurfacing; alternating drainage; and sediment trap
Nutrient Enrichment	Increase productivity, strengthen base of biotic production due to lack of anadromous fish	Carcass placement; fertilizer; and addition of inorganic materials
Restoring Riparian Functions	Restore riparian vegetation and process; stabilize bank and instream conditions	Replanting of native vegetation, thinning or removal of understory; fencing to remove livestock, livestock rotation, livestock stream crossings; and forestry practices
Floodplain Connectivity/	Reconnection of isolated habitats, natural	Levee or dam removal; tidegates; weirs; reconnect/restore/create sloughs,

Barrier Removal	migration of channels, restore natural transport of sediment and nutrients, and strengthen complexity of channel	ponds, off-channel habitat and wetlands; reduce/regulate water withdrawal; create/reconnect floodplain habitat; increase instream flows; restore natural flood regime; removal/replacement of impassible culverts; fish ladder improvements; beaver control management; and placement of diversion screens
Instream Habitat Improvements	Restore instream habitat for species	Placement of logs or boulders; engineered log jams; spawning grave; deflectors; and placement of rootwads, brush, or other vegetation cover

Table 4: This table shows a combination of the different stream restoration project types that are used for projects. It lists the goals associated with the project types and the techniques used to achieve the goals. (Information combined from 2 sources; Roni, Hanson, and Beechie 2005 and Katz et al. 2007).

The field of stream restoration is shifting to a holistic view, which is more closely aligned with the stream reconciliation approach. The idea revolves around defining the activities that a project pursues dependent on the findings of overall watershed in combination with the wants and needs of the surrounding community. This initial review tends to be in the form of a whole watershed scale assessment. However, sometimes the assessments have not been completed, and as a result, the project manager reviews the historical conditions of the watershed and creates an assessment. The watershed assessment gives a historical review of the watershed and identifies what has been altered due to human impact and helps to guide goal establishment of the project (Palmer et al. 2005). Implementing a project based off the watershed will allow for better outcomes of reconciliation because a strong foundation of understanding what caused the degradation of the stream has been achieved. In addition, the assessment aims to understand the species living in the creek, the requirements needed for the various stages of their life cycle, the water temperature variances, and composition of the water column.

After the watershed assessment has been completed, then the goals of implementation can be determined by what processes are no longer available or need improvement (Roni et al. 2002). Once these processes have been restored, then the ecosystem can start healing itself from the degradation that has taken place. For some projects, this will be all that is needed in order for that species to return or improve population numbers, while other streams might require additional steps (Roni, Hanson, Beechie 2005). Figure 2 shows the relationships between the processes and effects they have on the surrounding habitat. Understanding the correlation between disturbances with the processes and loss of habitat is paramount when establishing reconciliation goals. Pinpointing the weak link between what controls the processes and fixing what is causing the degradation of the stream, strengthens the whole watershed, not just a particular section of the creek.

Once the processes have been reestablished in the main stem of the stream, the project now can focus on the nearby habitats that have been isolated from the main stem of the

Figure 2: Stream habitat linkages between controls, processes, and effects

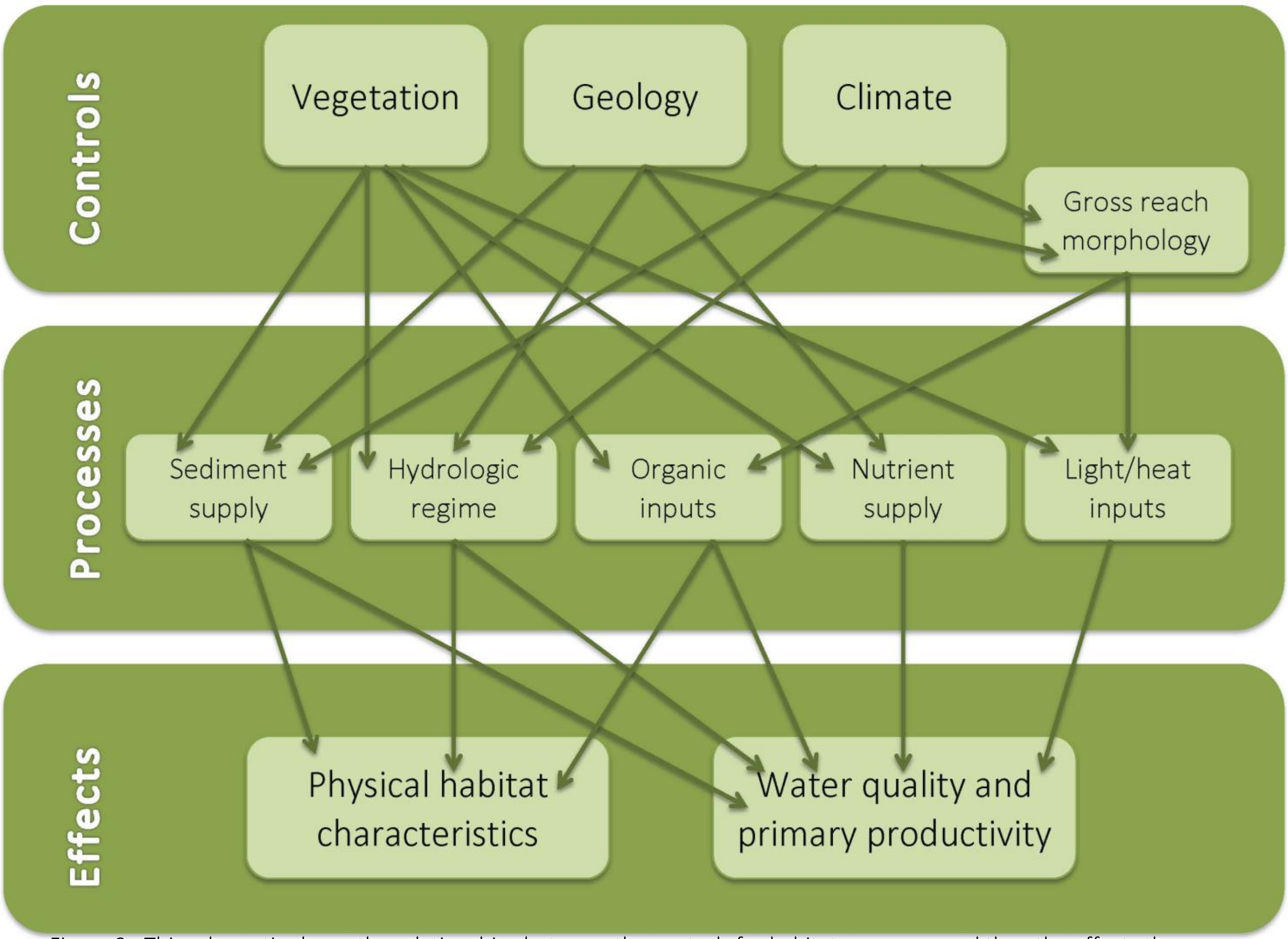


Figure 2: This schematic shows the relationships between the controls for habitat processes and then the effects those processes have on the surrounding habitat conditions (Roni et al. 2002).

stream. Reconnecting these remote reaches adds to the complexity of the stream, which allows for more biodiversity within the main stem of the stream (Roni, Hanson, Beechie upstream when the streambed is too steep. Making modifications that reconnect the stream with its isolated habitats allows for project managers to then wait and see if passive restoration, the natural recovery, of the stream takes place (Roni, Hanson, Beechie 2005).

It is only after these first three steps; watershed assessment, restoring processes, and re-connectivity have been completed that a project should then look at the instream habitat modifications. Habitat modifications have been popular since the start of the stream restoration movement (Roni, Hanson, Beechie 2005). The instream habitat modifications have been popular because of the quick turnaround time of being able to see the results of these activities. Some of the rapid turn around activities that restoration projects like to implement first are log jams, addition of large woody debris, or adding additional large boulders within the stream. These effects are short-lived if the stream is not able to support the processes that are needed to keep the desired species in that location so that it has a chance to reestablish the population (Roni, Hanson, Beechie 2005).

Many of the instream habitat modifications have different objectives depending on what the project is trying to improve. Instream habitat modifications are done for the species that would be found in a particular section of the stream. Some of the typical local species that can be found in northern California include local fish, anadromous fish, amphibians, reptiles and mammals like beavers that use the stream for its habitat. Common instream habitat modifications include placement of large woody debris (LWD), enormous boulders, engineered logjams, or placement of spawning gravel (Roni, Hanson, Beechie 2005 & Bennett et al. 2016). Fish species tend to vary in response times regarding different instream habitat modifications. It takes time to monitor the overall effectiveness of instream modifications. According to the study by Roni, Hanson, Beechie (2005), fish quickly recolonized the modified areas. However, 70% of the increase in fish was credited to barrier removal versus instream modifications.

The literature review demonstrated that while the country as a whole is spending enormous amounts of money on stream restoration, there has not been a consensus on what activities work best, or how to evaluate the success of stream reconciliation on a standardized level. It is known from the complexity of stream habitats that there is no cookie cutter way to establish stream restoration (Kondolf 1998). There are too many moving parts to the equation for stream restoration such as; diverse ecosystems, multiple habitats, climate change, geomorphology, elevation, hydrology, land uses, and pollution inputs. All of these factors need to be considered when designing a stream restoration plan. To make a single step by step manual that would restore all rivers in the United States would be a very large and complex guide. For this reason, before stream restoration can occur, there needs to be a firm understanding of what the underlying issues are within the watershed that do not allow the natural process of the stream to be present. Only after identifying the issues can reconciliation of streams move forward (Kondolf 1998).

2.2.3. Reconciliation Variables

With as much money that is being spent globally and in the United States for stream restoration, there needs to be a better way to quantify what is successful and what is not. To date, the field of restoration has not set forth guidelines that help practitioners approach the problem of degraded streams. Water is a resource that affects not only wildlife but also human life. Local streams are used to supply homes with water albeit after being filtered at the local water plant. The quality of drinkable water could be polluted if the water that naturally flows is also degraded. All things rely on water for survival. There are some significant variables that stream reconciliation projects encounter. Variables include funding, time, data collection, and criteria to determine if the restoration was successful. If the field does not address these variables, then it will be hard for reconciliation to move forward and improve.

2.2.3.1. Funding

The most significant variable is monetary. The study by Bernhardt et al. (2005) estimated that in 2005 roughly $15 billion dollars had been spent in restoration projects across the county since 1990. This was considered to be an underestimated amount because it did not include large restoration efforts like the restoration projects on the Missouri River or the San Francisco Bay (Bernhardt et al. 2005).

Typically restoration projects find funding in the form of a state or federal grants. Grant funding has very strict rules on what it allows the money to be spent on or which tasks it will support. Often suitable funding is used for; initial studies, development, and implementation of the project but does not allow for maintenance of the project. Stream reconciliation projects do not have sufficient sources of funding for the long-term. If project sites are not visited and evaluated periodically how can the goals and activities that were implemented be monitored effectively? How can future plans be improved, or new projects be justified if the outcomes cannot be sustained over the long-term?

The agencies regulating funding for reconciliation projects do not believe the budgeting for the maintenance of a project is an acceptable way to spend grant funds. Consequently, projects struggle in figuring out ways to keep maintaining funding to cover monitoring costs after implementation. The agencies are not entirely to blame as proper budgeting needs to be incorporated into the project from the beginning (Kondolf and Micheli 1995).

2.2.3.2. Time

Degradation takes time to occur, and consequently, it also takes time to determine if restoration was successful, which is a variable in current projects. Many of them want to report back to the communities that what they did was successful as soon as possible. However, studies have shown that fish, along with other species, can have large swings in abundance. The increase in fish populations could be based off two different factors. The first, the colonization of new reaches in the stream and therefore only lasting for a short time if the proper processes are not present and the second, an increase in population after an improvement in the habitat that reestablished processes that had been lost but needed a few years to establish and build food sources (Kondolf and Micheli 2015).

Shortening the lag in time to show the actual effects of actions is critical in helping the practitioners learn what activities implemented increase fish populations. Additionally, data needs to be collected at various times during the life stages of the species for understanding habitat uses for increasing populations. The data collection will take time to effectively evaluate different areas in order to monitor the various fish classes (Bennett et al. 2016). Numerous studies note that projects need to be monitored and data collected for up to 10 years after implementation to fully understand what changes have occurred. The date can then be used to evaluate whether the goals of the project were beneficial and if different life cycle of the species were identified (Roni et al. 2002).

2.2.3.3. Data Collection

Data collection is a variable of stream reconciliation. Science uses data to help guide decisions regarding a variety of actions for stream restoration such as: where to place large woody debris, what parts of the stream are degraded and identifying hot spots in water temperature. Nevertheless, there is no push for the collection of data during restoration projects. Analyzing the data from restoration projects is necessary in order for the field of stream restoration to advance and make lasting and efficient decisions for the community and the species within the stream (Kondolf and Micheli 2015). The variability of data collection is present throughout all aspects of the restoration project and is made apparent by the lack of data during opportunities that incudes; pre-project data collection, post-project data collection, long-term monitoring, funding and the lack of data needed to compare successfulness of the project.

The first limitation that impacts the variability of the entire data collection process is the absence of established guidelines. Instructions are needed for data collection during a stream restoration project. In order for a field practitioner to make decisions during the restoration project, they need to collect and analyze information. This gap in data collection has been identified, through peer-reviewed literature, that there are various ways to gather data for stream projects. According to Rumps et al. (2007), the lack of consensus on various aspects of a project were related to the practitioner's knowledge (22%), expert's knowledge (49%) and the requirements of the funding agency if provided a grant (22%; Rumps et al. 2007). It is important to note, the lack of a cohesive set of operational guidelines or standards makes stream reconciliation projects difficult to replicate from stream to stream (Kondolf and Micheli 2015).

Data collection is impacted by lack of available funds for reconciliation projects to monitor the long-term effectiveness of a project adequately. It has been postulated that the lack of funding for data collection is not an essential part of the reconciliation project of a stream. However, this is incorrect and is demonstrated by the following evidence. According to Rumps et al. (2007), 66% of project researchers/managers commented on the importance of a stream restoration project having long-term funding for the success of the project. Regardless, only 43% of the projects had the necessary funding secured for this kind of monitoring (Rumps et al. 2007). As discussed previously, these stream restoration practitioners are not entirely at fault. From the onset of a restoration project the project manager, needs to focus on the incorporation of funding needs for long-term monitoring into the budget. Additionally, the Wildlife Agencies do not help to make sure that funding for data collection is included from the beginning of the budget process. The guidelines for the fish and game grants excludes monitoring and maintenance as possible ways to spend grant funds. This simple yet power change in the code; could help many science fields learn more about today's projects (Kondolf and Micheli 2015).

In 2005, Bernhardt et al., tried to analyze projects from across the United States with the help of National River Restoration Science Synthesis. They compared 37,099 projects that were present in the database as of July 2004. Bernhardt et al. (2005), found that 10% of the projects were monitored or had some form of assessment to determine if the project made a difference (Bernhardt et al. 2005). Considering most reconciliation projects did not have funding for long-term monitoring identifies a substantial void in the evidence. This void has implications on the prior stream activities and whether implementation of these activities has been truly successful. The evidence would suggest the lack of data collection limits the knowledge in this field and as a result stream reconciliation is at risk for stagnation (Rumps et al. 2007).

Once the data is collected, there needs to be a database that can be accessed by practitioners to facilitate the review of various activities that have been successful and activities that have not. Currently, there is not enough data recorded to know if restoration is helping the species. The lack of data does not allow for the identification of potential connections between the restoration and the species (Katz et al. 2007). In 2007, there were over 23,000 different restoration projects alone, in the states of Washington, Oregon, Idaho, and Montana (Nehlsem, Williams, and Lichatowich 1991). Developing a database that allows other practitioners to see the various projects, in different regions, fosters an environment of collaboration thus encouraging shared goals and the evaluation of individual restoration projects.

2.2.3.4. Success Criteria

Determining if a project is successful is difficult if there are no established guidelines for project evaluation. The lack of a scale to determine project success that evaluates all aspects such as the project site, section of the stream, watershed, or regional scale would be beneficial (Katz et al. 2007). According to Bernhardt et al. in 2007, there was a rapid increase in restoration projects all over the country. The last 30 years, has demonstrated, however, the absence in review of the projects completed to determine successfulness of restoration projects (Bernhardt et al. 2014). Additionally, with more than one billion dollars being invested in stream restoration projects annually across the United States a cost-benefit analysis would prove beneficial in helping to improve project outcomes (Bernhardt et al. 2014).

According to Rumps et al. (2007), 70% of the practitioners stated that they thought their particular reconciliation project was successful. However, 43% of those projects have not been evaluated by defined success criteria. Furthermore, there may not have been any success criteria placed in the project from the onset (Rumps et al. 2007). The study by Bernhardt et al. (2014), stated that 47% of projects surveyed felt the restoration project was successful either by completing pre and post onsite visual observations or getting public feedback that was positive regarding the outcome of the project (Bernhardt et al. 2014).

The success of a project is tough to evaluate, the complexity of a stream is challenging. Making correlations between each activity to determine which of the actions created the successful outcome is extremely laborious. Additionally, many of the activities could potentially have cumulative effects on the surrounding area without actually understanding what made the difference (Kondolf and Micheli 2015). The lack of a standardized way to collect data or conduct monitoring before, during and after a project makes project comparison and the data syntheses difficult to determine real success rates on any particular project (Bennett et al. 2016). Successfulness can be defined in various ways, and different groups can report the information to suit their needs. Unless there is a common standard that defines success reported information is potentially biased (Palmer et al. 2005). Projects need to be willing to share both their success and failures so that the field as a whole can benefit at restoring streams.

These limitations are not just found in the United States but on a global level. There have been no long-term studies of river restoration, so data analysis is not available (Roni, Hanson, and Beechie 2005). If the goal is species preservation then shared global knowledge is both relevant and valuable to determine positive effects, adverse effects, and or noncontributory effects on the species.

3. Case Studies

In determining if Lower Putah Creek should be the template for stream restoration for other projects with similar objectives, will require shared analysis of plans to compare differences like, watersheds, community, pollutions, and other varying factors between them.

The Lower Putah Creek stream restoration is monitored mainly by a streamkeeper who is the liaison between the agencies, the community, and other stakeholders. Together they make up a team whose main goal is maintaining and improving the streams habitat, water, and the surrounding area. The streamkeeper is a position that came out of a lawsuit in 2000 referred to as the Accord. It established that Solano County Water Agency has a fiscal responsibility every year of contributing to the funds for maintaining the improvement of Putah Creek.

Non-profit organizations and tribal groups control the Klamath River stream restoration plans. Funding can be a constant challenge. Non-profits rely on donations or grant sources, and the amounts can vary drastically from year to year. However, like Putah Creek, Klamath River has a community that has been involved in restoration and other projects on the river for 20 years that tries to work with the fluctuating needs of the users while improving conditions for the salmon species.

Russian River is similar to Klamath River in that funding for projects vary from year to year depending on what governmental agency has funding. While there are some non- profits throughout Russian River watershed, the main driving forces are governmental agencies. Russian River is like Putah Creek in the fact they have non-profit groups that are trying to take on the roles of a streamkeeper through volunteers. Volunteers can be beneficial but more often than not, the volunteer's ability and attendance fluctuates. The uncertainty makes it hard for the stream to receive consistent advocacy.

3.1. Putah Creek

3.1.1. Geographic Location

Putah Creek is located in the Sacramento River Basin. The Sacramento River Basin encompasses the northern part of California and a small section that crosses over into the southeastern part of Oregon. Twenty-five tributaries contribute to help make the Sacramento River Basin the dominant source of fresh water in northern California. The Sacramento River Basin is approximately 27,000 square miles making it the largest basin in California (Sacramento Watershed Program 2010). The Sacramento Basin is made up of six watershed subregions which include; Northeast which drains into Lake Shasta, Westside which ranges from the coastal mountains and drains into the Sacramento River, Eastside which drains from the Cascade Mountains and the Sierra Nevada's, Sacramento Valley, Feather River, and American River all drain into the main stem of the Sacramento River. Figure 3 shows the location of the Sacramento River Basin along with its six sub-basins (Sacramento Watershed Program 2010).

Figure 3: Map of Sacramento River Basin

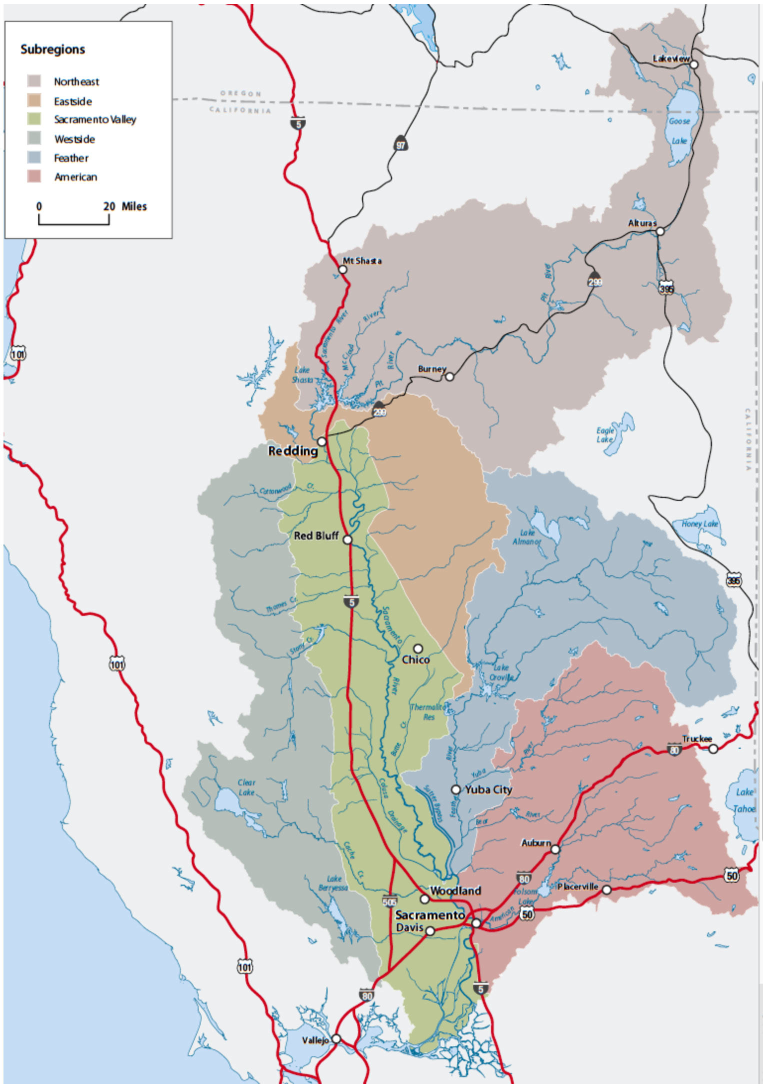


Figure 3: This map showing the boundaries of the Sacramento River Basin broken down into the six sub-watersheds (Sacramento Watershed Program 2010).

The Westside subregion covers approximately 4,343 square miles and contains the tributaries that drain into the Westside of the Sacramento Valley and thus into the Sacramento River. The water that drains from this side of the valley is rainfall and not snowmelt. During the wet season, this subregion can maintain water in its reaches; however, as the dry season presents most of the reaches become dry. The Westside subregion is broken down into six smaller watersheds that span the counties of Shasta, Tehama, Glen, Colusa, Lake, Yolo, Napa, and Solano. These smaller watersheds include, Clear Creek, Cottonwood Creek, Tehama West, Stony Creek, Cache Creek, and Putah Creek

(Figure 4; Sacramento Watershed Program 2010). Figure 4 shows the Westside subregion

Figure 4: Map of the Westside watersheds

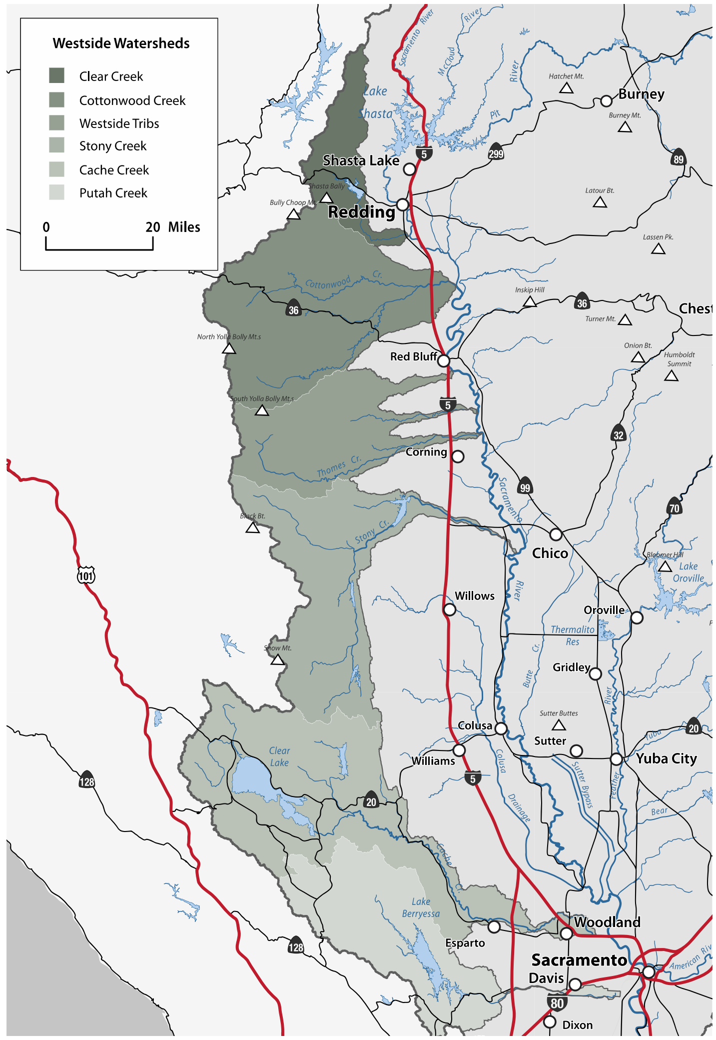


Figure 4: This map shows the smaller watersheds that make up the Westside sub-basin, which is in the greater Sacramento River Basin (Sacramento Watershed Program 2010).

of the Sacramento River Basin. The square miles for each watershed vary with the largest being Cache Creek at 1,300 square miles and Putah Creek, the smallest, at 71 square miles.

Putah Creek is the smallest watershed in the Westside subregion at 71 square miles and is thought to have approximately 70 miles in channels. The headwaters of Putah Creek start in the Mayacamas Mountains, which are part of the coastal range (Putah Creek Watershed 2010). The journey starts on the east side of Cobb Mountain, a few tributaries like Bear

Canyon, Dry, Helena, Crazy Harbin and Big Canyon Creek join the mainstream before merging with Butts Creek and ending at Monticello Dam creating Lake Berryessa. Lake Berryessa defines the ending of the upper part of the Putah Creek watershed.

It is here, below the Monticello dam, that the creek enters the Central Valley floor and becomes the Lower Putah Creek watershed. The creek continues for approximately five to eight miles before the second dam (LPC Restoration Proposal 2011). The Putah Creek diversion dam stops the flow of the creek. After the diversion dam, the creek is merged with a few more tributaries. The tributaries included are Pleasants, McCune and Dry Creek. After Dry Creek, there are no additional tributaries adding to the water and creek. This portion of Lower Putah Creek travels the Yolo and Solano County lines defining the counties boundaries. Before Putah Creek reaches Davis it splits into North and South forks. The north fork is inactive while the south fork continues along until it reaches the Yolo Bypass where it flows into the Sacramento River Deep Water Ship Chain via the Toe Drain. Figure 5 shows the creek's path from the Monticello dam to the Yolo Bypass (Figure 5, DFW ERP Application 2015).

Figure 5: Map of Lower Putah Creek

Figure 5: Map showing the Lower Putah Creek from the Monticello Dam to the Yolo Bypass (DFW ERP Application 2015).

3.1.2. History

3.1.2.1. People on Putah Creek

Many different generations have lived on the banks of Putah Creek using its resources of wildlife, vegetation, housing, clothing, and tools. Moreover, Putah Creek resources have been utilized for spiritual, cultural, and aesthetic reasons. Over the years all those who have lived near the Creek have valued the resources it has provided, from the Patwin Indian's to settlers after the gold rush to today's communities (Quail Ridge Reserve 2005).

The Native Americans that lived along the Putah Creek watershed were thought to be a subgroup from the Wintun tribe. Native Americans were believed to have lived in this region since 1400 BCE. This subset, called the Patwin was broken down into two groups based on the region of the valley they lived in and included the Hill Patwin and the River Patwin. The Hill Patwin tribes lived mostly in what is called today the upper part of the Putah Creek watershed, but the territory included land all the way to Dry Creek. Shortly after Dry Creek, the territory became part of the region occupied by the River Patwin tribes. Both of these Native American groups used the creek for fishing and the riparian habitat along the creek for hunting and gathering (Putah Creek Council 2017). As Putah Creek made its way toward the tribal town of Topaidihi, it became less of a creek and more of a swamp providing a different source of fish and vegetation for those of the River Patwin that lived further downstream (Putah Creek Council 2017).

After the gold rush, settlers moved north to the fertile grounds of the Lower Putah Creek watershed and forced out the Native Americans from the area and onto reservations (Quail Ridge Reserve 2005). As the gold rush settlers established occupancy much of the riparian forest and the nearby floodplains were cleared for farmland. Over time these new settlers learned that Putah Creek was unpredictable in the amounts of water that it would provide to the lower watershed. Often, weather systems that produced storms flooded Putah Creek and sometimes destroyed the farmhouses that were built along its banks. When the storms did not come, the farms did not have the water they needed for crop sustainability, and the fields perished. The settlers decided to reroute the creek in order to optimize farming and as a result, today's creek looks nothing like it did before the 1870s (Quail Ridge Reserve 2005).

3.1.2.2. Dams on Putah Creek

There are two main dams on Putah Creek, Monticello Dam and Putah Creek Diversion Dam. The Monticello Dam marks the end of the upper Putah Creek watershed and the Putah Creek Diversion Dam marks the starting point of areas of concern for stream restoration. The scope of this paper does not discuss the possibility of dam removal as a possible stream restoration technique as the term restoration refers to a reconciliation view of stream restoration. However, an understanding of how the dams play a role in the degradation of Putah Creek is valuable in determining the success of the restoration projects. The following paragraphs give a brief history of the two dams and a start date to when the lower watershed began to degrade seriously.

The Monticello Dam was built by funds provided by a federal project, the Solano Project, in conjunction with the Bureau of Reclamation and Solano County in what was called the Solano project. The Monticello Dams was part one of a two-part project (Marchetti and Moyle 1995). The Monticello Dam was to help aid in the protection of the cities downstream from flooding as well as providing water for the growing population and agricultural industry. The dam finished in 1957 and by 1963 was at its holding capacity of approximately 1.6 million acre-feet (Putah Creek Watershed 2010). Currently, it remains one of the largest human-made bodies of water in the state of California (Quail Ridge Reserve 2005). The Monticello Dam releases more water in winter than during the summer months due to storage capacity limits and agreements for timed agricultural releases (Putah Creek Watershed 2010).

The second part of the Solano project was the building of the Putah Creek diversion dam (Marchetti and Moyle 1995). It is here, that water either travels the natural way continuing down Putah Creek or is diverted to South Putah Canal (LPC Restoration Proposal 2011). The water that is released from the diversion dam into the South Putah Canal is used for agricultural and urban uses in Solano County (LPC Restoration Proposal 2011). The water not diverted from the creek bed continues to flow for the purpose of environmental protection of fish species and other water rights for those consumers along the natural path of Lower Putah Creek (Solano County Water Agency 2017). The releases of water from the Putah Creek Diversion Dam are pre-established a year ahead on a monthly schedule. The predetermined release numbers are the minimum cubic feet per second that are needed to maintain a flow in the Lower Putah Creek (Solano County Water Agency 2017).

3.1.2.3. Droughts on Putah Creek

California is located in a Mediterranean climate region. Mediterranean climate means that winters are very mild in temperature but bring rain, while the summers are scorching in temperature with very little rain. California is always in some stage of a drought, which varies from year to year, based on the rainfall from the previous year. This fluctuation in temperature and water levels have allowed for species to adapt and create endemic species that can only be found in certain areas of California. There have been two major droughts that lasted for multiple years and that have affected Lower Putah Creek.

The drought of 1987 lasted for six years making it one of the worst in all of California's recorded climate history (Nash 1993). Precipitation was recorded to be roughly three-quarters of the normal average and the actual level of water in streams was below average. The 1987 drought put stress on an already stressed ecosystem in California, and as a result, many of the species that were already listed on the Endangered Species Act became very close to complete extinction. Additionally, from the 1987 drought, many other species population dipped and needed to be listed on the Endangered Species Act (Nash 1993).

The high temperatures and lack of rain caused stream temperatures to rise, specifically in the Sacramento River Basin. It was recorded that 50% of the Chinook spring run salmon eggs were lost in 1992 because of the increase in stream temperatures (Nash 1993). Lower Putah Creek also saw a decrease in spawning numbers due to the fact that the dams had been put in place and as a result, the creek saw less water and the present water had temperatures higher than 75 °F (Jasper and Hamilton 2016). Salmon cannot tolerate temperatures much higher than 75 °F and temperatures of 57 °F or less are required for the eggs to survive (Nash 1993). During the drought, large sections of Lower Putah Creek dried up in addition to many other locations across the state of California (Jasper and Hamilton 2016).

Native fish populations were low enough to be considered borderline for being listed on the endangered species act before the drought had additional serious declines during the drought. According to Nash (1993), it is estimated that the number of species at risk for being listed on the Endangered Species Act increased from six to twenty-eight (Nash 1993). The drought of 1987 caused an increase of over four-fold for species needing to be listed or proposed for listing on the Endangered Species Act. The drought of 1987 demonstrated the lack of prolonged drought preparedness and the importance of developing a contingency plan for the state and its waterways (Nash 1993).

3.1.3. Restoration

The community in the Putah Creek watershed has tried to find the balance between the terrestrial and aquatic species that use the creek along with the increasing human demands for water (Marchetti and Moyle 1998). After the drought on Lower Putah Creek in 1987 a group of concerned citizens joined together and formed the Putah Creek Council. The Council's purpose was to protect the remaining riparian habitat and water levels for 23-mile stretch of the creek between the Putah Creek Diversion Dam and the Yolo Bypass (Putah Creek Council 2017). During the 11-year lawsuit partnerships were started and cultivated between the key stakeholders, Solano Water Agency, Solano Irrigation District, UC Davis, and the City of Davis. In 2000, the Accord was finalized. The agreement that was reached took into account all those in the community and outlined a path for moving forward. The Accord satisfied goals for all parties, and established water security, awareness of the necessity of water reduction during droughts, outlined strategies for management of riparian diversions, set new maximums and minimum water instream flows, provided perpetual restoration funds, and a permanent streamkeeper (Putah Creek Council 2017).

The Accord laid out the initial groundwork for Lower Putah Creek. Since then the streamkeeper, Putah Creek Council, the Solano Water Agency, and UC Davis have worked together over the last decade restoring Putah Creek in various ways. There are many projects that are going on along the banks of the Lower Putah Creek that include birds, native fish, water quality, invasive removal, flood protection, replanting of native species which all take into account the needs of both humans and wildlife in the surrounding areas (LPCCC Annual Report 2016). There are a few unique things about the restoration that goes on at Putah Creek, because of the 2000 Accord. Putah Creek knows that it has a set amount of funding from year to year, this allows for a full time position of a streamkeeper and money for the constant ongoing of monitoring and data collection that restoration projects need to be able improve their outcomes through adaptive management.

Another unique benefit about Putah Creek is that it is travels through part of the campus at University of California, Davis (UC Davis). This allows for monitoring, data collection, and studies to be done at a fraction of the cost and quicker turnaround times because of the association with the university. UC Davis is able to provide student volunteers, students in field classes, graduate research students and professor pursuing research all on various aspects of the Putah Creek Watershed. This additional monitoring, data collection, and studies is invaluable for Putah Creek. Constant flow of information to the streamkeeper of Putah Creek allows adaptive management decisions earlier. The streamkeeper can try new restoration techniques, monitor them and make adjustment as they come up. The ability to change course as information is updated and evaluated allows for Putah Creek to be able to push the boundaries of the scientific method.

3.2. Klamath River

3.2.1. Geographic Location

The Lower and Middle parts of the Klamath River are part of the greater Klamath River Basin. This basin like the Sacramento River Basin crosses over the California border into Oregon and drains an area of approximately 12,000 square miles (KRBFTF 2006). The Klamath River Basin only has a few tributaries that add to its annual mean flow of about 17,900 cubic feet per second (Reclamation MWW 2016). Even though there are seven major tributaries in total, the Klamath River Basin is approximately 5,700 square miles (Reclamation MWW 2016) thus making the Klamath River the second largest river by volume in California (CAA report 2006). The main stem of the Klamath River travels 254 miles starting at Lake Ewauana in Oregon and traveling along the Cascade Mountains and into California where it then travels westward and southerly in a direction making its way to the Pacific Ocean (Reclamation MWW 2016). The Klamath River Basin is the third largest producer of salmon in the western part of the United States. The Columbia River and Sacramento River being the first two respectively (KRBFTF 2006; and EPA 2017).

Figure 6 shows the entirety of the Klamath River Basin in both California and Oregon.

The Klamath River Basin is divided into two watershed subregions, the Upper Klamath Basin and the Lower Klamath Basin (USDA 2017). The division between two subregions is the Iron Gate, which is one of the six dams that can be found on the main stem of the Klamath River (USDA 2017; and Reclamation MWW 2016). Upper Klamath Basin covers an area of approximately 5.1 million acres (USDA 2017), and travels through Klamath and Lake counties in Oregon, along with Modoc and Siskiyou counties in California (Reclamation MWW 2016).

The Lower Klamath Basin, shown partially in Figure 7 covers 4.8 million acres (USDA 2017) and only travels in the California counties of Del Norte, Trinity, and Humboldt (Reclamation MWW 2016). The Lower Klamath Basin contains four of the seven major tributaries, Shasta, Scott, Salmon and Trinity rivers (EPA 2017) and together they provide 44% of the mean average flow for the Klamath Basin (Reclamation MWW 2016). There are seven sub-basins located within the Lower Klamath Basin; Upper Klamath West (also know as the Middle Klamath), Shasta, Scott, Salmon, Lower Klamath, Trinity and South Fork Trinity. The Lower Klamath sub-basin is approximately 984,709 acres, the Middle Klamath sub-basin, is approximately 489,887 acres (USDA 2017). Together the two sub-basins, Lower and Middle form the portion of the Klamath River that will be compared to Putah Creek, and these sub-basins cover 30% of the total acreage contained in the Lower Klamath Basin.

Figure 6: Map of Klamath River Basin

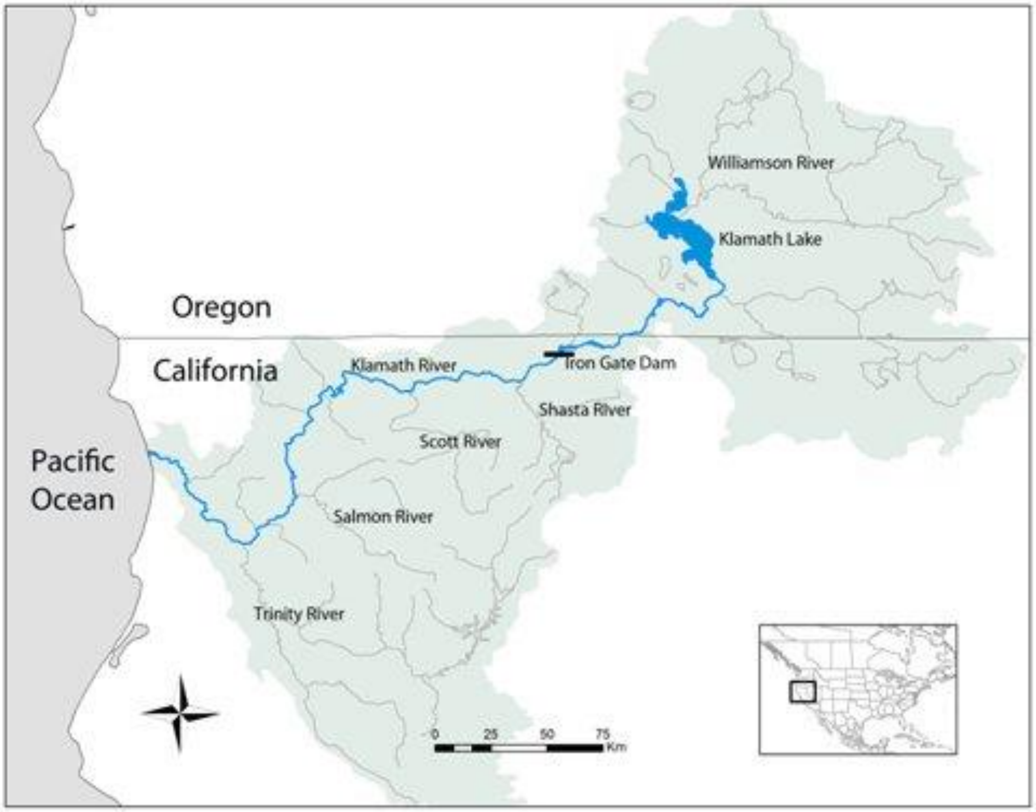


Figure 6: Shows the location of the Klamath River Basin, and the route of the main stem of the river from the headwaters to the ocean (KRBFTF 2006).

Figure 7: Map of Lower Klamath River Basin

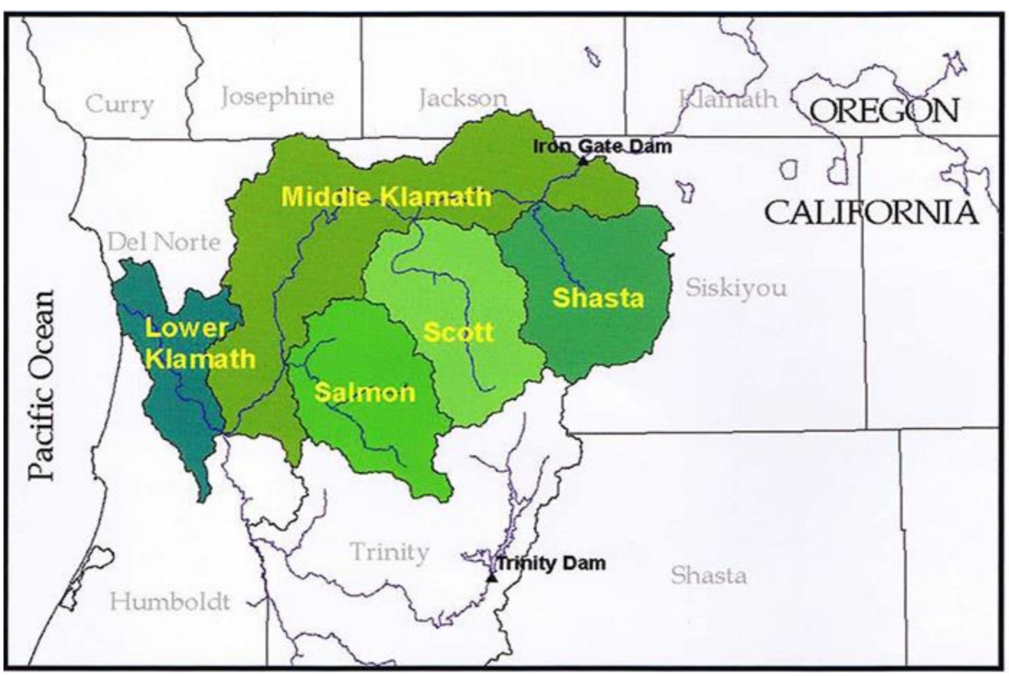


Figure 7: Shows the five of the seven watersheds of the Lower Klamath River sub-basin (KRBFTF 2006).

3.2.2. History

The history of the Klamath River Basin includes many turbulent years, between the Klamath Tribes, federal and state agencies, homesteaders, farmers and urban users. The water availability and the salmon have been the limiting sources that have continuously caused the friction. However, the aforementioned stakeholders have united in the efforts to work together to reach the common goal of a better Klamath River Basin for all its stakeholders.

3.2.2.1. People on Klamath River

The Klamath River Basin is home to many different Indian tribes both located in California and Oregon all using its waterways as a source of food and transportation to trade among the various tribes. The Upper Klamath Basin comprised of a group of tribes call themselves the Klamath Tribes of Oregon. The tribes included in the group are: the Klamath tribe, the Yahooskin Bands, and the Modoc tribe. The Modoc's tribe is located in the northeastern part of California (Klamath Tribes 2017). There are five tribes that are located along the Lower Klamath River they include the Hoopa Valley Tribe, Yurok Tribe, Karuk Tribe, the Resighini Rancheria, and the Quartz Valley Indian community (KTWQC 2017). These tribes were the original settlers of the Lower Klamath River and used the river as a means of transportation by carving out redwood trees to make canoes (Redish and Lewis 2009 2017). The canoes allowed for travel up and down the stream, which allowed for fishing and trading among the tribes along the Lower Klamath banks. All the tribes were known to be peaceful. A significant portion of land was taken from the tribes by various acts put in place. Additionally, populations diminished as the result of outside disease or hostile attacks (Native American Indian Facts 2017). One such action was the 1891 Forest Reserve Act by Theodore Roosevelt that in 1905 claimed the Klamath Forest Reserve as public land when it belonged to the Karuk Tribe (Karuk Tribe 2017). The Karuk Tribe had 1.04 million acres of its reserve taken as the result of the Forest Reserve Act and was given to homesteaders (Karuk Tribe 2017).

In 1917 the land in the Lower Klamath Basin was open to homesteaders interested in farming (Water Education Foundation 2017). The homesteaders were able to set up settlements and start farming due to the Klamath project in 1918. The first of a series of dams was built on the river for both irrigation and hydroelectric purposes (Water Education Foundation 2017). As the population grew along the banks of the Klamath River fishing became more of a commercial industry. As a result, the Klamath River became one of the top rivers in the country at producing salmon. By 1933 the actions of overfishing were prevalent as a result commercial fishing was banned on the Klamath River (Water Education Foundation 2017). The Klamath River commercial fishing ban led to irrigation and the start of a farming industry that is deeply rooted even in current times and results in a continuous relationship with various stakeholders on water issues.

The 10 million acres of the Klamath River Basin can be broken down into the different land uses and ownership by the basins of the Upper and Lower Klamath River. The land uses are broken down into either private land or federal/state and tribal lands. Private land makes up 3.7 million acres, tribal land makes up 90,000 acres and the remaining 6.2 million acres is public land (NRCS; Klamath River Basin 2004). Private lands estimated at 3.7 million acres are broken down by land use and they are: cropland and pastures, rangeland, forestland, urban/developed land, commercial/industrial, residential, streams/lakes, and other. The multiple land uses demonstrates the many different groups of people who use the river for varying activities each with various water needs (NRCS; Klamath River Basin 2004).

3.2.2.2. Dams on the Klamath River

The Klamath River Basin has multiple dams located throughout the Upper and Lower Klamath River. There are six dams along the main stem of the Klamath River, and there are five located in various outreaches. Of the six dams located on the main stem of the river, four are for power generation, and two are for irrigation (KRBFTF 2006). The other five dams located in the basin are for irrigation in the Upper Klamath and water supply for the Lower Klamath region and the Central Valley Project. Figure 8, shows the locations of all the dams located on the Klamath River (Reclamation MWW 2016).

The first of the dams to be built on the main stem was the Copco 1 in 1917 and it stopped the salmon runs from reaching the Upper Klamath Basin (Water Education Foundation 2017). The next dam affecting the Salmon population was the Dwinnell Dam built in 1928 on Shasta River. Shasta River is one of the tributaries for the Lower Klamath River and this dam stopped the return of salmon for one of the largest runs on the Klamath (Water Education Foundation 2017). The last dam located on the main stem of the river is called the Iron Gate and was built in the mid-1960s for hydropower (Reclamation MWW 2016).

Degradation of the stream was occurring before the dams were built. However, the dams decreased the amount of spawning habitat that the anadromous fish had access to and effectively blocked over 400 miles of streams (KRBFTF 2006). Table 5 shows the locations of the dams identifying the river location by river mile, year of completion, capacity, and the purpose of the dam (Reclamation MWW 2016). Some of the dams are subject to removal if the licensing renewal is denied to PacifiCorp. After weighing the benefits and implications of dam removal many stakeholders hold to the hopes of restoring the habitat, and historical anadromous fish runs that removing the dam will provide. These benefits, however, need to be weighed against the public interest and the impacts that would affect the key stakeholders by the removal of the dam.

Figure 8: Shows the location of the dams on the Klamath River, both those on the main stem and in the further reaches (Reclamation MWW, 2016).

Figure 8: Map of the dams located in the Klamath River Basin

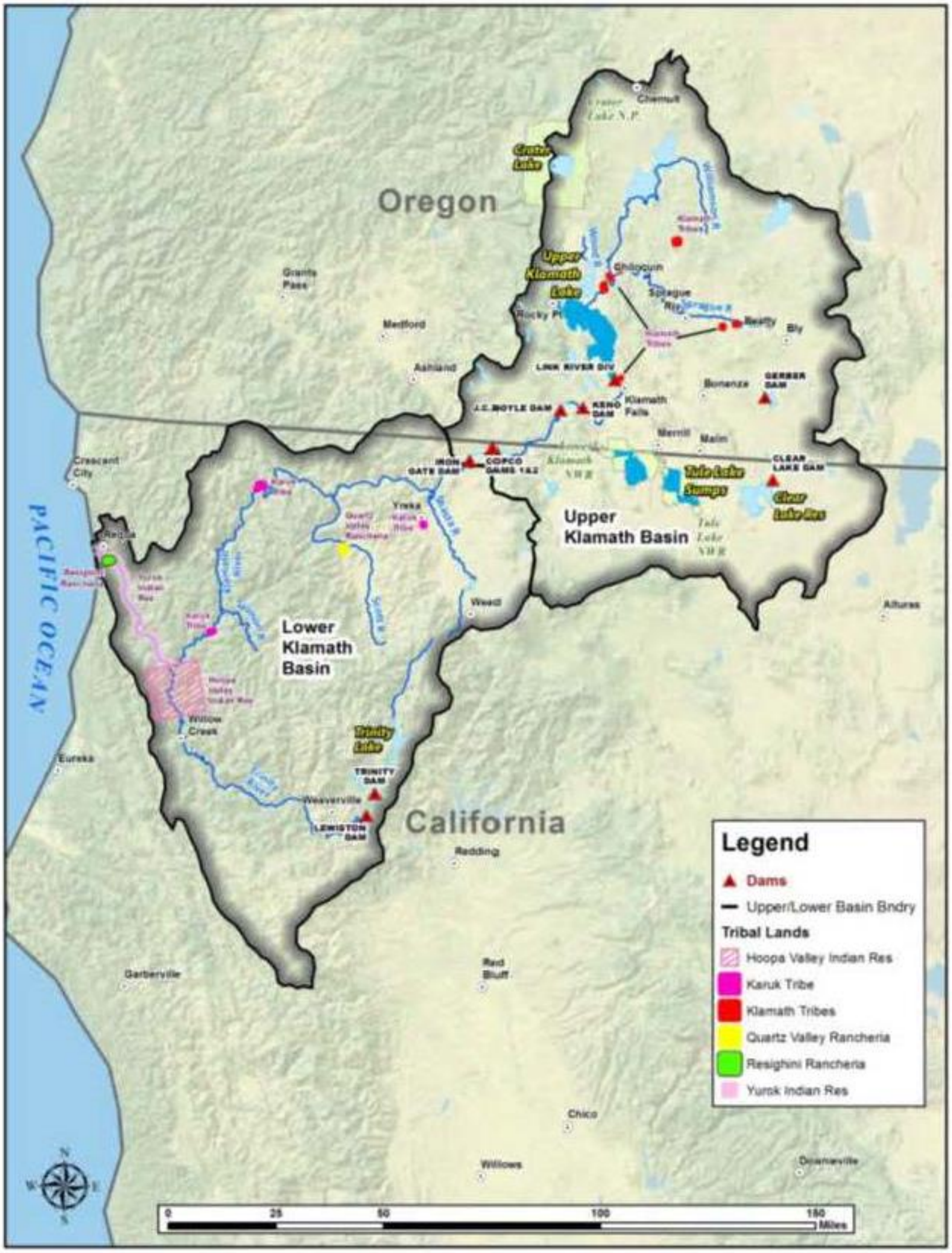


Table 5: List of Dams locating the Klamath Basin

3.2.2.3. Drought on the Klamath River

Northern California is on the outer region of the range that has the Mediterranean climate. Thus California is prone to droughts due to the Mediterranean climate that covers most of the state. However, the Klamath River is also influenced by the neighboring mountains located in Southern Oregon, which tend to be colder and rainier due to the higher elevations than that of the portion of the Klamath River located in California. The straddling of these two states allows for the Klamath River Basin's weather conditions to be highly variable and at high risk for droughts due to large swings in climate changes.

One of the biggest droughts on the Klamath River was in the early 2000s. It made the national news because of the devastating affects the drought had to the watershed and the surrounding communities (NRCS 2004). In the summer of 2001, water that was typically used for irrigation of crops was instead kept in the Upper Klamath Lake and was released in controlled flows downriver. The goal of the controlled flow was to protect the fish that lived in the stream and listed on the Endangered Species Act (Levy 2003).

The economic impact that came from the agricultural losses that season has been estimated in the millions (Levy 2003). Oregon State University estimated that $157 million dollars were lost in agricultural sales and $79 million was lost in reduced employment, business owner income, and other property value. The reduction of 3.5% in employment came as a result of the lack of farming and harvesting jobs; this translates into a loss of 2,000 jobs in the community (NRCS 2004). The following year as the drought continued the Bush administration decided to change the decision of the previous year and allowed the irrigation need to be fulfilled over protecting the fish that fall under the Endangered Species Act.

The decision the Bush Administration made in letting water go to irrigation over the streams for the fish, led to one of the worst fish kills in the western United States (Levy 2003). The lack of water and low water levels trapped salmon in warm shallow pools resulting (Levy 2003) in over 33,000 adult salmon deaths in the Klamath River and it reaches as they tried to migrate (EPA 2017). Figure 9 demonstrates carcasses of the salmon, with the majority being Chinook. The photograph was one of many taken within five miles of Blue Creek (Levy 2003).

Figure 9: Dead fish in massive die-off in Blue Creek 2002

The current drought situation has biologist worried that a similar situation could again occur (Associated Press 2015). In 2015, as the temperatures stayed elevated the temperature of the water also rose making streams uninhabitable for salmon. Therefore the salmon were crowding in cool water pools, which increased the spread of disease among the fish (Associated Press 2015). The tensions between farmers and other stakeholders in the basin drove groups to work together so that future disasters could be prevented in ways that meet all stakeholder needs. The Klamath River fall-run of Chinook has fallen an estimated 62%; from 142,200 fish in 2016 to 54,200 fish in 2017 due to the lingering drought effects (Pacific Institute 2017).

Figure 9: Shows the massive salmon die-off that happened in the Klamath River in 2002 (Levy 2003).

3.2.3. Restoration

People living on the banks of the Klamath River watched as the river condition declined. Many in the community pleaded to Congress bringing the situation into the spotlight stating that the degradation was due to the construction and operation of dams, diversions and hydroelectric projects, past mining establishments, timber harvest, and road construction (KRBFTF 2006). It was not until 1986 when Congress acted by created the Klamath Act, which was a 20-year long cooperative program, aimed at restoring the declining anadromous fish populations in the Lower Klamath River (KRBFTF 2006). The Klamath Act was the first restoration project on the Klamath River.

The Klamath Act provided funding for restoration activities, planning, fishery research and monitoring, along with community outreach through one million dollars each year for 20 years (KRBFTF 2006). The act formed two groups that would work together to give advice to Federal and State agencies regarding decisions as well as create a forum for discussion of the Klamath River Basin issues. The stakeholders in the groups worked together to help gather information and devised plans for salmon harvest issues and the implementation of habitat restoration on the main river and its reaches.

The act focused on four main efforts, which included: restoration planning and coordination, restoration improvements for fisheries and habitat, assessment and research, and public outreach and education of the basin. In total, during the whole span of the project, the Department of Interior spent approximately $18.8 million dollars on the Act. Different stakeholders throughout the program raised additional funds and much of the seed money was invested in efforts that can be used in perpetuity for individual projects (KRBFTF 2006). The pie graph (Figure 10) shows the breakdown of the funding related to the four main focuses of the act, project management (11%), federal committee support (14%), program administration (15%), and restoration projects (60%). The restoration projects portion of the funding totaled $11,231,313 for the 20-year period, broken down in five categories, planning and coordination, (14%) habitat improvements (10%), fish rearing (7%), assessments and research (25%) and outreach and education (4%; KRBFTF 2006).

After the massive die-off of salmon in 2002, as mentioned in the previous section, another wave of protecting the fish, other species, and their stem habitat was deemed necessary. Agreements called the Klamath Basin Restoration Agreement, and Klamath Hydroelectric Settlement Agreement, were negotiated to help resolve long-standing conflicts in the

Figure 10: Expenditures for Restoration Projects in Klamath River Basin

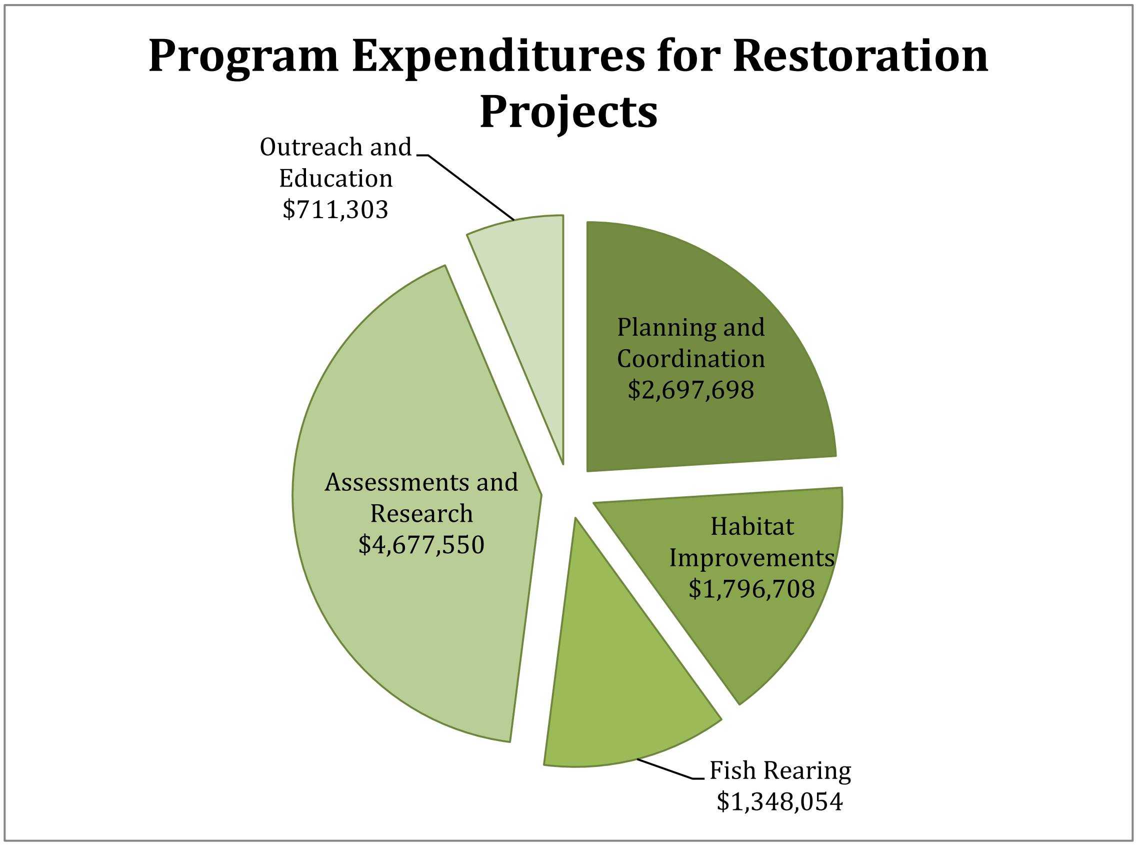


Figure 10: Shows the breakdown of the $11,231,313 spent for expenditures during the 20-year program within the category of restoration projects (KRBFTF 2006).

Basin (KlamathRestoration.gov 2017). The goals of the agreements were as follows; to restore and sustain wild salmon populations while allowing for participation of harvesting throughout the Klamath Basin, maintain and strengthen the agricultural, community, and National Wildlife Refuges uses of both water and power, and increases the sustainability of the Klamath Basin communities (KlamathRestoration.gov 2017).

3.3. Russian River

3.3.1. Geographic Location

The Russian River watershed is located in the Northern part of California. The Russian

River drains 1485 square miles as it travels through Mendocino and Sonoma counties (NOAA 2017). The Russian River has over 238 streams and creeks along with its main tributaries they are; East Fork Russian River, Big Sulphur Creek, Mark West Creek, Dry Creek, and Maccama Creek (Sonoma County Water Agency 2017). The river runs about 110 miles from the headwaters located in the Mayacamas Mountains range and travels south to Mirabel Park then changes direction to a western route and goes through the coastal range and dumps into the Pacific Ocean near the town of Jenner (Russian River Watershed Association 2017). The Russian River watershed has six main valleys as it travels downstream between the Mayacamas Mountains and the Mendocino Highlands these valleys make up 15% of the watershed leaving the remaining 85% to hills and mountains (SCWA & UCCE/CSG 2015).

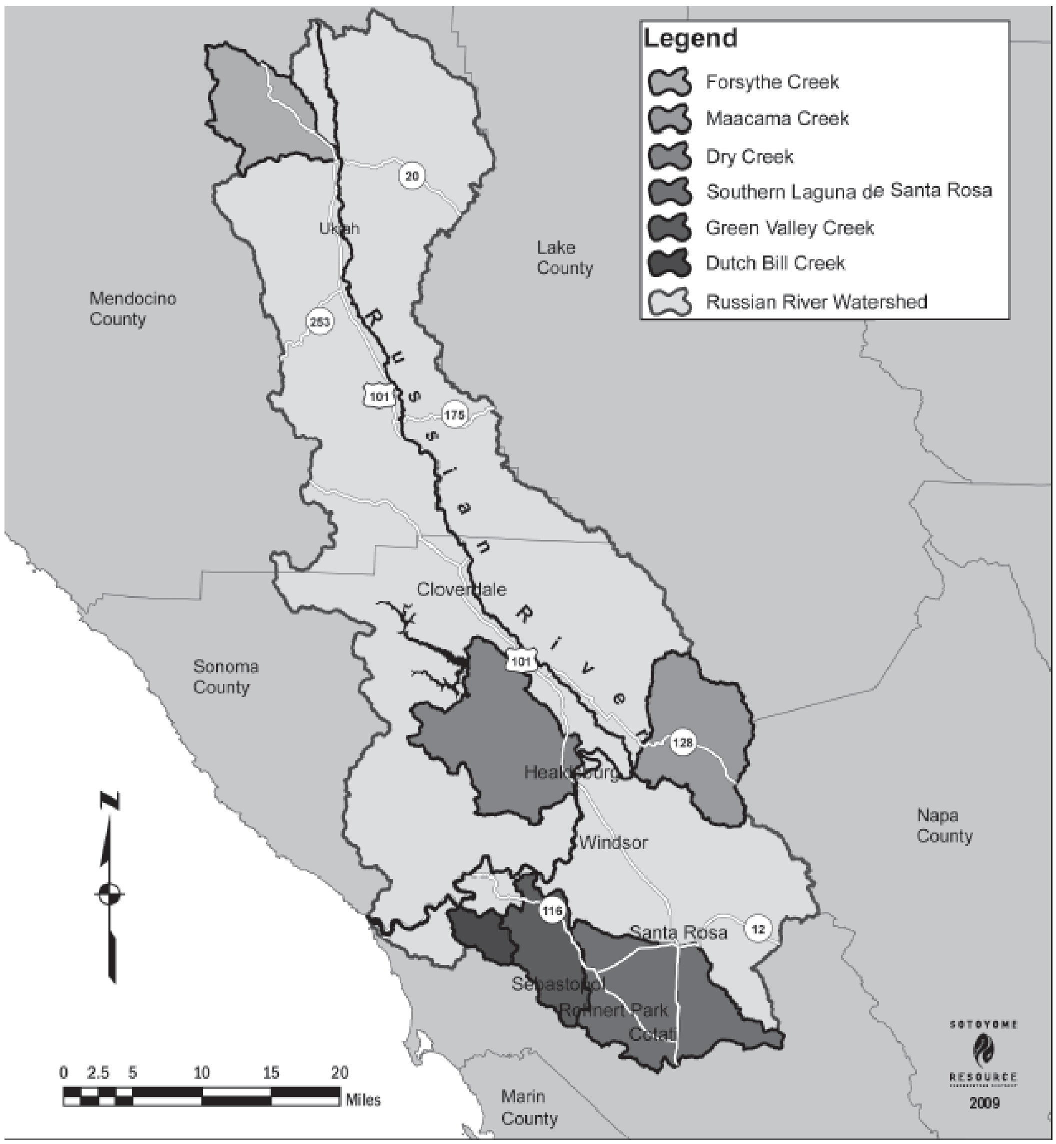
The Russian River watershed is divided into the Upper Russian River watershed and the Lower Russian River watershed. The distinction is at the county line, the upper watershed being located in Mendocino County and the lower watershed being located in Sonoma County (Sotoyome RCD 2009). The greater Russian River watershed has six sub-basins; one is located in Mendocino County, and that is Forsythe Creek located in the northwest corner of the Russian River watershed. The remaining five sub-basins are located in Sonoma County and are as follows; Maacama Creek which is 70 miles square, Dry Creek which is the only sub-basin with large dams; Laguna de Santa Rosa which is the biggest sub-basin in the watershed, Green Valley Creek which has the major tributary of the lower Russian River watershed and Dutch Bill Creek which still has a wild coho population within its boundaries (Sotoyome RCD 2009). Figure 9 shows the entire Russian River watershed and the sub-basins located within the greater basin. The basin contains 360,000 people and 63 different fish species with Coho, Chinook, and Steelhead being listed on the Endangered Species Act (Russian River Watershed Association 2017).

Figure 11: This map shows the Russian River Watershed with the sub-basin shaded in different greys (Sotoyome RCD 2009).

3.3.2. History

The Russian River watershed is one of the largest watersheds for the Coho species, and is listed as their critical habitat (SCWA & UCCE/CSG 2015); the species population is

Figure 11: Map of Russian River Basin



estimated to be only 15% of its original abundance in the Russian River watershed (Ca. Sea Grant 2017). Like many of the watersheds across California since the gold rush, streams have begun to degrade causing salmon populations to decline due to human impacts such as stream diversion, damming, mining, logging, agriculture, urban development, and overfishing (Ca. Sea Grant 2017). The only remaining wild population of Coho in California is in Lagunitas Creek located in western Marin County (Ca. Sea Grant 2017).

3.3.2.1. People of the Russian River

Like the other watersheds before the settlers moved into the region during the gold rush, Native Indians occupied much of the land along the rivers; in the Russian River watershed, the Pomo's were the original settlers (Redish and Lewis 2009 2017). The Pomo people lived throughout the watershed from the coast through the forest and into the mountains, with the majority of the population residing in the Russian River Valley. The main source of food for the Pomo people was freshwater fish, specifically salmon (Social Studies Fact Cards 2017).

The fisherman would use two different ways to catch the salmon depending on the time of year and the direction the salmon were traveling. When salmon were migrating upstream to spawn, they used a spear like a harpoon that had two prongs on the end. When salmon were migrating downstream to transition to the ocean the Pomo people used a scoop net to catch the young salmon (Mendocino Railway History 2017). They would catch the salmon and dry it out so that they had a source of food all year long (Social Studies Fact Cards 2017).

As the settlers moved in for gold mining, they removed timber, clearing areas for farming along with draining wetlands for the fertile ground (Sotoyome RCD 2009). The land was used for agricultural purposes formerly orchards, hops, and rangelands and now it consists mainly of vineyards, row crops, few orchards and some rangeland for cattle and sheep (SCWA & UCCE/CSG 2015). Gravel Mining in the eighties is considered to have caused the degradation of the stream to be expedited due to the removal of 10 million tons of gravel that lowered the riverbed 20-50 feet (Kondolf 2017). In the 1930s due to the Dust Bowl that was taking place in the Great Plains, resource conservation districts (RCD) were established to help farmers and serve as local leadership in conservation of soil, water, and related natural resources (Sotoyome RCD 2009).

There are currently 103 Regional Conservation Districts (RCD) in California and three are located within the Russian River watershed. They have helped to start and promote fish-friendly farming. The RCD's raise awareness to those in the watershed that fish use the Russian River as a "highway" to the tributaries where they spawn and those needed for juvenile habitat (Sotoyome RCD 2009). 98% of the land in the Russian River watershed is privately owned (Christian-Smith and Merelender 2010) the three RCD’s in the watershed are trying to promote good stewardship with tools for the current residents to use (Sotoyome RCD 2009).

3.3.2.2. Dams of the Russian River

There are two dams located within the greater watershed, one is in Mendocino County, and the other is in Sonoma County. Coyote Dam is located on the main stem of the Russian River in Mendocino and Warm Springs Dam is located on one of the major tributaries, Dry Creek in Sonoma (Sonoma County Water Agency 2017). Heavy floods in the Russian River watershed in 1937, prompted Congress to authorize a study to determine if dams should be built throughout the watershed where flooding was abundant. In 1941, the findings from the study suggested dams could be constructed and would help in flood control and water supplies for the growing region (Lake Sonoma Friends 2017). US Army Corp of Engineers operates the dams and is in charge of the maintenance that goes with it (Sonoma County Water Agency 2017).

The US Corp of Engineers built the Coyote Dam five miles northeast of the city Ukiah. Coyote dam was built due to the authorization of the Flood Control Act of 1944, and the dam was completed in 1958 (USACE 2017). Once filled, Coyote dam has a capacity of 118,000 acre-feet creating Lake Mendocino (Sonoma County Water Agency 2017). Lake

Mendocino also offers recreation to the area in the form of campgrounds, swimming beaches, picnic areas, trails and boating opportunities.

The second dam, Warm Springs Dam, was authorized by the Flood Control Act of 1962 and construction started (USACE 2017). However, in 1969, when the Environmental Policy Act became law and these new regulations halted construction in 1974 when a group opposed to the dam came forward and pushed for the evaluation of building a dam in the area (Lake Sonoma Friends 2017). The evaluation took place and Warm Springs Dam was not completed until 1983. The capacity of the dam is 381,000 acre-feet, and created Lake Sonoma (Sonoma County Water Agency 2017). Besides flood control, water supply, irrigation, the lake offers recreation and environmental stewardship to the watershed and its community (USACE 2017).

3.3.2.3. Drought on the Russian River

During the years 2007-2009 the Russian River watershed was dealing with drought conditions. The surface water and groundwater recharge were declining and Lake Mendocino was dangerously close to being unable to supply even drinking water to its users (EPA 2017). In 2008, even with the drought, wineries in the Russian River watershed continued with normal watering practices, dropping the already low flow rates from dry conditions down to 168 cubic feet per second (EPA 2017). The State Water Resources Control Board responded with regulations that lead to a lawsuit that was overturned in 2012 in favor of the wineries. This flip-flop in which priorities should take precedent prompted the National Integrated Drought Information System to use Russian River as a pilot project for a drought early warning system that could help reduce impacts and economic losses (EPA 2017).

The current drought has created much attention aimed at the Russian River watershed. The Lower Russian River watershed was granted an Emergency Regulation to enhance conservation measures in a few of the key tributaries for the watershed, Dutch Bill, Green Valley, Mark West and Mill Creek in 2015 and 2016 (SWCRB 2017). In 2014, there had been an effort to obtain a voluntary drought initiative. The initiative asked stakeholders not to divert excess water, therefore, allowing for the already low flows, due to the fourth year of drought, not to be entirely reduced making the water conditions unsuitable for the endangered fish.

There were only 20 landowners that opted to sign the voluntary agreement in 2014 (SWCRB 2017). The lack of willing participation caused the California Department of Fish and Wildlife along with National Marine Fisheries Service to bring the matter to the State Water Board. In June 2015, the State Water Board adopted the emergency regulation that was in effect at the beginning of this year (SWCRB 2017).

3.3.3. Restoration

Like the other watersheds previously discussed, restoration on the Russian River was first prompted by the threat of a lawsuit regarding violations of the Public Trust Doctrine back in 1995 (RussianRiverKeeper 2017). This doctrine allowed for a Watershed Council to be formed and tackle the issues that were in Russian River Watershed. The group started by working a comprehensive watershed management and fishery restoration plan. Unlike the other two watersheds Putah Creek and Klamath River, the Russian River has gotten attention from former presidents including Robert Kennedy Jr., and Barack Obama. President Barak Obama supported the Resilient Lands and Water Initiative in 2016 and made sure funding was available for projects (NOAA 2017).

Studies done on the global level and outside of California show that society is recognizing how important the rivers and salmon are not just to communities but the overall health of the environment. Since 1995 there have been various projects that have been implemented throughout the watershed. However, the majority of the habitat restoration has been done in the Lower Russian River Basin. The Lower Russian River Basin was determined a priority area even before the Water Initiative in 2016 (RussianRiverKeeper 2017). Some of the restoration projects have been prompted from lawsuits required to provide funding that would help with pollutants that had been deposited into the watershed. A specific lawsuit was focused on a company's effect of gravel mining, which is still present and ongoing in the watershed (RussianRiverKeeper 2017).

Many of the projects have been on some of the major tributaries of the Russian River, Dry Creek Mill Creek, and Willow Creek estimated at around $54,200,00 over the past two decades since restoration has been present in the watershed (Russian River Funding Needs 2009). However, it is still estimated that $15,921,000 is still needed to complete projects that have been previously identified (Russian River Funding Needs 2009). The restoration on Mill Creek was focused on reconnecting 11.2 miles of isolated habitat that was thought to be the best habitat in the watershed for both the coho salmon and steelhead trout. This project was upgrading a large flashboard dam that was considered a fish barrier to the habitat upstream. Willow Creek's project was focused on the removal of fish barriers; a series of culverts had become impassable by fish that were migrating upstream (NOAA 2017). The culverts had become clogged often flooding the surrounding area and creating a stream across the road, which fish tried using see Figure 12. The

Figure 12: Fish crossing the road

Figure 12: A salmon swimming upstream using it's "nose" and traveling on top of the road because the culvert underneath is clogged with debris (NOAA, 2017).

project rerouted the creek to an area where a 43–foot clear-span bridge was put in, the rechanneling also allowed the creek to reconnect to an isolated wetland (NOAA 2017). Overall this project created seven miles of pristine nursery habitat and reconnected a wetland that serves as a nursery habitat for fish.

Dry Creek has had various types of restoration projects on its banks as it continues to supply water to more than 600,000 users (Sonoma County Water Agency 2017). Dry Creek is the 14 miles water between the Mendocino Dam and the Russian River's main stem. The Biological Opinion of 2008 determined that for juvenile fish the velocities of water were too fast during this stretch of the creek. As a result juvenile fish were being swept out to the main stem of the river instead of allowing them the rearing time needed in the unique habitats along Dry Creek (Sonoma County Water Agency 2017). Therefore many of the restoration projects on Dry Creek are focusing on ways to slow the velocity of the water. They are also hoping to give alcoves or side channels thus allowing areas for the fish to rest. The project is aiming for six miles of these low-velocity areas to be in place by 2020. Currently, one and a half miles have been created with additional bank stabilization projects, to make sure the river meanders, see figure 13 (Sonoma County Water Agency 2017). The pairing of these projects has also decreased erosion in the creek and increased vegetation cover, which offers additional benefits to both the salmon and the water quality (Sonoma County Water Agency 2017).

Figure 13: Map of Dry Creek enhancement program

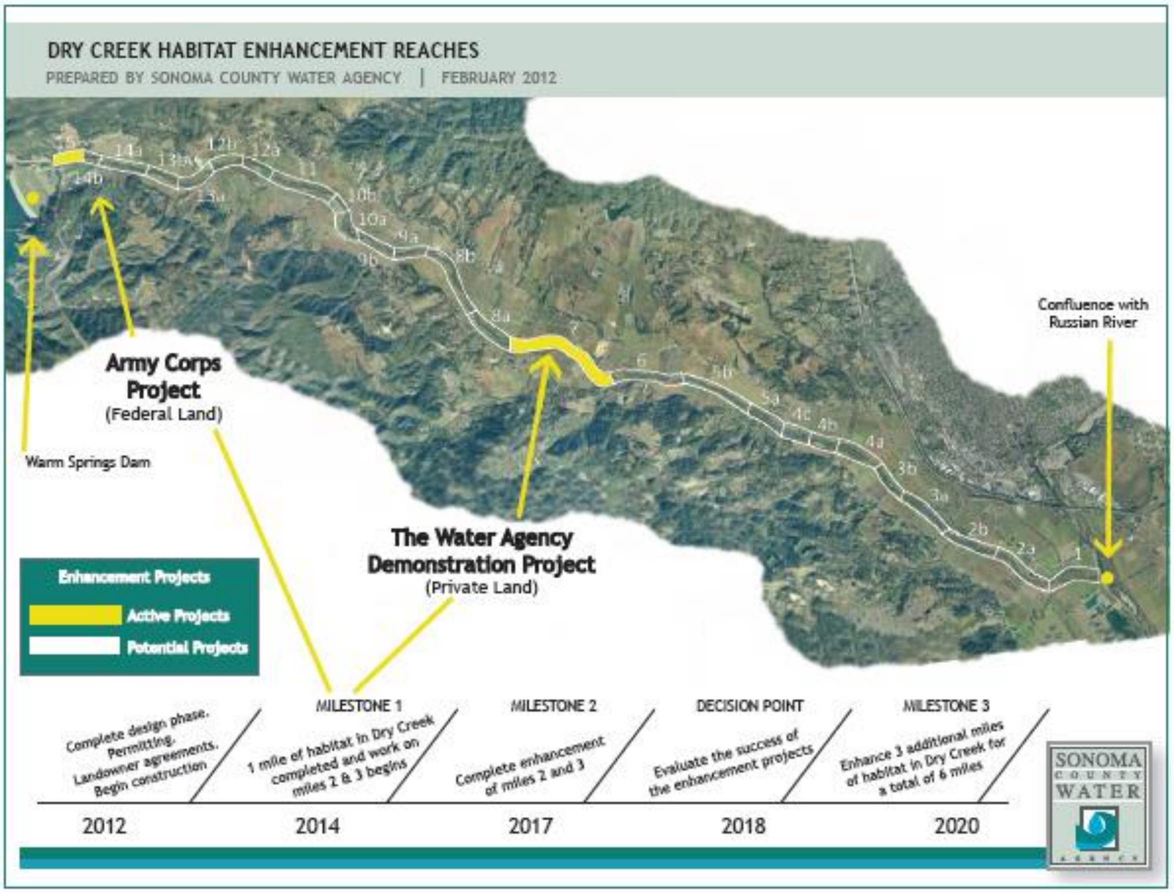


Figure 13: Map showing Dry Creek Enhancement Projects and the timeline for completion (Sonoma County Water Agency, 2017).

4. Methods and Analysis

4.1. Measures of Success of Stream Restoration

Success can mean different things depending on how it is defined and evaluated in a restoration plan. Success can be a combination of the physical factors, a stream restored with its natural processes, improved habitat, or the biota returning increasing in their numbers strengthening the base of the food chain. The research demonstrated that while there are millions of dollars every year being spent on restoration plans; there has not been standardization on how to evaluate the success or failures of the project's defined restoration goals (Rumps et al. 2007).

A restoration plan needs to have a clearly defined set of objectives and standards that determine if the goals have been met and to what degree of success was achieved. To make the determination if a restoration plan was successful requires the data from monitoring the restoration project to be collected after the implementation of the entire project. Jeanne Rump's study shows that 66% of project managers state long-term maintenance and monitoring was needed for their stream restoration plans to show success; however, only 43% were able to obtain the necessary funding to be able to monitor and maintain the project after implementation. Without some standardization, it will be challenging for the field of restoration to improve. Quantifiable data is needed to understand the success and failures of stream reconciliation (Kondolf and Micheli 1995).

The research did not find a standardization tool for restoration projects, which is needed for restoration, plans to be duplicated. Each watershed and stream are unique that standardization is a challenge with all the variables within the watersheds. All restoration plans will need to be designed site specific. The field of restoration could establish a set of guidelines based on quantifiable data that each restoration plan could use as a template to follow specific actions that have been shown to be successful. The guidelines could establish a standard way of collecting data so that monitoring and maintenance could be performed with more ease and reliability. Kondolf and Micheli (1995) believed that the first step needed to help in evaluating restoration plans was to establish a set of transects in the implementation phase that would be routine monitoring transects every time. These would be the set transects for the project and would be what practitioners came back to each time monitoring was done regarding a particular project. The projects, had if any, very limited funding, budgeted for a period of time after the implementation phase had been completed to monitor the project's outcomes. (Kondolf and Micheli 1995).

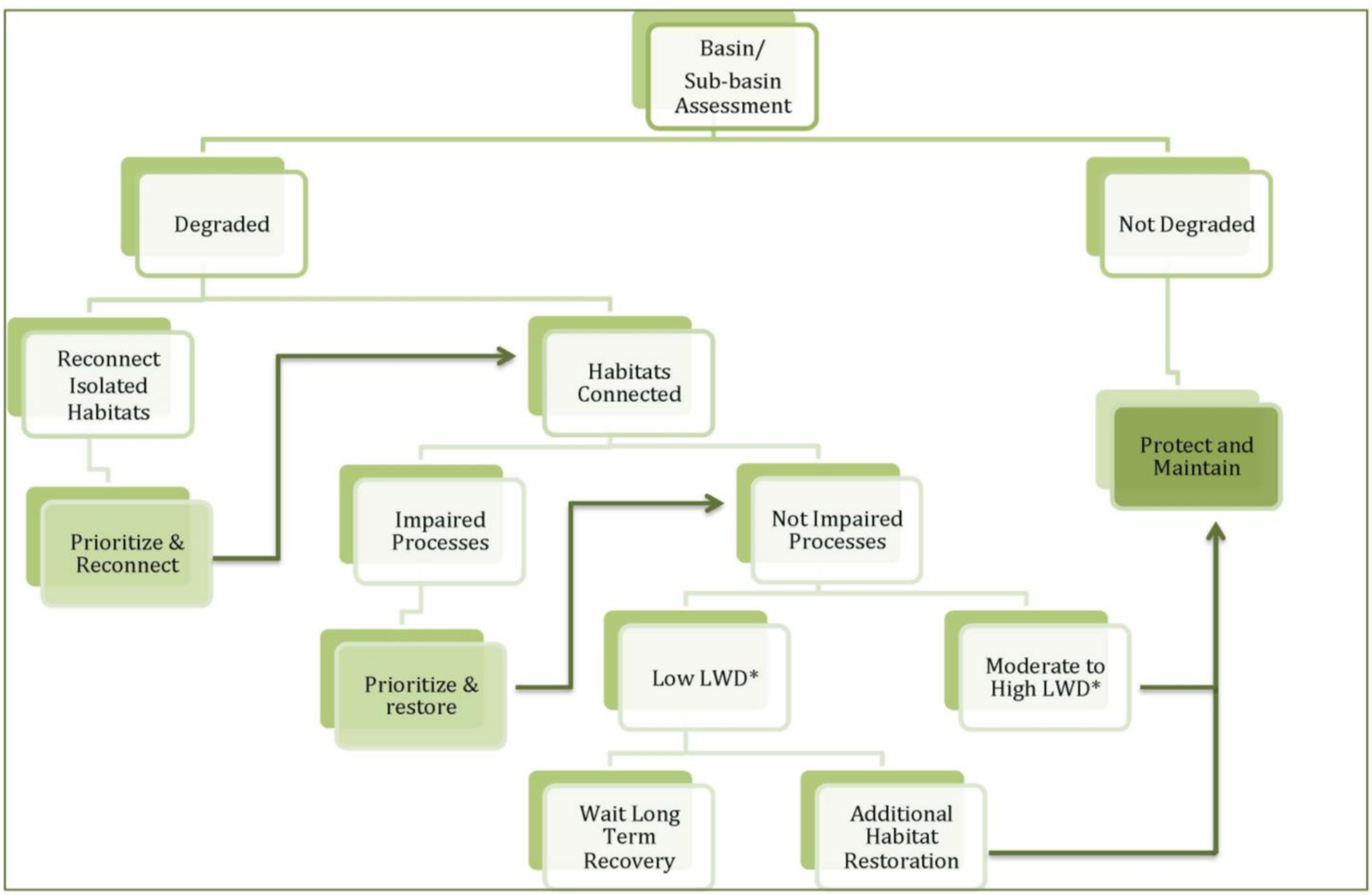
The research agrees it takes time, years, or even decades to see the effects of stream restoration and to be able to quantify the benefits over time. As a result, funding is needed for long-term maintenance and monitoring (Bennett et al. 2016). The data demonstrates the suggested amount of time is ten years after the completion of a project. An important consideration in funding a project is to plan for long-term contingencies at the onset of the project.

The methods used for verifying if a restoration plan was successful will be from Philip Roni's (2002) study where utilizing a hierarchical strategy determined if a restoration plan was successful. The first step in the hierarchy is evaluating the watershed as a whole, then focusing on re-connectivity of the watershed, followed by restoring the processes and concurrently restoring the habitat (Roni et al. 2002).

Roni's (2002) study claims that for a restoration to be successful there needs to be an understanding of what happens throughout the whole watershed. The idea of holistic approaches has recently been accepted for a wide variety of applications, not just in the environmental field. Understanding the interactions that play between the upper watershed and the lower watershed as well as, the interactions with the side tributaries will help determine what objectives the restoration plan needs to achieve. This large overarching picture will be able to inform the restoration plan of some possible challenges individual reaches may face depending on their location within the overall watershed (Roni et al. 2002). Figure 14 helps with visually understanding the connections of the hierarchical strategy, which forces thinking about the relationships while formulating the restoration plan. After looking at the watershed as a whole, you can clearly see where degradation is taking place. Some of the degradation could have created areas of isolated habitat. If isolated habitats are present within the watershed, then the hierarchical

Figure 14: Flow Chart of Hierarchical Strategy for Stream Restoration

Figure 14: The flow chart shows the way Roni et al. (2007) suggests the set-up for stream restoration projects to be successful (Roni et al. 2007). It shows the most important points, and area's where there may need to be a cyclical process a few times to fix all the issues within the watershed.



*Large Woody Debris

strategy would push for the re-connectivity of those isolated habitats as the next step of the restoration plan (Roni et al. 2002).

After the re-connectivity of the isolated habitats has been completed the next step is to focus on the restorative part, which has both short-term and long-term objectives within the restoration plan. The long-term step is restoring the natural processes while the short-term step is restoring habitat in the stream that has degraded over time. The long-term objectives are thought to be of more significance because they have a longer turn around before results are seen and are the backbone of the restorative part of the restoration plan. If you do not have the right processes taking place in the stream, then the habitat restoration objectives completed will not be able to persist if the processes are not in place to help it survive. The effects that the processes have on the stream can change the original habitat or affect water quality and productivity, refer back to Figure 2. Consequently, the processes that need to be restored or strengthened in the stream need to be identified before the restoration plan moves forward to habitat restoration for the reasons stated earlier (Roni et al. 2002).

For example, the processes for sediment supply have been altered because the section of the stream below a dam does not have the natural influx of sediment transport. This deficit happens because the stream no longer is connected to the main stem of the creek and thus loses the natural input of sediment from the headwaters. For this reason, as you travel further down the stream this lack of sediment transport can affect other processes or alter the overall habitat that once was present. A restoration plan objective would need to address the lack of sediment and the effects it will have on the surrounding habitat as shown in the figure 2.

4.2. Variables in Stream Restoration

As discussed in Chapter 2, there are some limiting factors which cause extreme variability for stream restoration, including time, funding, data collection and success criteria; such as evaluation of the project's outcomes over both the short-term and long-term. Analyzing the literature of the topics as mentioned earlier within the three watersheds, Lower Putah Creek, Klamath River, and Russian River demonstrate the consistent limiting variables of time, funding, data collection and success criteria remain prevalent. It is important to note that some watersheds are successful working within the defined variables. A checklist to evaluate whether a watershed was able to overcome the described variable limitations or succumbed was created to compare the watersheds of Lower Putah Creek, Klamath River, and Russian River.

In evaluating time both short-term and long-term data were analyzed. The short-term time scale evaluated the immediate effects after completion of a project within the first year. If there were immediate results within the short-term, the watershed was given the criteria of overcoming the limiting variable. The long-term scale evaluated the effects of the stream restoration for the years following the short-term time scale, the second year after completion of the project and beyond. Looking at the long-term timescale of a project, if there were additional projects that had the same goal near the project site the project was given the criteria of failing. Additionally, if there was no project follow-up after the first year, then the watershed was given the criteria of failing. If a watershed revisited the projects five and ten years out then, they received marks for each increment for overcoming the limiting variable of long-term funding by preparing for the needs of data collection on the long-term scale.

Funding was analyzed for the three phases of a project; planning, construction, and post-implementation. Funding for the planning phase of a project was given the criteria of overcoming the limiting variable if the project had established funding for baseline studies before the construction phases of a project. The construction phase was given the criteria of overcoming the limiting variable once the project was complete. Lastly, the post-implementation funding was given the criteria of overcoming the limiting variable if there was funding for maintenance and monitoring following completion for the three following increments, one year, five years and ten years after project completion.

The analysis of data collection followed they same structure as funding. If data was collected during the planning and construction phase, it was given the criteria of overcoming the limiting variable. Similarly, for post-implementation, the project was only given the criteria of overcoming the limiting variable if it collected data during the two different time scales, short-term, and long-term. It was dependent on how often post- implementation data collection was gathered during the two identified timescales. Some projects the only post-implementation data collected was observational data. A mark of overcoming the limiting variable was given as no standard in data collection for post- implementation of stream restoration projects has been established.

A project was given the criteria of overcoming the limiting variable of defining its success criteria in different ways, identification in planning phase, reflection after completion, and community feedback. A project met the criteria for overcoming the limiting variable if a defined success criterion was identified in the project-planning phase. This means from the beginning of the stream restoration project planning a set list of goals and the action needed to obtain the outcome were provided in the document. Additionally, the project was given the criteria of overcoming the limiting variable if post implementation reports discussed whether or not the project had reached its outcomes and/or goals. These reports were updated documents of the restoration plan, updates of the project on the organization's website, or other publications of project updates, via local news, newspaper, and blogs. Lastly, the project was also given the criteria of overcoming the limiting variable if there were reports from the public regarding its success or failure. Research demonstrates there is a gap in how success criteria have been defined. There is no current standardized way that the science community can determine if a stream restoration project has been successful.

4.3. Comparative Analysis

The following table will discuss the hierarchical strategy flow chart previously mention in Section 4.1.; it shows a comparison of the three watersheds, Lower Putah Creek, Klamath River and Russian River. The hierarchical strategy is used in planning for restoration priorities so that stream restoration is successful. The first test used to compare the three watersheds was the completion of watershed assessment evaluating one/both the basin and the sub-basin of the three watersheds, Lower Putah Creek, Klamath River and the Russian River. Secondly, looking at the task of reconnecting the isolated habitats of the three watersheds, Lower Putah Creek, Klamath River and the Russian River. Lastly, the tasks of restoring processes and restoring habitats of the three watersheds, Lower Putah Creek, Klamath River and the Russian River will be compared (Roni et al. 2002). Table 6 shows the results of the comparison of the flow chart for strategy for each watershed.

Watersheds are complex habitats, and many priorities can be happening concurrently, throughout the watershed while some parts of the watershed are degraded to different amounts of severity. The hierarchy strategy from Roni et al. (2002) helps to organize the priorities of a project, which can be helpful to the success of a project. Currently, the stream restoration community is not utilizing a guideline for establishing restoration projects that will be successful at accomplishing the outcomes of the plans and restoring processes and habitats that have been degraded. The goal of this analysis includes that developing a process and prioritizing tasks within the stream restoration project will improve the success of stream restoration, and other projects should use the hierarchical strategy template as a guide for setting up their stream restoration projects.

Table 6: Comparison of Watershed Implementation of Hierarchical Strategy

<table>
<tr><th rowspan="2">Tasks</th><th rowspan="2">Sub-Tasks</th><th colspan="3">Watersheds</th></tr>
<tr><th>Lower Putah Creek</th><th>Klamath River</th><th>Russian River</th></tr>
<tr><td rowspan="2">Assessment</td><td>Basin</td><td>√</td><td>Only Upper Basin</td><td>√</td></tr>
<tr><td>Sub-Basin</td><td>√</td><td>Random sub-basins</td><td>Random sub-basins</td></tr>
<tr><td colspan="2">Reconnection of Isolated habitats</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td rowspan="2">Restore Processes</td><td>Roads Impairments</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td>Riparian Functions</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td rowspan="2">Restore Habitats</td><td>LWD</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td>Others</td><td>√</td><td>√</td><td>√</td></tr>
</table>

Table 6: The table shows how each watershed handled the strategy steps for setting up a restoration plan (Roni et al. 2002).

Table 6 shows that Putah Creek has done work on all parts of the flow chart consistently using adaptive management to make adjustments to its priorities based on the watersheds current needs while maintaining and adjusting projects based on the data collected while monitoring the outcomes of its stated goals in the restoration projects. The table also shows how the Klamath and Russian Rivers are lacking documentation on the assessment for either the whole basin or the sub-basin (see Table 6). Without that evaluation data, a project cannot be adequately analyzed to identify the challenges, which in turn drive the project priorities and overall success. Not having the assessment data the project is at risk for having minimal or no lasting effect on the watershed or subsection of a watershed being restored. We can see from Table 7; that having an intended purpose, restoration guidelines, and planned implementation goals can save time and money.

Table 7: Comparison of Watersheds in cost spent for Restoration Projects

	Watersheds		
	Lower Putah Creek	**Klamath River**	**Russian River**
# of years	**15**	**9**	**7**
Covered years	2001-2016	2000-2009	2009-2016
Approximate total amount spent	$13,000,000	$134,971,061	$54,200,000
Approximate yearly amount spent	$866,667	$14,996,785	$7,742,857

Table 7: Comparison of amount of money spent in watersheds on an annual basis and a total amount for a set given amount of years (LPCC Grant Budget Report 2016; NOAA; Report to Congress 2010; and Russian River Funding Needs 2009).

After looking at the watersheds from the hierarchical strategy comparison, the limiting variables of time, funding, data collection, and success criteria were analyzed. Stream Restoration is a complex topic, and research shows that these variables are connected. As a result, if a weak link exists then the overall restoration project is at risk. Table 8 shows a comparison of the watersheds. As the comparison chart below demonstrates the watersheds of the Klamath, Russian Rivers have not overcome the limiting variables.

Putah Creek has managed to collect long-term data including information on invasive plants, birds, macroinvertebrates and overall water quality. All of the data collected is then available to the watershed, allowing for adjustments to projects and goals through adaptive management, thereby increasing long-term success of the restoration. The long- term collection of data allows for the sharing of prior knowledge, which in turn improves the process for new watershed projects.

Table 8 shows that there are data collection and funding for hatchery fish in the

Klamath and Russian Rivers, which is helping to better understand the effects of the population salmon in this subset versus the wild population of salmon. This collection of long-term data on hatchery fish is outstanding, which is the focus of the Klamath and Russian rivers. The additional aspects of the stream need to be incorporated such as restoring habitat, processes, and water quality so that both hatchery fish and wild population of salmon can survive. Collecting a variety of data provides an overview of the current processes and can guide the decisions and the priority actions that would benefit the stream while helping guide other restoration projects.

Table 8, shows that Putah Creek has additional secured funding for all stages of a project, due to litigation funds that came out of the 2000 Accord. The annual funding that the 2000 Accord established allows for Putah Creek to continue to support restoration projects on all levels despite what is currently allocated thought grants at the State and Federal level. This secured funding allows for the sustaining of the PutahCreek watershed when other funding has been cut or reallocated. Also, the 2000 Accord established annual funding for monitoring and maintenance of projects, which as discussed in Chapter 2, typically is not covered either by State or Federal funding. The research showed that monitoring restoration projects at least ten years after completion is critical to understanding if the action of stream restoration was successful. If no funding is available for monitoring and long-term data collection, the question becomes if the restoration project is beneficial to the watershed and the goals trying to be achieved.

The last variable on Table 8 is success criteria. Goals are important, and each watershed has specific goals based off of stakeholders needs in that area. Be that as it may, more than a set of goals is necessary, to be successful. Milestones need to be established so a restoration project can be held accountable. The benchmarks created

Table 8: Comparison of Watershed regarding the variables, Time, Data Collection, Funding and Success Criteria.

		Watersheds					
		Lower Putah Creek		Klamath River		Russian River	
Variable		Completed	Source	Completed	Source	Completed	Source
Time	Short-term[1]	√	N/A	√	N/A	√	N/A
	Long-term[2]	√	N/A	√	N/A	√	N/A
Data Collection	Short-term[1]	√	Volunteers & UCD Students	√	Volunteers	√	Volunteers
	Long-term[2]	√		Hatchery fish only		Hatchery fish only	
Funding	Planning	√	Grant based (State, Federal)	√	Grant based (State, Federal) & Tribal Funds	√	Grant based (State, Federal) & Nonprofits
	Construction		Grant based (State, Federal)	√	Grant based (State, Federal) & Tribal Funds	√	Grant based (State, Federal) & Nonprofits
	Post Implementation	√	Litigation Funds				
Success Criteria	Goals	√	N/A		N/A		N/A
	Milestones	√	N/A		N/A		N/A

1= Short-term is during construction and up to one year after completion of project

2= Long-term is anything after the first year after completion of a project.

Table 8: Comparison of the three watersheds on the limiting variables of time, data collection, funding, and success criteria of stream restoration projects.

need to have the ability to reflect on the completed projects and make adjustments as time moves forward. Further, there needs to be funding for long-term data collection, standards on how to collect data, and definitions that help guide what is considered to be successful actions. This continuous cycle of balancing time, funding, data collection, and success criteria make stream restoration a very complicated and often a controversially topic. Nevertheless, this cycle needs to happen for long-term restoration success.

5. Conclusions & Recommendations

5.1. Conclusions

The research demonstrates clear gaps in the collection of stream restoration data. For the field of stream restoration to have long-term success revision of various areas of data collection is recommended. The evidence demonstrated that Putah Creek incorporated successful activities that when compounded helped lead to the successful Chinook winter-run of December 2016. Findings show there is no single silver bullet but rather a collection of actions needed for stream restorations long-term success. The identified actions of watershed assessments, project planning regarding funding, data collection standards, and defining success criteria need to work in harmony with each other for the entire watershed or a portion of the watershed to be successful.

Putah Creek followed the hierarchical strategy recommended by expert Philip Roni to make stream restoration successful, as well as overcoming the demonstrated limitations in the variables that stream restoration contains. One of the main advantages to Putah Creek's success comes from the 2000 Accord and its ability to help with ongoing evaluation and management of the stream restoration projects.

Annual funding from the Solano County Water Agency has allowed Putah Creek to continuously maintain, monitor, and collect data on the different stream restoration projects over the years. This annual funding has allowed for the creation of a permanent Streamkeeper position, which is an advocate, for Lower Putah Creek. The role of the streamkeeper is to make sure that the streams voice is heard at stakeholders meetings and that the best interest of the creek is considered when decisions are being made.

Another benefit unique to Putah Creek is its location. Putah Creek is located next to a research university, University of California, Davis. UC Davis has a science-based curriculum that requires students to participate in fieldwork. Putah Creek's convenient location to UC Davis allows for a stewardship of the waterways, by providing volunteer labor for construction, maintenance, monitoring and data collection.

The work that has taken place on the Klamath and Russian Rivers is valuable and needed. While the threat of extinction forces quick action, the measures taken need to be intentional and with a defined goal. Stream restoration projects completed because funding happened to be available will not address the root of the problem and subsequently become at risk for repetitive restoration, draining the sources of financing. Restoration for the sake of restoration is not an appropriate goal for the long-term success of protecting the salmon species or California’s 39 native salmonid stocks.

5.2. Management Recommendations

The research and conclusions have lead to seven management recommendations, one is an over arching recommendation, three are policy level, two are practitioners recommendations. All recommendations focus on the areas of gaps in the information my research found; the lack standardization and funding, along with subsets of what is included in those topics. The overarching recommendation is the implementation of Tara’s restoration triangle, the adaptive management circle can be very overwhelming and hard to implement. Tara’s restoration triangle focuses on the reiterative processes that are needed within restoration plans. Figure 15 lists the three points of the triangle they are: collection of data, evaluation, and adjusting actions. Keeping in mind that humans need to share streams and rivers with wildlife this constant relationship requires repetitive check-ins to make sure both parties are getting what they need. The restoration triangle focuses on just that and reminds both policy makers and practitioners how important understanding the data collected for making important environmental decisions is.

Figure 15: Tara's Restoration Triangle

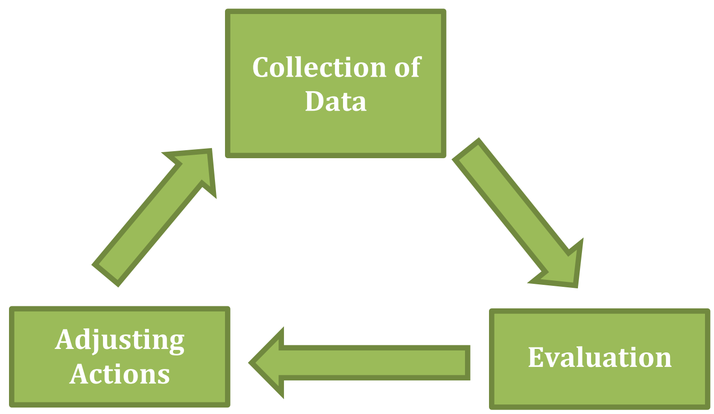


Figure 15: Shows the cyclical process of gathering data evaluating it and then making adjustments to the restoration plan or goals as needed.

5.2.1. Policy Level Recommendations

Stream restoration is a complex issue and even after assessment and evaluation are initially completed practitioners may not understand the outcome of a prior action for many years. Waiting many years before implementing a change endangers the ability to prevent the extinction of Salmon. Decisions need to be made with the best available science gathered from regular field assessments in a time efficient manner that aids in a streams restorations success. The management recommendations incorporate the broader perspective of stream restoration as a field of study and include the key policy makers who determine the standards, data platforms, and funding of projects.

The first management recommendation is a set of standards for stream restoration that include action plans and the establishment of detailed data collection. Once stream restoration actions become standardized comparisons can be made between watersheds and subsequent recommendations can be provided. Comparison of watersheds allows for field of stream restoration to progress with new knowledge of actions that work and discontinue activities that have been proven not to get results. The standardization needs to include guidelines for practitioners to follow: as not all watersheds have a streamkeeper or University student to aid in data collection. Therefore, the recommendation is that stream restoration should include data collection recorded in universal units as well as a standard operating procedure for collection.

The second recommendation is a continuation from the standardization of data collection. Once the data has been collected; a question arises as to where the data is stored and how it will be shared with other parties. The management recommendation for storing and sharing data collection includes incorporating a third party to establish a platform that allows for practitioners on all levels to have access to the data. This promotes conversations with those in different watersheds and allowing for knowledge and data to be shared. Sharing allows the lessons learned from the successes and failures of colleagues. The Bay-Delta Science Conference in November of 2016 discussed this topic and the lack of data platforms and data accessibility. The conference focused on getting scientist, practitioners and decision makers, aware of problem in hopes of starting discussions so that this gap in information could be closed. Currently, valuable data is being collected across the state for various projects and is not being shared among colleagues. This lack of communications creates a vacuum for information and can impact the success of a stream restoration projects.

The third recommendation for the field of stream restoration at the policy level is that State and Federal funding sources understand the value of monitoring, maintenance, and long-term data collection. For this to be achieved a discussion of changing the way agencies choose projects, to the wording in the fish and game code, allowing projects to use funding for data collection and/or studying outcomes of previous actions. This discussion is needed not just for the field of stream restoration but for understanding actions for specific species to help to advance the field of science in general. Funding for data collection, long-term monitoring, and maintenance will aid in advancing the field of stream restoration. The recommendations do not call for additional funds but rather a reallocation of current resources available. A reallocation of funds would facilitate the collection of data from the appropriate people, at the right time for the correct duration. The present practice of spending millions of dollars annually to complete projects that are never evaluated again fosters an environment of wasteful spending. Additionally, a valuable and necessary opportunity to understand the actions utilized during a streams restoration project is lost and does not allow for maximizing the long-term success of the restoration.

5.2.2. Practitioner Level Recommendations

The following recommendations are for practitioners of stream restoration and are categorized for a top down approach from the watershed to sub-watershed to creeks and tributaries. The recommendations include advocacy and funding.

The first management recommendation at the practitioner level is that each watershed and sub-watershed within a basin needs a devoted advocate that speaks for the specific requirements of the stream. Stakeholders have agendas that may not be aligned with the streams needs thereby, putting the long-term success of restoration at risk. Putah Creek has such an individual, Rich Marovich, called the streamkeeper. Other watersheds have called this position various names including a creekkeeper, creek steward, and riversteward. The streamkeeper position is to take into account the needs of the stream. The streamkeeper has no hidden agenda and money is not a driving force. The recommendations the streamkeeper provides are strictly based on the current needs of the stream. Having an advocate for the creek ensures the streams voice, which may be different from other stakeholders, and heard at any discussion impacting the protection of species, particular habitats, or the local water users.

A subset for the advocacy recommendation includes community outreach and education, as a community can be a benefit from a restoration project or it can become a hindrance to a project. Therefore watershed stakeholders need to get out and make the local population understand why waterways are important and the economic benefits they provide. Having strong community support can also help with getting future projects funded and assist with labor needs. It builds a stronger community and teaches the next generation of streamkeepers.

The second management recommendation is finding alternate sources of funding that are above and beyond state and federal grant funding. Evaluating different organizations with similar missions, special water districts, or county water agencies may secure additional funding which in turn contributes to the long-term success of stream restoration. The prospect of partnering with county water agencies to fill in financing gaps not covered by state and/or federal grants is an exciting possibility. A successful example is seen with Putah Creek and Solano County Water Agency. This partnership has assured Putah Creek's restorations long-term success. The partnership that has been built between the Lower Putah Creek and the Solano County Water Agency is beneficial for both parties because the relationship that has developed allows for both parties to achieve their goals.

A sub management recommendation under alternate funding sources includes incorporating an economic benefits study of stream restoration. The purpose of an economic benefits study would include actions for decreasing a water agencies cost for filtering water of urban users. During and interview with Putah Creeks streamkeeper, Rich Marovich, questions arose regarding the economic benefit of stream restoration projects and their impact on reducing pollution. In the streamkeepers opinion, if water agencies took a more proactive role and partnered with streamkeepers, and restoration project organizations there could be economic benefits for both parties. The financial assistance that water agencies would make in helping local watersheds with restoration projects could reduce spending that the water agencies used during the process of purifying the water for its urban users.

In conclusion I believe that with the combination of a local streamkeeper, additional funding sources and the use of Tara's restoration triangle that the field of stream restoration can become more standardized and advance the field strengthening restoration projects and the goal of increasing the native salmonid stock populations across the state.

6. Cited Literature

About Us- Resighini Rancheria. (2014). Retrieved from http://resighinirancheria.com/

Alvarez, F. 2016. "Record numbers of salmon are spawning in Putah Creek". Davis Enterprise. 2016.

Barnard, J. (2015, August 7). Biologists fear a repeat of 2002 salmon die off. The Associated Press [Grants Pass]. Retrieved from http://www.oregonlive.com/environment/index.ssf/2015/08/biologists_fear_repeat_of_2002.html

Biological Opinion: Frequently Asked Questions. (2017.). Retrieved from http://www.scwa.ca.gov/files/docs/projects/rrifr/RRIFR%20-%20BO%20FAQs%20-%20final%208-19-13.pdf

Beesely, S.. 2011. Lower Klamath Sub-Basin Coordination & Planning FY 2011 Final Report. Yuork Tribal Fisheries Program. Klamath, California.

Bendor, T. K., A. Livengood, T. W. Lester, A. Davis, and L. Yonavjak. 2015. Defining and evaluating the ecological restoration economy. Restoration Ecology 23:209-219.

Bennett, S., G. Pess, N. Bouwes, P. Roni, R. E. Bilby, S. Gallagher, J. Ruzycki, T. Buehrens, K. Krueger, W. Ehinger, J. Anderson, C. Jordan, B. Bowersox, and C. Greene. 2016. Progress and Challenges of Testing the Effectiveness of Stream Restoration in the Pacific Northwest Using Intensively Monitored Watersheds. Fisheries 41:92-103.

Bernhardt, E. S., M. A. Palmer, J. D. Allan, G. Alexander, K. Barnas, S. Brooks, J. Carr, S. Clayton, C. Dahm, J. Follstad-Shah, D. Galat, S. Gloss, P. Goodwin, D. Hart, B. Hassett, R. Jenkinson, S. Katz, G. M. Kondolf, P. S. Lake, R. Lave, J. L. Meyer, T. K. O'Donnell, L. Pagano, B. Powell, and E. Sudduth. 2005. Synthesizing U.S. river restoration efforts. Science:636.

Bernhardt, E. S., E. B. Sudduth, M. A. Palmer, J. David Allan, J. L. Meyer, G. Alex, Jennifer Follastad-shah, B. Hassett, R. Jenkinson, R. Lave, J. Rumps, and L. Pagano. 2014. Restoring rivers one reach at a time: results from a survey of US river restoration practitioners.

Bisson, P. A., Reeves, G. H., and Dunham, J. B. 2009. Freshwater ecosystems and resilience of Pacific salmon: Habitat Management based on natural variability. Ecology and Society 14.

California American Indian Facts. (2017). Retrieved from http://native-american-indian-facts.com/California-American-Indian-Facts/California-American-Indian-Facts.shtml

California Indians. (2012). Retrieved from http://factcards.califa.org/cai/pomo.html

Christian-Smith, J., & Merenlender, A. M. (2010). The Disconnect Between Restoration Goals and Practices: A Case Study of Watershed Restoration in the Russian River Basin, California. Restoration Ecology, 18(1), 95-102.

Coastal Monitoring Program | California Sea Grant. (2017). Retrieved from https://caseagrant.ucsd.edu/project/coho-salmon-monitoring/coastal-monitoring-program

Coho Salmon Conservation Program | California Sea Grant. (2017). Retrieved from https://caseagrant.ucsd.edu/project/coho-salmon-monitoring/coho-salmon-conservation-program

Coyote Valley Dam Lake Mendocino CA (O&M). (2017). Retrieved from http://www.spn.usace.army.mil/Missions/Projects-and-Programs/Projects-A-Z/Coyote-Valley-Dam-Lake-Mendocino-CA-O-M-/

Daily Democrat. 2011. “10 years of restoring Putah Creek celebrated”. Daily Democrat. 2011.

Earthman, L. 2011. “Restoration work needed for Putah Creek”. Daily Democrat.2011.

Eastman, D. 2003. Klamath River Basin Conservation Area Restoration Program. U.S. Fish and Wildlife Service, Yreka Fish and Wildlife Office, Yreka, CA, USA.

encyclopedia.com. (2017). Retrieved from http://www.encyclopedia.com/earth-and-environment/ecology-and-environmentalism/environmental-studies/environmental-movement

FACTSHEET: Russian River Habitat Focus Area Projects are Underway. (2017). Retrieved from https://www.habitatblueprint.noaa.gov/habitat-focus-areas/russian-river-california/

Focus Areas Join Resilient Lands & Waters - NOAA's Habitat Blueprint. (2016, April 18). Retrieved from https://www.habitatblueprint.noaa.gov/habitat-focus-areas/focus-areas-join-resilient-lands-waters/

Gustafson, R. G., R. S. Waples, J. M. Myers, L. A. Weitkamp, G. J. Bryant, O. W. Johnson, and J. J. Hard. 2007. Pacific salmon extinctions: Quantifying lost and remaining diversity. Conservation Biology 21:1009-1020.

Habitat Enhancement Monitoring | California Sea Grant. (2016). Retrieved from https://caseagrant.ucsd.edu/project/coho-salmon-monitoring/habitat-enhancement-monitoring

Hilderbrand, G. V., S. D. Farley, C. C. Schwartz, and C. T. Robbins. 2004. Importance of salmon to wildlife: Implications for integrated management. Ursus 15:1-9.

Historical Conditions of the Creek | Putah Creek Council. (2017). Retrieved from https://www.putahcreekcouncil.org/historicalcreek

History - Friends of Lake Sonoma. (2017). Retrieved from http://lakesonoma.org/about-lake-sonoma/history/

Hodge, B. W., M. A. Wilzbach, W. G. Duffy, R. M. Quiones, and J. A. Hobbs. 2016. Life History Diversity in Klamath River Steelhead. Transactions of the American Fisheries Society 145:227-238.

Home - Resighini Rancheria. (2014). Retrieved from http://resighinirancheria.com/

Karuk Tribe. (2015). Retrieved from http://www.karuk.us/
Klamath Restoration: Home. (2017). Retrieved from https://klamathrestoration.gov/

Jasper, C., and B. Hamilton. "2014-2016 Putah Creek Fall-run Chinook salmon Study: Observing an intermittent Chinook salmon population on a heavily managed California Creek." Center for Watershed Sciences Wildlife and Fish Conservation Biology, University of California, Davis, 2016.

Katz, S. L., K. Barnas, R. Hicks, J. Cowen, and R. Jenkinson. 2007. Freshwater Habitat Restoration Actions in the Pacific Northwest: A Decade's Investment in Habitat Improvement. Restoration Ecology 15:494-505.

Katz, J., P. Moyle, R. Quiones, J. Israel, and S. Purdy. 2013. Impending extinction of salmon, steelhead, and trout (Salmonidae) in California. Environmental Biology of Fishes 96:1169.

Kimball, S., M. Lulow, Q. Sorenson, K. Balazs, Y. -. Fang, S. J. Davis, M. O'Connell, and T. E. Huxman. 2015. Cost-effective ecological restoration. Restoration Ecology 23:800-810.

Klamath River Basin - Water Education Foundation. (2016). Retrieved from http://www.watereducation.org/aquapedia/klamath-river-basin

Klamath Tribal Water Quality Consortium Home Page. (2015). Retrieved from http://www.klamathwaterquality.com/

Kondolf, G. M. 1998. Lessons learned from river restoration projects in California. Aquatic Conservation: Marine and Freshwater Ecosystems 8:39-52.

Kondolf, G. M., and E. R. Micheli. 1995. Evaluating stream restoration projects. Environmental management 19:1-15.

Kondolf, M. (n.d.). Overview and History of the Russian River Watershed. .

Lackey, R. T. 1999. Salmon policy: science, society, restoration, and reality. Environmental Science and Policy 2:369-379.

Lackey, R. T. 2015. Wild salmon recovery and inconvenient reality along the west coast of North America: indulgences atoning for guilt? WIRES Water 2:433.

Lake Sonoma/Warm Springs Dam. (2017). Retrieved from http://www.spn.usace.army.mil/Missions/Projects-and-Programs/Projects-by-Category/Projects-for-Flood-Risk-Management/Lake-Sonoma-Warm-Springs-Dam/

Levy, S. 2003. Turbulence in the Klamath River Basin. Bioscience 53:315.

Loke, L. H. L., R. J. Ladle, T. J. Bouma, and P. A. Todd. 2015. Creating complex habitats for restoration and reconciliation. Ecological Engineering 77:307-313.

Lower Putah Creek Coordinating Committee Annual Report 2015-2016.

Marchetti, M. P., and P. B. Moyle. 1995. Conflicting values complicate stream protection. California agriculture (USA) :73.

Marchetti, M. P., and P. B. Moyle; J Baldrige, and TL Taylor, Fish health and diversity: Justifying flows for a California stream: Fisheries, vol. 23, no. 7, pp. 6-15, Jul 1998.

Moyle, P. B. 2014. Novel Aquatic Ecosystems: the New Reality for Streams in California and Other Mediterranean Climate Regions. River Research & Applications 30:1335.

Nash, Linda Lorraine. (1993). Environment and drought in California 1987-1992: Impacts and implications for aquatic and riparian resources. Oakland, CA: Pacific Institute for Studies in Development, Environment, and Security.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:4-21.

Nilsson, C., A. L. Aradottir, D. Hagen, G. Halldórsson, K. Høegh, R. J. Mitchell, K. Raulund-Rasmussen, K. Svavarsdóttir, A. Tolvanen, and S. D. Wilson. 2016. Evaluating the process of ecological restoration. Ecology and Society 21(1):41.

NOAA's Habitat Blueprint: Historic Coho Salmon Breeding Ground Re-Opened in California. (2011, December 13). Retrieved from https://www.habitatblueprint.noaa.gov/highlights/willowcreekrestoration.html

NOAA's Habitat Blueprint: Habitat Improvements Reduce Flooding, Recover Fish. (2013, January 23). Retrieved from https://www.habitatblueprint.noaa.gov/highlights/drycreekcarestoration.html

NOAA (2017). Retrieved from http://www.habitat.noaa.gov/restoration/techniques/srrestoration.html

Pomo Tribe: Facts, Clothes, Food and History. (2017). Retrieved from http://www.warpaths2peacepipes.com/indian-tribes/pomo-tribe.htm

Putah Creek Watershed | Putah Creek Council. (2017). Retrieved from https://www.putahcreekcouncil.org/putah-creek-watershed

Palmer, M.A., Bernhardt, E.S., Hassett, B., Allan, J D, Alexander, G, Lake, P S, Brooks, S, Carr, J , Hart, D D, Clayton, S , Goodwin, P, Dahm, C N, Follstad Shah, J, Galat, D L , O'Donnell, T K, Loss, S G, Jenkinson, R, Kondolf, G M, Lave, R, Pagano, L, Meyer, J L, and Sudduth, E. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42:208-217.

Pomo Indians of Northern California. (2017). Retrieved from http://www.mendorailhistory.org/1_redwoods/pomo.htm

Quail Ridge Reserve - Human History Patwin. (2005). Retrieved from http://nrs.ucdavis.edu/quail/Natural/Human_Patwin.htm

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 22:1-20.

Roni, P., Hanson, K., Beechie, T. 2008. Global Review of the Physical and Biological Effectiveness of Stream Habitat Rehabilitation Techniques. North American Journal of Fisheries Management 28:856-890.

Rosenzweig, M. L., 2003. Win-Win Ecology How Earth's Species Can Survive in the Midst of Human Enterprise. Oxford, New York; Oxford University Press.

Rowley, C. A., & Craig, S. E. (2005). Contemporary Streamkeepers: a comparison of two urban horticultural restoration programs in arid California. In International Conference in Design and Nature & M. W. Collins (Eds.), Design and nature II: Comparing design in nature with science and engineering. Southampton, MA: WIT Press.

Rumps, J. M., S. L. Katz, K. Barnas, M. D. Morehead, R. Jenkinson, S. R. Clayton, and P. Goodwin. 2007. Stream restoration in the Pacific Northwest: Analysis of interviews with project managers. Restoration Ecology 15:506-515.

Sonoma County Water Agency and University of California Cooperative Extension/California Sea Grant. 2014. Implementation of the California Coastal Salmonid Monitoring Plan in the Russian River. Santa Rosa, CA.

Stefanes, M., J. Ochoa-Quintero, O. R. de, L. S. M. Sugai, L. R. Tambosi, R. Lourival, and S. Laurance. 2016. Incorporating resilience and cost in ecological restoration strategies at landscape scale. Ecology & Society 21:216-226.

Redish, L., & Lewis, O. (2009). Native Languages of the Americas. Retrieved from http://www.bigorrin.org/

Russian River Estuary |Sonoma County Water Agency. (2017). Retrieved from http://www.scwa.ca.gov/russian-river-estuary/

Russian River: Restoration Highlights. (2016). Retrieved from http://www.casalmon.org/salmon-snapshots/population/russian-river-1

Russian River Watershed Association. (2016). Retrieved from http://www.rrwatershed.org/

Russian Riverkeeper. (2016). Retrieved from http://russianriverkeeper.org/

Solano County Water Agency : Putah Creek. (2017). Retrieved from http://www.scwa2.com/water-supply/habitat/putah-creek

Sonoma County Water Agency and University of California Cooperative Extension/California Sea Grant. 2015. Implementation of California Coastal Salmonid Population Monitoring in the Russian River Watershed. Santa Rosa, CA.

Sotoyome Resource Conservation District, Gold Ridge Resources Conservation District, Chatham, INC. (2009). Stewardship Guide for the Russian River. Santa Rosa, CA: Sotoyome Resource Conservation District.

State Water Board Drought Year Water Actions - Russian River. (2017). Retrieved from www.waterboards..ca.gov/waterrights/water_issues/programs/drought/water_action_russianriver.shtml

United States. Bureau of Reclamation, issuing body. United States. Congress. (2016). SECURE Water Act section 9503(c) Report to Congress Chapter 5: Klamath River Basin. Washington D.C, DC: United States. Bureau of Reclamation.

United States. Natural Resources Conservation Service. (2004). Work plan for adaptive management: Klamath River Basin, Oregon & California. Washington, D.C.: Dept. of Agriculture, NRCS.

United States Department of Commerce, National Oceanic and Atmospheric Administration, & National Marine Fisheries Service. (2010). Klamath River Basins 2010 Report to Congress. Arctata, CA: National Marine Fisheries Service.

United States Department of Agriculture. (2017). Klamath River Basin | NRCS. Retrieved from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=nrcs143_023523

Willson, M. F., S. M. Gende, and B. H. Marston. 1998. Fishes and the forest: expanding perspectives on fish-wildlife interactions. Bioscience 48:455.

Watershed Priorities: Klamath | Region 9: Water | US EPA. (2016). Retrieved from https://www3.epa.gov/region9/water/watershed/klamath.html

United States Census Bureau. (2016). Retrieved from https://www.census.gov/quickfacts/table/PST045215/06,00

US Population 2017. (2017). Retrieved from http://uspopulation2017.com/population-california-2017.html