4. Chapter 4: Physical and Land-Use Context for Aquatic Habitat in the SFER

Introduction

Successful aquatic habitat restoration requires an understanding of both the natural processes that define habitat potential under unimpaired conditions as well as the effects of anthropogenic disturbance. Considering how riverscapes once supported salmon and steelhead life histories, what changes have occurred, and how they limit these species helps us determine what conditions are attainable within existing geomorphic constraints. Evaluating the historical context of land-form and land use was fundamental to the Collaborative's thought process as we identified limiting factors and restoration treatments. The South Fork Eel River Watershed Assessment (SFER WA) conducted by the California Department of Fish and Wildlife and Pacific States Marine Fisheries Commission (CDFW 2014) served as a basis for the sub-basin setting. Throughout the SFER SHaRP planning process, Collaborative members (including representatives of a Native American tribe, government agencies, non-governmental organizations (NGOs), landowners and universities) contributed relevant information and personal experience that, when brought together, resulted in a more comprehensive understanding of the planning area. In this chapter, we summarize the geophysical processes of the SFER sub-basin that we considered throughout the SFER SHaRP planning effort, explore historic and current land use patterns, and consider potential interactions in the context of salmon recovery.

Attributes of the South Fork Eel River

- Mediterranean climate characterized by dry summers and wet winters
- Principle communities: Garberville-Redway, Laytonville, Branscomb (headwaters), Miranda, Weott (confluence of SFER and mainstem Eel)
- Anadromous salmonids: Steelhead, Coho Salmon and Chinook Salmon
- Watershed statistics:
  - Eel River basin size: 3,684 square miles
  - SFER sub-basin size: 690 square miles
  - Mainstem length: 105 miles
  - Total length of stream: 683 miles

Figure 4-1. Location of the South Fork Eel River sub-basin within the Eel River Basin.

Hydrologic and Geomorphic Processes

The SFER Basin exhibits a seasonally dynamic hydrology and diverse geology. These characteristics, combined with variable micro-climates, give rise to variation in land form, plant communities, land use, and the resulting habitats that influence salmonid distribution and abundance across the basin.

Prolonged winter rains and foggy to dry summer conditions are characteristic of the climate in the SFER basin. The rainy season, which generally begins in late October and lasts through April, accounts for 90 percent of the mean annual runoff in the SFER sub-basin (Monroe et al. 1974). The dry season typically lasts from May through September. The western sub-watersheds of the SFER are strongly influenced by the coastal marine layer and are defined by morning fog and overcast conditions, whereas the inland eastern sub-watersheds become very hot and dry as the year progresses. This spatial and seasonal pattern of rainfall and runoff results in ecological challenges and opportunities that have shaped the life histories of aquatic organisms.

The concept of functional flow periods is to partition the natural flow regime into elements that support important ecosystem processes for a broad range of native taxa and assemblages (Yarnell et al. 2020). The linkage of quantifiable measures of flow regime (Patterson et al. 2020) with ecosystem process provides a framework for assessing how different flow management scenarios may result in ecologic change (Lane et al. 2017). Functional flow periods in the SFER are exemplified by the following characteristics: short but important fall flow events that initiate the wet season, elevated winter base flows punctuated by extreme peaks, followed by a period of spring recession, and finally dry season low flows through the summer (Yarnell et al. 2020) (Figure 4-2). As flow regimes have shaped salmonid ecology over evolutionary timescales, each of these periods have important implications for critical salmonid life history events. The onset of fall precipitation and its wet-season initiation trigger upstream movement of adults from the estuary to mainstem staging areas while cooling temperatures and altering water quality. Winter base flows, punctuated by storm events, result in moderate increases in discharge. This allows access to and occupation of spawning grounds. These peak winter flows also mobilize substrate, form channel features that provide habitat for salmon, and prepare spawning gravels for future cohorts (Lane et al. 2018). The spring recession is understood to be a critical period for fry re-distribution and parr growth, while the summer low-flow period can constrain juvenile salmon growth and distribution as temperatures reach annual maxima and channels may dry, limiting both habitat for rearing fish and aquatic invertebrate food production.

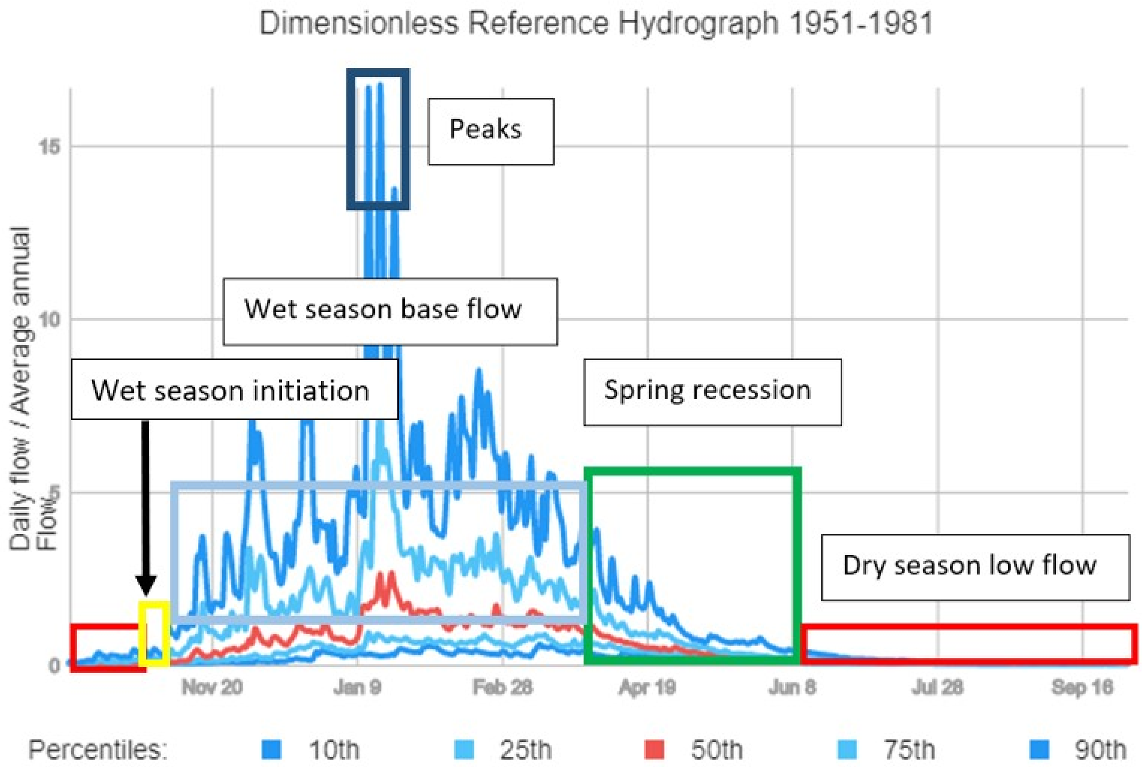

Figure 4-2. Dimensionless reference hydrograph for the South Fork Eel River at Miranda based on discharge records from 1951-1981, highlighting functional flow periods of the annual hydrograph. (Lane et al. Functional Flows Calculator v2.31 https://eflows.ucdavis.edu/ Accessed: 8 June 2020).

Combinations of flow and geomorphic attributes generate hydraulic patterns that support distinct life histories, and largely dictate the timing and spatial distribution of life history events for salmon and steelhead. Where and how animals fulfill life history requirements is largely controlled by the intersection of seasonal hydraulics and the shape and composition of the river corridor and channel. Temporal water cycles are mediated through the critical zones—the vertical extent of the Earth where water is received, stored, and released to support surface flows or vegetation. Critical zones extend from the top of vegetation canopies down to the top of unweathered bedrock, where water becomes immobile on ecological time scales (Rempe and Dietrich 2018). The western and eastern portions of the basin sit upon two distinct accreted belts of the Franciscan Complex, leading to different water holding capacities of the critical zone, timing of spring recession stream discharge and dry season stream base flow. The eastern sub-watersheds are characterized by critical zones that have poorer water holding capacities than the mélange geology in the western portion of the SFER (Hahm et al. 2019).

The combination of geologic and hydrologic forces have sculpted a diversity of channel forms in the SFER. Guillon et al. (2019) classified seven geomorphic archetypal channel types within the SFER based on watershed contributing area, valley form and slope, bankfull width-to-depth statistics, and substrate size distributions in an effort to categorize channels into morphological types that display distinct fluvial patterns (Figure 4-3). The seven focus areas selected through the SHaRP process for further planning occur exclusively in confined valley forms (Figure 4-3 and Figure 4-4). It is notable that the west side tributaries selected by the SHaRP process contain the majority of the gravel-cobble, bed undulating channel type which is characterized by gravel and coble substrates, high depth variability with pool-riffle sequences, and include forced bed structures (Guillon et al. 2019) that are responsive to large wood.

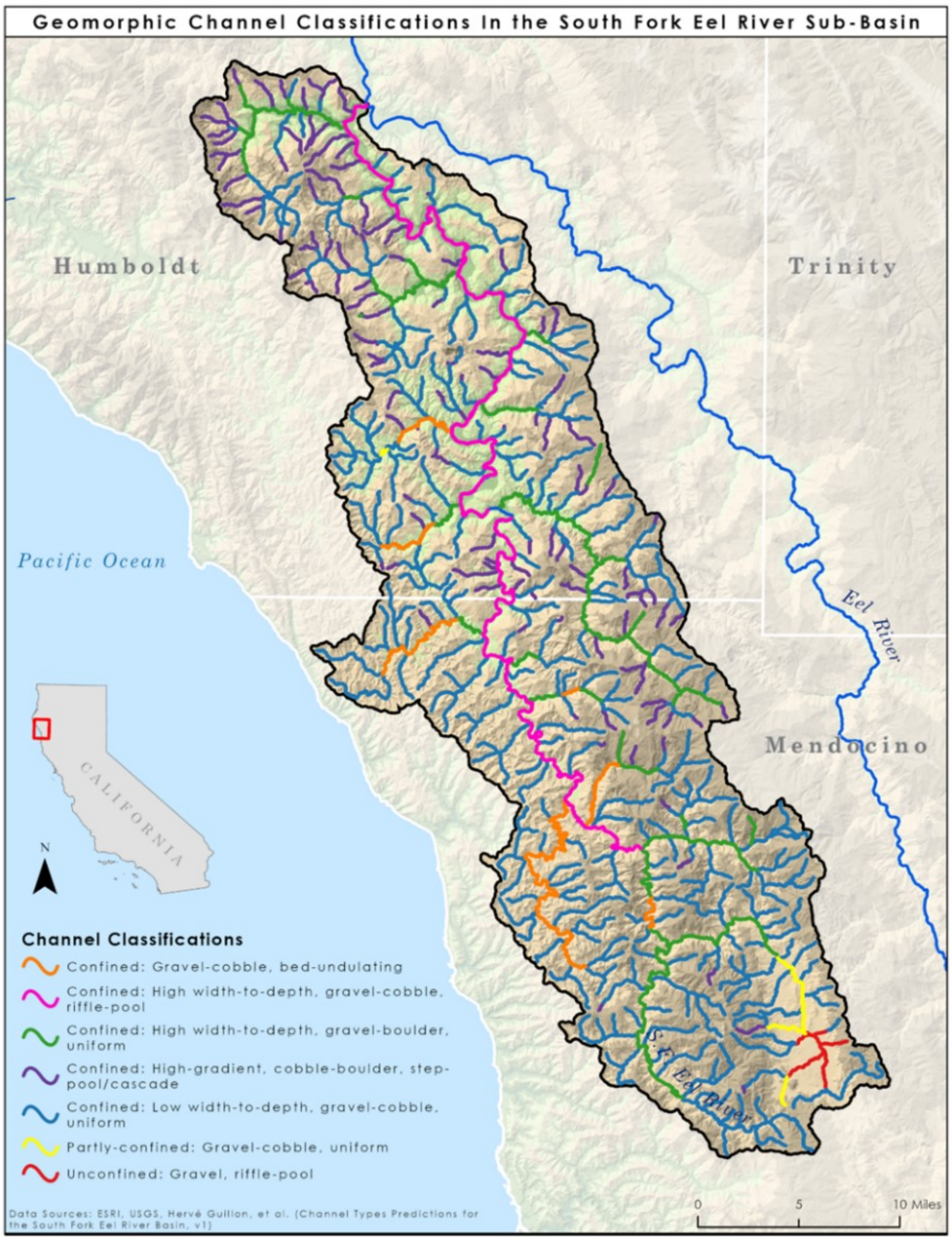

Figure 4-3. South Fork Eel River archetypal channel types classified by Guillon et al. (2019).

Figure 4-4. The seven sub-watersheds shown in red were selected for further restoration planning using SHaRP and subsequently described as focus areas.

Watershed History and Human impacts[2]

Time Immemorial to mid-19th century

Native American tribes have inhabited the Eel River watershed for at least 5,000 to 10,000 years (USBLM et al. 1996). Pomo Indians and Athabascan people, including aboriginal groups of Wailaki, Sinkyone and Cahto tribes occupied the SFER. They lived in small semi-sedentary villages, moving throughout the basin to take advantage of seasonally available resources. Natural resources, such as large and small game, plants, and fish (salmon, steelhead, sturgeon, and lamprey) were plentiful throughout the basin, and the population density within the SFER Basin equaled or exceeded the density seen in other North American agricultural societies (USBLM et al. 1996). Even with this comparatively high density of people, their cumulative impact on the fisheries resources and the environment was relatively small (Yoshiyama and Moyle 2010). Based on the earliest photographs, there is support however, for the hypothesis that Native Americans managed forest structure through the use of fire in the headwaters of the SFER (Dr. Sharon Edell, personal communication, SHaRP Expert Panel, December 2020).

European arrival and settlement

The first Euro-Americans came to the SFER in the 1850s. Trappers were the first to arrive, followed by homesteaders and ranchers after the passage of the Homestead Act in 1862 (HCRCD 2002). Conflict between Native Americans and settlers between 1855 and 1865 resulted in the extirpation of a substantial population of people living in the basin. The number of settlers increased rapidly, and during this period nearly all public lands were conveyed to private ownership.

Beginning in the early 1900s, settler homesteads slowly began to transition to ranches as agriculture became one of the primary economic activities in the region. Many ranches consisted of thousands of acres of converted pasture, most of it used for intensive sheep-grazing. The land conversion from forest to pasture affected the landscape by compacting soil and forever changing the vegetation type and soil pH on vast tracts of land.

The tanbark industry was the first large-scale forest management practice in the SFER, beginning in the early 1900s and ending in the 1950s with the development of synthetic tannins (JMWM 2000). Peak production of natural tannin occurred between 1900 and 1920. Tanoak bark was peeled from trees and transported out of the area or sent to a plant in Briceland where the bark was converted to tannin extract. Stripped tanoak trees were left on the ground, and nearly all of the tanoak trees in the sub-basin were harvested during this time (HCRCD 2002).

Early logging activity in the mid-19th and early 20th century resulted in the removal of all accessible old growth redwood along the

[2] Portions of the content of this section is drawn from SFER WA, CDFW (2014).

creek mouths throughout the Subbasin. Due to the long distance between the harvest areas and larger mills near Fortuna and Humboldt Bay, many trees were used for split products such as railroad ties, shingles, and grape stakes. These split products were produced at sites where trees were felled, then transported out of the basin more easily than whole logs (O'Hara and Stockton 2012).

Intensified logging

Prior to World War II, Douglas-fir was considered unmerchantable timber, but after the war, nearly all Douglas-fir in the watershed was harvested in an effort to keep up with the post-war building boom (BLM et al. 1996). Mechanized road building, log skidding and additional transportation options allowed harvesters to access remote areas with steep terrain, which resulted in an increase in logging operations throughout the basin. Roads, skid trails, and landings were often located in creeks so logs could be easily skidded downhill, and instream log ponds were constructed to preserve and transport logs further downstream. During this time, extensive damage to streams and poor road building techniques combined with unstable geology led to increased sedimentation in streams throughout the sub-basin (JMWM 2000).

Improvements in timber harvest techniques and equipment led to increased harvest efficiency. This new ability to harvest timber was coupled with a financial incentive to harvest quickly: in 1956, the Humboldt County Supervisors levied a tax on standing timber. As a result, most landowners were forced to harvest timber for financial reasons rather than leave it standing (O'Hara and Stockton 2012); subsequently the late 1950s and early 1960s experienced peak timber harvest.

Forest practice regulation

Timber harvest continued relatively unregulated until the implementation of the 1973 Z'Berg-Nejedly Forest Practice Act. This legislation established a politically appointed Board of Forestry (BOF) whose mandate was the control over forest practices and forest resources in California. The Act requires that Timber Harvest Plans (THP) be prepared by a Registered Professional Foresters (RPF) and include regeneration of forested sites. In 1993 the BOF adopted rules requiring sustained yield planning, with requirements that all forest landowners develop at least 15% late-seral-stage forests on their ownership. Although timber harvest levels have declined recently; the timber industry is still an important component of the economy and harvest rates vary with individual ownership, resource management objectives and timber product market forces.

Floods

Floods are natural periodic occurrences that play a major role in formation of channels and have sculpted aquatic organisms over evolutionary time scales. The effect of the floods of 1955 and 1964 in the SFER must, however, be considered in the context of the human impacts with which they coincided. During the larger and more devastating December 1964 flood, the maximum mean daily flow at Miranda was 161,000 Cubic Feet/Second (CFS) and the maximum peak flow was 199,000 CFS on December 22 while just four days before the event the SFER discharge was near baseflow at 1,180 CFS.

Prior to the 1964 flood, the SFER had just experienced an intense period of accelerated logging, where poor road construction, tractor logging and skid trails combined with largely denuded riparian and upland forests generated a catastrophic event for aquatic habitats. This event unraveled the vulnerable hillslopes, washing massive amounts of sediment into channels. During the 1964 flood, it is estimated 105 million tons of suspended sediment were transported past Scotia, near the mouth of the Eel River, during a 3-day period, compared to 85 million tons transported during the previous 8 years (Brown and Ritter 1971). Many millions of tons of gravel and logging slash was transported into stream channels. Channel capacity was thus impaired, forcing water laterally and eroding streambanks which caused large streamside mass wasting events. The result of this sedimentation was highly aggraded, wide, shallow stream channels. Much of the riparian forest that had been logged was laid bare. A large volume of the sediment from tributaries deposited at tributary mouths, disconnecting them from the mainstem. As the waters receded the tributaries cut through the gravel leaving unpaired terraces and knickpoints at ecologically important hydrologic junctions (Sloan et al. 2001). Large quantities of logging slash clogged tributary channels, storing large volumes of sediment and creating barriers to upstream fish passage.

Watershed process and channel form have experienced considerable recovery, setting watershed processes on a somewhat different trajectory. Suspended sediment concentrations declined to pre-flood levels within about 5 years (Lisle 1990). Channel beds in most tributaries scoured to stable levels in years following the 1964 flood, and are currently at or above pre-flood elevations. During channel-bed degradation, some channel geometries recovered to pre-flood arrangements with reestablishment of pre-flood channel widths. (Lisle 1982). Channels in many alluvial reaches have incised into flood deposits, however, leaving a narrower channel bounded by new riparian vegetation now disconnected from its associated floodplain. The colonizing riparian vegetation has largely locked in low-flow channel margins. The resulting riparian community is also drastically altered from the historic redwood late seral stage to primarily red alder and willow. In response to the massive loss of aquatic habitat associated with the floods, a large effort to clear debris jams and restore fish passage to upper tributary spawning reaches ensued. Through much of the 1970's through 1980's, the first concerted restoration efforts in the SFER focused on clearing the large volume of wood from channels (R. Gienger personal communication, SHaRP Expert Panel meeting, September 2019). While many of the large debris jam barriers necessitated clearing for fish passage, it is now recognized that this effort was too vigorous. Much of the large wood that we now understand to play a beneficial role in maintaining channel form, aquatic habitat, and sediment regulation was completely removed. In the years that ensued, the lack of large wood in tributaries to the SFER has been deleterious to channel sediment maintenance and retention, especially in large wood forced channel types, and has resulted in reduced or simplified aquatic habitat formation in much of the basin.

Subdivision and accelerated land-use through the green rush

By the late 1960s, aside from preserved State Parks groves, most of the merchantable timber had been removed from the northwestern SFER basin. Land developers bought up large tracts of land, subdivided the smaller parcels (40-80 acres), and sold them to “new settlers”, also known as “back-to-the-landers”. Significant changes to the watershed from these activities included the development of roads to access every parcel, an increase in the number of water diversions, and collectively an increase in the total amount of water diverted from streams in the basin to supply additional residences.

Many of these “back-to-the-landers” also started cultivating marijuana, and these operations slowly expanded in both size and number. Development of this underground industry beginning in the 1970’s provided an economic boost throughout the sub-basin (JMWM 2000). Illegal marijuana cultivation proliferated through the 1980’s and 1990’s, and the illicit nature of the industry resulted in unregulated development of water resources, land clearing and grading and additional road building.

California’s Proposition 215 ballot passed in November of 1996, opening the industry to legal cultivation for medical use with limits to size of operations. These regulations proved hard to enforce and spurred the quasi-illicit operations to proliferate with little regulation. By 2002-2007, large-scale growing operations or “mega grows” started showing up on the landscape. Simultaneously, financing was readily available to anyone, regardless of their financial stability, who wanted to buy real estate. By 2010, it was estimated that nearly 80% of the nation’s cannabis came from California and most of that from the Emerald Triangle within the heart of the Eel River basin (Mathis 2020). The cannabis industry (permitted and unpermitted production) nearly doubled in area under cultivation from 2012-2016 in Northern California (Butsic et al. 2018).

The quantity and magnitude of stream diversions associated with this expansion was voluminous, increasing water temperatures, reducing flow at critical times for fish rearing and migration, and altering water chemistry across the entire basin. The unregulated road building and grading was once again impacting stream channels with excessive fine sediments.

In 2015, the Governor approved the Medical Cannabis Regulation and Safety Act and by November 8, 2016, the voters of California passed Proposition 64 -the Medicinal and Adult-Use Cannabis Regulation and Safety Act. This legislation required any person wishing to commercially cultivate cannabis lawfully in California and obtain a license from the California Department of Food and Agriculture. The regulatory framework accompanying this legislation came with environmental protections including water development, land development in accordance with state and county ordinances, and compliance with state fish and wildlife regulations, among others.

Salmon and steelhead decline

The Eel River watershed historically supported a significant number of salmon and steelhead, with populations present in all major tributaries (NMFS 2014). Yoshiyama and Moyle (2010) examined commercial fishery and cannery records from as early as 1854 through 1921. Extrapolating these data to minimal population estimates, these authors estimated an average annual population of approximately 93,000 fish during this period with a peak roughly six-fold higher in 1877. Chinook Salmon represented most of this commercial catch, as the timing of river entry likely made them highly vulnerable to the netting operations in the lower river. The authors also noted, "given that the cannery records result in a very conservative estimate of Chinook numbers, the records suggest that historic runs of Chinook Salmon probably ranged between 100,000 and 800,000 fish per year, declining to roughly 50,000-100,000 fish per year in the first half of the 20th century". The winter and summer steelhead run (combined) likely numbered between 100,000 -150,000 adults per year during the late 1800s and early 1900s. Coho Salmon numbers were less than those of steelhead; nonetheless, historic numbers probably ranged in the 50,000-100,000 fish per year (Yoshiyama and Moyle 2010).

It is estimated that by the turn of the 21st century, Coho Salmon were reduced to 6 -15% of abundance estimates from the 1940's (CDFG 2004). Within the entire range of Southern Oregon-Northern California Coast (SONCC) Coho Salmon, only the SFER population of Coho Salmon is thought to persist marginally above its depensation threshold (NMFS 2014).

The fish ladder installed at the former Benbow Dam at river mile 40 on the South Fork Eel River was operated from 1938 to 1976 capturing and counting passing fish. Data from the Benbow fish ladder arguably provides the most robust information on population declines. The most precipitous decline in the era of post-commercial river harvest occurred during a period when habitat conditions were significantly affected by timber harvest activities and punctuated by the catastrophic floods of 1955 and 1964 (Figure 4-5). These data show declines in populations of all three anadromous fish species from highs of 10,000-20,000 fish immediately prior to the beginning of post-WWII tractor logging in 1945, to lows of less than 5,000 fish at the end of the time series in 1976. Coho Salmon, in particular, were captured in precipitously low numbers in the last few years of ladder operation.

Contemporary data collected from 2010 to 2019 by the California Salmonid Monitoring Program (CMP) indicate Coho Salmon populations have not recovered in the past 45 years. Rather, populations appear to continue to fluctuate around disparagingly low abundances that approach the critical population depensation levels outlined by NMFS (2014). Taking incomplete CMP abundance data on steelhead and Chinook Salmon, together with anecdotal information on these species, indicates these species also continue to fluctuate around critically low levels (Figure 4-5). Most recently, in 2018-2019, California Trout partnered with the CDFW and the California Conservation Corps to estimate Chinook Salmon entering the South Fork Eel River using a sound navigation ranging (SONAR) camera. Estimates produced with this technique placed Chinook Salmon escapement in the range of 3,150 to 4,500 fish, with slightly lower steelhead estimates between 2,500-4,000 fish (Methany *in prep*).

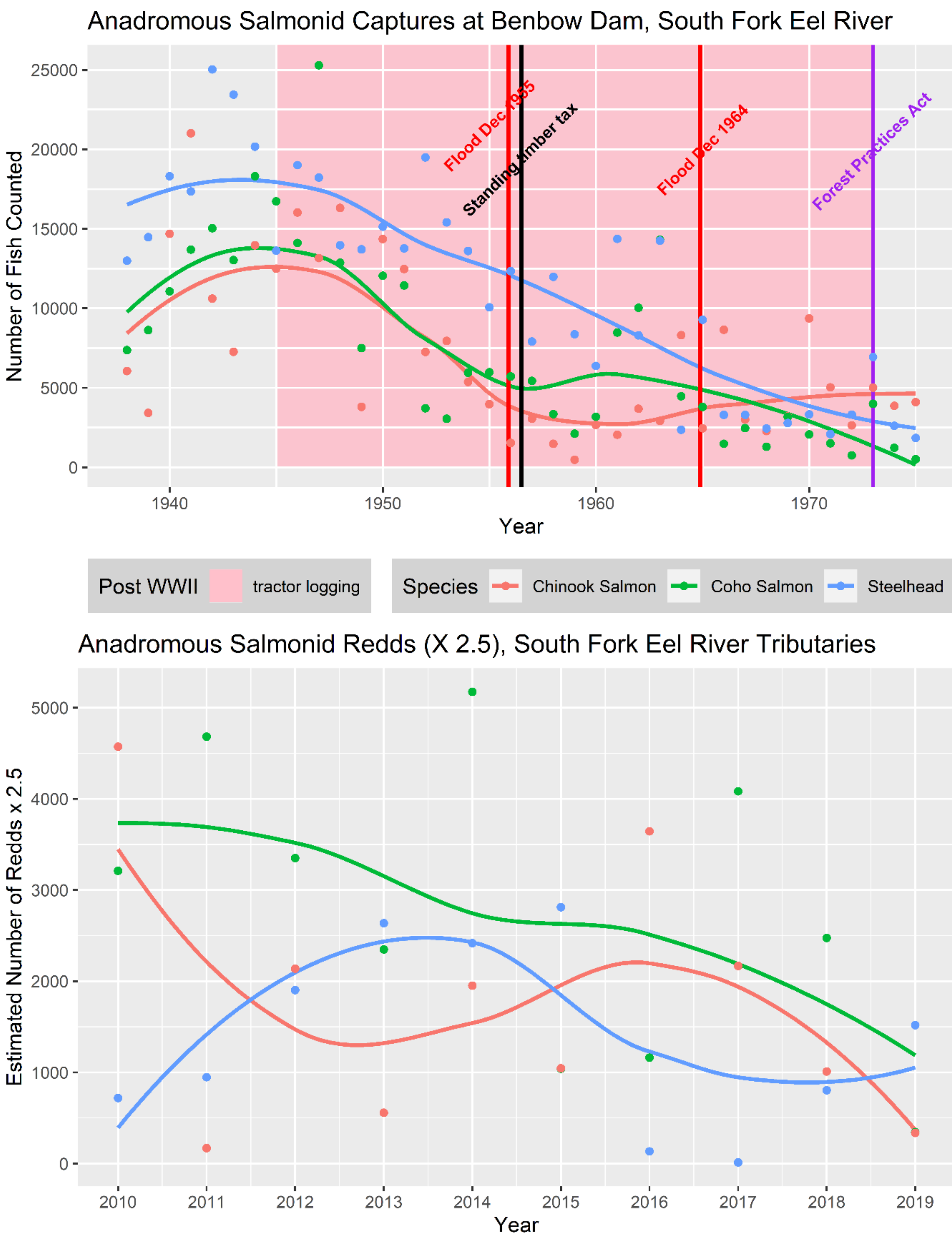

Figure 4-5. Top Panel: Counts and smoothed trend line of adult salmonids at Benbow Dam (RM 40), SFER, 1938-1976. Shaded area indicates the period of increased post WWII tractor logging, and vertical lines indicate timing of major flood occurrences, and forest management legislation. Lower Panel: Number of salmonid redds (multiplied by 2.5 to scale redds to escapement) estimated by the California Monitoring Plan and smoothed trend line.

History of Habitat Restoration

Restoration efforts throughout the SFER have been ongoing since the 1970s. Similar to other areas in the region, early efforts were largely volunteer opportunistic, and primarily addressed treating symptoms caused by unregulated land use (CDFW 2014). While well intended, much of these efforts were not optimally designed. Restoration efforts have since evolved to include a systematic approach for collecting and analyzing data, assessing watershed condition, and identifying critical issues. This information culminates in project designs that address habitat deficiencies and consider natural watershed processes.

CDFW's Fisheries Restoration Grant Program (FRGP) was established in 1981 and has provided much of the funding for aquatic habitat restoration within the SFER and across the North Coast. During the 1980s and early 1990s, limited funds were available for the program. Restorationists primarily pursued small-scale instream habitat improvement and bank stabilization projects that were spread across the watershed and were limited in their overall effectiveness. Small cooperative fish rearing facilities and rearing pond operations were undertaken in several SFER tributaries but proved to be somewhat ineffective at producing salmonids (CDFW 2014).

As salmonid populations remained depressed in the late 1980s and 1990s, restoration organizations successfully petitioned state and federal agencies to list salmonid species under their respective Endangered Species Acts. In response to species listing and the need to organize and expedite watershed restoration to support recovery of these species, CDFW developed the Stream Habitat Restoration Manual (Flosi et al. 1994). The manual provided guidance and a systematic approach to developing and implementing restoration projects. However, funding shortfalls limited the manual's initial utilization.

Landmark legislation passed in 1997, when Senate Bill 271 provided an additional funding source for FRGP's watershed planning, upslope erosion control, organizational support, and monitoring categories. Furthermore, the U.S. Congress established the Pacific Coastal Salmon Recovery Fund (PCSRF) in 2000 to reverse the declines of Pacific salmon and steelhead in California, Oregon, Washington, Idaho, and Alaska. NMFS administers the program and has granted California millions of dollars through PCSRF since 2000, which CDFW has allocated through FRGP.

While the FRGP has been a significant driver in funding and guiding restoration activities, other agency funding, private funds, and numerous landowner contributions have supported a diverse array of additional restoration projects in the SFER. For example, NMFS has funded SFER projects since 2001 through its Community-based, Open Rivers and Coastal Resiliency Programs. In addition, funds available through the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (commonly known as Proposition 1) has supported restoration efforts throughout the SFER sub-basin.

Role of Restoration and the SHaRP Process

As discussed, insufficient funding and emerging watershed science shaped the initial scale and scope of restoration efforts from the 1960s to the 1990s. In the 2000s, diverse and increased funding sources allowed for expanded, more systematic restoration planning and project execution. Between 2004 and 2018, FRGP funded 112 projects in the SFER and its tributaries, totaling over 14 million dollars (North Coast Salmon Project *in prep*). About 70 percent of this funding supported three project types: Upslope Watershed Restoration, Instream Habitat Restoration, and Fish Passage at Stream Crossings. Upslope watershed restoration received nearly half (44%) of this funding, addressing the critical need to decommission numerous miles of old logging roads. This large-scale road decommissioning improved drainage and reduced the sediment loads entering streams. Such upslope work was essential to prevent compromising the effectiveness of future riparian and instream work.

The SFER WA compared habitat suitability indices from data collected in 1990 – 1999 to values from 2000-2010 and determined that overall habitat suitability has increased in the northern and western portions of the watershed. While it is difficult to discern the relative contribution of restoration actions, improvements in environmental regulation, and natural processes to this improvement, it is noteworthy that some aspects of habitat conditions, such as canopy cover, pool-tail embeddedness, and percentage of pool habitat are improving given the fact anthropogenic threats and stressors continue to affect surrounding areas. However, pool depth and pool shelter indices, overall, have not shown improvement, which indicates sediment inputs are on-going and instream habitat complexity is still lacking. To date, about 8% of the 275 miles of tributaries in the SFER have been treated to improve instream complexity and a smaller percentage of upland habitat has been restored since 2004 (North Coast Salmon Project *in prep*). Scientific literature, including Roni et al. (2010) describe the need to treat a noticeably higher percentage of a stream/watershed before a population response can be detected. Considering the size of the SFER watershed, it is evident that a significant amount of restoration is still needed.

The SFER SHaRP process culminated in identification of the highest-priority restoration projects in seven focus areas of the sub-basin, as detailed in Chapters 5 through 11 of this plan. SHaRP restoration planning utilized local expertise, advanced knowledge in watershed sciences, and improved restoration techniques to collectively; identify current barriers needing fish passage modifications, incorporate updated large wood loading target metrics (Kier Associates and National Marine Fisheries Service (NMFS) 2008) to advance large wood loading effectiveness, GIS mapping exercises to integrate potential for restoration of floodplain connectivity and identify potential winter refugia (rearing habitat); and mapping of key road networks and other significant sediment sources requiring treatment to reduce sediment input.

Resiliency in the Face of Climate Change

Over thousands of years, evolution has given rise to a diverse set of life history patterns in California salmon and steelhead. Relatively short-term environmental variability leads to certain strategies having better success than others at different times and places (Bisson et al. 2009). A diverse portfolio of life history options serves to spread the risk of mortality across a population during cyclical periods of climate anomaly or acute catastrophic events (Hilborn et al. 2003, Schindler et al. 2010, 2015) when portions of the landscape or periods within the life cycle become less productive. Climate variations include the cyclical but increasing severity of temperatures and drought (Robeson 2015) (Figure 4-6), and multi-decadal patterns of ocean productivity (Mantua et al. 1997, Mantua 2015). Catastrophic events include wildfire, floods, earthquakes, and landslides that often occur in combination.

One of the most serious threats to salmon and steelhead in the Eel River is changes to the timing and location of rainfall in the basin, and the availability and temperature of surface waters. It is widely recognized that human induced global climate change is, in part, responsible for recent changes in climatic patterns (Williams et al. 2015, Obama 2017) (Figure 4-6), and increased human demand for water likely responsible for more localized dry season deficits (Asarian and Walker 2016). Shifting patterns in the onset of the wet season, and the magnitude and timing of peak flows can disrupt the timing and upstream distribution of adult anadromous salmonid spawning and subsequent juvenile rearing distribution. The timing of springtime downstream juvenile migration, however, appears relatively invariant to local spring discharge regimes (Kelson et al. 2018), but displays larger regional scale latitudinal gradients indicative of adaptation to longer term climatic trends (Spence et al. 2014). Near the southern end of distribution in North America, SFER salmon and steelhead are at the critical edge of genotypic adaptation and phenotypic plasticity that allow population persistence through periods of rapid climate change (Herbold et al. 2018).

Collaborative members recognized that climate change contributes to many of the concerning habitat conditions and disrupted watershed processes identified in the seven focus sub-watersheds, however, it was beyond the scope and authority of the Collaborative to address the proximate causal factors of climate change (e.g. greenhouse gas emissions) through the SHaRP process. Rather, the Collaborative believes that completion of the restoration treatments identified in the following Chapters 5-11 will help to both directly address acute stressors (e.g. water enhancement and conservation, habitat complexity) as well as restore watershed processes (i.e. delivery and distribution of sediments), which will collectively contribute to an increased range and diversity of habitats necessary to support a broad array of salmon life-histories.

The concept that habitat diversity leads to resiliency is in contrast to restoration approaches that attempt to engineer instream habitats to conform to an idealized condition (Bisson et al. 2009). An idyllic but over-simplified version of what a salmon stream 'should' look like may result in the loss of the life-history diversity necessary to support populations through periods of change. Recovery of habitats in the SFER sub-watersheds alone cannot address the entire suite of diverse freshwater and estuarine habitats necessary to support the complex life-histories of salmon and steelhead in the SFER. Consequently, the next SHaRP planning areas of the main-stem SFER through the main-stem Eel River and estuary are necessary, and currently underway.

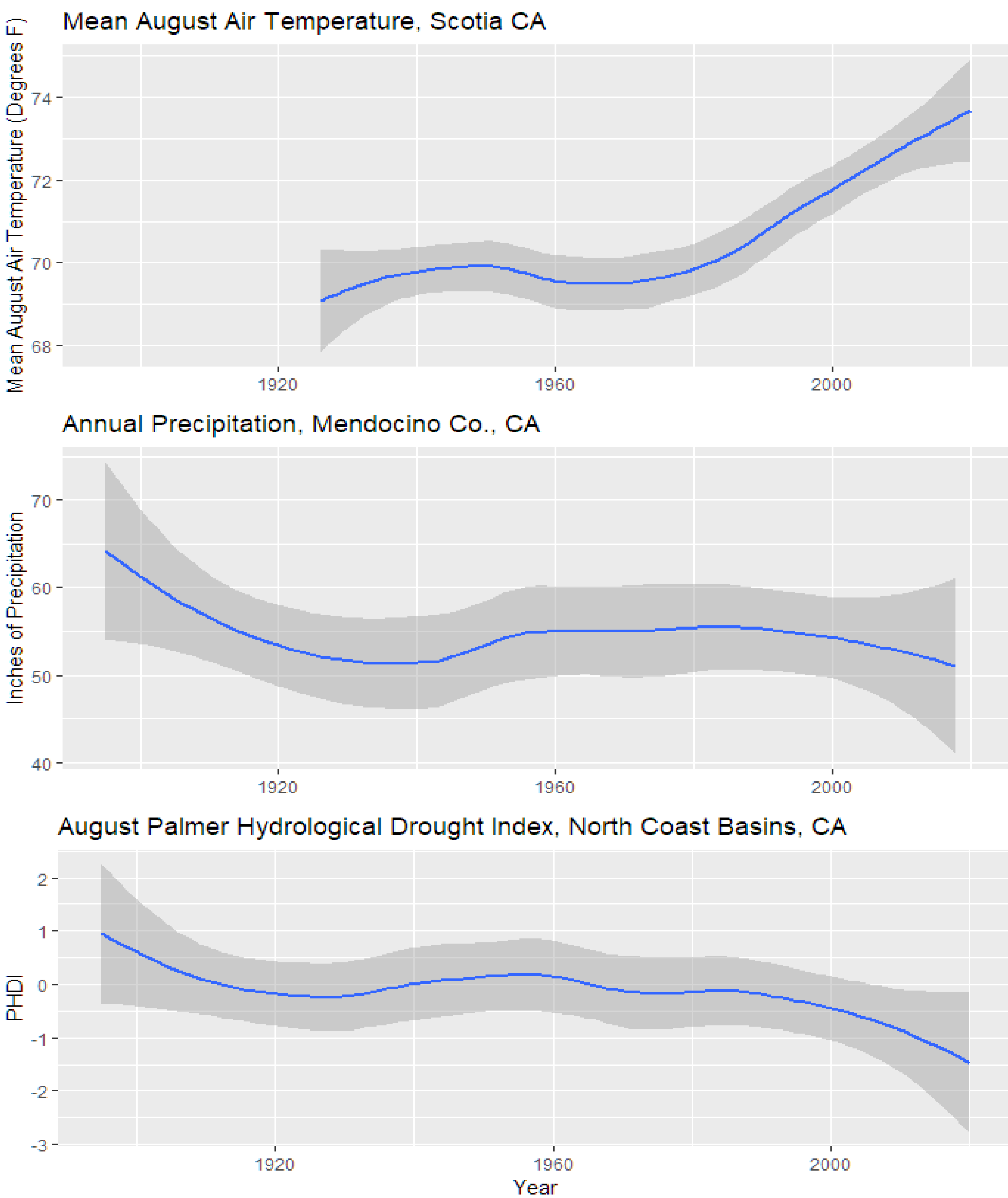

Figure 4-6. Top panel displays the Mean August Air Temperature in Scotia, CA from 1930 to 2020. The middle panel displays the Annual Precipitation received by Mendocino County, CA from 1890-2019. The bottom panel displays the Palmer Hydrological Drought Index (PDHI) for North Coast Basins in California. The PDHI is a standardized index based on rainfall, temperature and soil water balance and is used as an index of longer-term drought that reduces surface and groundwater supply. The magnitude of PHDI indicates the severity of the departure from normal conditions. A PHDI value >4 represents very wet conditions, while a PHDI <-4 represents an extreme drought. Blue trend lines in the panels represent a LOESS (locally weighted scatterplot smoothing) trend line and the grey envelopes surrounding the trend line indicate the standard error. Sources: https://calclim.dri.edu/index.html Accessed: 21 January 2021.