STEELHEAD ABUNDANCE MONITORING IN THE SANTA MONICA BAY
January 2017 – November 2019

Arroyo Sequit lagoon and culvert post Woolsey Fire (November 2018)

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EXECUTIVE SUMMARY

This report builds upon previously submitted reports by providing updated information on the abundance and distribution of *Oncorhynchus mykiss* in Arroyo Sequit, Malibu and Topanga Creeks from January 2017-November 2019. This contract specifically required monitoring of *O. mykiss* abundance, spawning and reproductive success, flow conditions and fish passage opportunities, water temperature, benthic macro-invertebrate abundance and composition, and invasive species impacts. Given the drought conditions between 2012-2018, the data collected during this study has provided important information on the response of *O. mykiss* to these conditions and underscores the need for continued long-term monitoring in order to identify opportunities for this species to recover.

The population of *O. mykiss* in Topanga Creek was documented by CDFW up until 1980, then was extirpated for multiple years, and re-colonized following some high rain years associated with El Nino events in the mid to late 1990's (Bell et al. 2011b). Data collected during the entire study period from 2001-2019 provides a snapshot of natural re-establishment and response of a small coastal population to the dynamic and ever-changing conditions related to precipitation, drought, floods and wildfire.

Monitoring in Arroyo Sequit started in 2005. Few *O. mykiss* were observed in Arroyo Sequit overall but following the removal of all instream barriers below the Mulholland culvert in 2016, rains in 2017 supported arrival of two anadromous adults. Due to on-going drought conditions, the stream dried down and one fish was found dead in September and the other found refugia in the culvert undercut but had to be moved to Topanga Creek in November 2017 when that pool dried out as well. Following the 2018 Woolsey Fire which burned the entire watershed, the creek was filled with sediments and all pool habitat destroyed, including most of the riparian tree canopy. Surface flows were shallow (<5cm) and not passable for *O. mykiss* through all of 2019.

Malibu Creek has been the focus of on and off monitoring first by volunteers from CalTrout in the 1990's and then more consistently by the RCDSMM since 2005. During the 15 years of monitoring, we documented a peculiar die off in 2006 when the trout turned yellow (Dagit et al. 2009a), downstream impacts from wildfires in 2007, 2009, 2018, extreme flood events in 2010 and 2017, and restoration of Malibu Lagoon in 2012, resulting in a population of *O. mykiss* that ranged from a high of almost 3,000 young of the year in 2008 to none observed since 2018.

Analysis and synthesis of all collected data has led us to revise hypotheses discussed in previous reports (Dagit and Krug 2011, Krug et al. 2014, Dagit et al. 2015a, Dagit et al. 2017b). With over 19 years of data in hand, our current working hypotheses include the following:

- ***The response of O. mykiss abundance and distribution to rainfall driven changes in creek conditions and passage opportunities varies depending on other biotic and abiotic factors as well as the time frame analyzed.***

When looking at high rainfall years such as 2005 and 2008, *O. mykiss* abundance increased in Malibu and Topanga Creeks as fish were able to expand into additional habitat above low flow barriers. By contrast, if one looked only at the low flow periods of 2013-2018, overall abundance declined, despite documentation of several anadromous adults in Arroyo Sequit, Malibu and Topanga Creek in 2017. Neither high nor low flow conditions accurately reflect the dynamic and resilient nature of *O. mykiss* populations in these small coastal creeks, where abundance and distribution are affected by not only rainfall, but also accessibility to anadromous adults, resident *O. mykiss* fecundity, water temperature, low flow barriers, sediment impacts from wildfires, and high flow reduction of reproductive success. Natural background population variability makes it difficult to draw conclusions, but the combined local and regional population decline leaves the population in the Santa Monica Bay very close to local extirpation. The abundant rainfall from January-March 2017 and in the winter of 2019 provides some hope for recovery, but further emphasizes the importance of consistent monitoring.

- ***Overall, abundance of O. mykiss in the Santa Monica Bay creeks has declined with the seven-year drought, despite flow augmentation in Malibu Creek.***

No *O. mykiss* were observed in Arroyo Sequit between 2015-2016, when the creek went almost entirely dry. Previously three *O. mykiss* were observed in 2005, another high rain year, and one in 2014. Two anadromous adults entered the system in January 2017 but as stream flow declined, one fish died by September and the other was relocated from the dry Culvert Pool to Topanga Creek. The creek was impassable due to post fire sedimentation during 2019.

Malibu Creek receives flow augmentation whenever summer flow levels drop below 2.5 cubic feet per second (cfs). Between 2013-2018, the Tapia Water Reclamation Facility released approximately 82 million gallons per year during the summer months to meet this flow requirement at the stream gauge, located upstream of Rindge Dam. Despite this augmentation, Malibu Creek had pools dry down by early summer and remain disconnected until mid-November, when regular releases from Tapia resumed. In early summer 2016, the gauge broke and augmentation flows were not initiated until September, resulting in extensive loss of surface flows and constriction of habitat to compromised refugia pools, resulting in fewer than 15 resident *O. mykiss* observed during the summer/fall months. We observed an anadromous adult in spring 2017 but she apparently died prior to spawning. No *O. mykiss* have been observed since that time.

The numbers of *O. mykiss* in Topanga Creek also declined substantively as reaches of the creek dried that had previously been stable spring-fed refugia pools. Dagit et al. (2017a) summarized the relationship between lower flows, intermittent dry reaches, and declining numbers of *O. mykiss.* The above average rains in 2019 were sufficient to restore base flow for much of the study reach but no anadromous adult were observed.

- ***Redds are difficult to document and appear primarily associated with resident O. mykiss.***

No redds have been observed in Arroyo Sequit Creek. Only 2 redds produced by anadromous adults have been observed in Malibu Creek throughout all study years, although 1-4 redds total were observed from 2010-2017. No redds were observed in Malibu in 2018-2019. Since 2010, a few redds have been observed each year in Topanga Creek, and those that were documented have been associated with resident *O. mykiss*, ranging in size from 150-300 mm Fork Length. When a redd was identified, we were often not able to find any trace of it, even in subsequent days, despite flagging to mark the site.

- ***Recruitment of young of the year into larger size classes has declined with the drought conditions in both Malibu and Topanga Creeks.***

The number of young of the year and intermediate size class *O. mykiss* declined during the drought (2012-2018) in both creeks. Fewer young were hatched and even fewer of these matured into adulthood. There have been no young of the year observed in Arroyo Sequit and none in Malibu Creek since 2015. Numbers in Topanga Creek declined as well during the drought but rose following the rains of 2019.

- ***The amount of available spawning gravel was not considered to be a limiting factor prior to 2012, but conditions associated with low flows and increased emergent vegetation caused a decline in potential spawning areas during the drought. The storms of winter 2017 and 2019 resulted in limited recovery in Topanga Creek.***

Both the quantity and quality of spawning gravel changed during the drought in Topanga Creek. Increased embededness, increased sedimentation, and growth of emergent vegetation encroaching into the creek channel reduced available spawning habitat between 2012-2016. The flushing flows in winter 2017 restored some habitat but even with additional rains in 2019 the percentage of available spawning gravel has not recovered to pre-drought conditions.

- ***Maximum and average temperatures have not changed significantly during drought, but minimum temperatures are slowly rising.***

Increased water temperature can be a limiting factor for all life stages of *O. mykiss*. Southern *O. mykiss* are distinct in their ability to withstand higher temperatures; an upper thermal maximum of 26.7°C has been reported by multiple sources (CDWR 1988, Carter 2005). Our data summarizes the increases in minimum temperatures, the decrease in range between maximum and minimum temperatures and the implications of these changes to *O. mykiss*.

- ***The abundance of some important benthic macro invertebrate species decreased with drought and the community shifted from Baetis sp. to Chironomid n.d. dominated.***

During the 2012-2018 drought, the community composition of benthic macro-invertebrates (BMI) in Topanga Creek changed (Montgomery et al. 2015). Using the Southern California Coastal Index of Biotic Integrity (SCC-IBI) as a metric, scores in Topanga and Arroyo Sequit Creeks have declined over time. The main stem of Malibu Creek has always scored poorly, but it too has declined for the first time; samples in the mainstem (MC15) were under the 500 individuals needed for the SCC-IBI analysis. Interestingly, samples collected in Cold Creek (CC3 - an upper tributary of Malibu Creek) were one of the only locations in the region where scores remained good, but even those scores suffered from the drought. Data for Arroyo Sequit and Malibu Creeks was not collected since 2016 due to lack of funding. Information on BMI in

Topanga Creek is reported in Dagit et al. (2018b) and not repeated here. The 2019 Topanga samples await processing.

- ***Invasive red swamp crayfish abundance increased with warmer temperatures and low flow conditions, despite regular removal efforts. They appear to have direct (predation) and indirect (competition for food resources) effects on O. mykiss.***

Changes in the abundance and distribution of red swamp crayfish (*Procambarus clarkii*) have been documented since 2006 in both Malibu and Topanga Creeks. By fall 2016, they were the dominant species observed during snorkel surveys. Crayfish were observed attacking both California newts and young of the year *O. mykiss* (RCDSMM *unpublished data*). The flushing flows of winter 2017 significantly reduced the abundance of crayfish and between January-April 2017, fewer than 10 individuals were observed in Malibu and Topanga Creeks. However, the population recovered in 2018 and this invasive species remains a threat in both systems.

No non-native species have been documented in Arroyo Sequit Creek. In summer 2016 New Zealand Mud Snails (NZMS) were observed in a short reach of Topanga Creek, but none have been observed since. They have also declined substantially in Malibu Creek since first documented in 2006. The numbers of non-native fish (carp, largemouth bass, green sunfish, bluegill, catfish, etc.), crayfish, and bullfrogs have also decreased significantly in spring 2017 and rebounded somewhat in 2018 and 2019 in Malibu Creek.

Management Implications

The above hypotheses led to the following management recommendations, which build upon those previously recommended.

- Protect both anadromous and resident life histories of *O. mykiss* in all creeks within the Santa Monica Bay.
- Increase fish passage opportunities in Topanga Creek by restoring Topanga Lagoon.
- Protect and enhance instream habitat complexity, especially following the loss of riparian cover during the drought and the Woolsey Fire (2018).
- Continue efforts to remove invasive species from the upper watershed of Malibu Creek (red swamp crayfish) and throughout the Topanga Creek watershed (red swamp crayfish and fathead minnows).
- Protect Arroyo Sequit Creek from invasion of non-native aquatic species.
- Protect the relatively undisturbed flow regimes of both Arroyo Sequit and Topanga Creeks.
- Remove Rindge Dam and restore upstream connectivity in Malibu Creek.
- Protect existing instream flows in Arroyo, Malibu, and Topanga Creeks.
- Examine the augmentation flow requirements in Malibu Creek to determine if it is possible to increase summer connectivity and reduce summer water temperatures.
- Continued long-term monitoring is needed to document response of *O. mykiss* to changing climate and post fire conditions. Snorkel and redd surveys provide a relatively low-cost, non-invasive method for observing population trends over time.

- Consider all possible methods for preventing extinction of localized sub-populations, such as genetically informed captive broodstock rearing, in order to preserve genetic diversity.

Recovery Plan Implications

To address needs identified by the Coastal Monitoring Program (Adams et al. 2011) for the Santa Monica Bay sub-population, we examined our data to examine questions related to abundance such as:

- ***Does population persistence in a representative small southern California coastal stream, such as Topanga Creek, rely solely on local recruitment?***

It appears that local recruitment is primarily responsible for population persistence in these small coastal creeks. No anadromous adults were able to access Arroyo Sequit creeks between 2005-2016 due to passage obstructions, but two anadromous adults were observed in Arroyo Sequit in January 2017, following removal of those barriers. To date, no redds have been found at this location. Between 2005-2019, there was no reproduction or recruitment documented in the study reach of Arroyo Sequit Creek.

Since the peak documented in 2008, numbers of young of the year in Malibu Creek continued to decline, despite observing one to three anadromous adults each year 2009-2017. In Topanga Creek two anadromous adults were detected in 2017, and a total of 774 young of the year were observed. Resident adults were responsible for most reproduction in Topanga Creek, which also increased in June 2019 to 370 young of the year following a good rain year.

- ***What is the role of anadromous individuals in maintaining long-term population sustainability?***

The role of anadromous adults in maintaining the population is episodic and although important, fairly limited. During the drought, the role of anadromous adults was extremely limited, with only Malibu Creek having any individuals observed. In spring 2017, anadromous adults were observed in Arroyo Sequit, and Malibu Creeks, but no redds were observed. Based on our genetic data, at least one of the anadromous adults observed in Topanga Creek spawned and over 30 young of the year produced. Incidental input from anadromous adults clearly contributes to maintaining the population.

- ***What are the sizes and/or ages of O. mykiss smolts leaving Topanga Creek?***

Between 2001-2019, flows and ocean connectivity were extremely variable and often limited to fewer than two days per year. A total of 43 smolts were captured in traps prior to the seven-year drought but no smolts were observed leaving during the flushing flows of winter 2017 and 2019 by either the DIDSON camera or instream antenna.

Genetic analysis of the individuals captured in the weir trap between 2003-2011 suggested that 23 were males ranging in size from 110-324 mm and females ranging in size from 115-485 mm. The majority of individuals were age 0 or 1 (n=32) and the largest female was age 4.

- ***How many smolts outmigrate and under what flow conditions?***

Very few smolts were observed. We are not able to answer this question due to low overall numbers of smolts and extremely limited outmigration opportunities.

- ***How are O. mykiss, both juveniles and adults, using available habitat?***

An extensive analysis of habitat use in Topanga Creek was described in Dagit et al. (2017a) and in Dagit et al. (2018a). During the low flow conditions, the abundance of *O. mykiss* declined and the number of locations where fish remained also decreased. The rains of winter 2017 allowed the creeks to connect completely until subsurface flows returned in June 2017. The creek was disconnected through most of 2018 and base flows were restored in January-June 2019 following a rainy year. Habitat availability increased with the return of base flows, but overall numbers of *O. mykiss* remain low. Distribution of *O. mykiss* extends from the ocean upstream to the limit of anadromy in both Malibu and Topanga Creeks although instream movement has been limited during the drought.

- ***What are the seasonal and age specific growth patterns?***

Growth patterns of PIT tagged individuals between 2008-2017 suggested that growth in Topanga Creek was year-round and comparable to that observed in other creeks (Krug et al 2012, Krug et al. 2014, Dagit et al. 2016). Intrinsic growth did not appear to decrease during the drought, suggesting that the lower density of fish inhabiting remaining refugia pools found sufficient food.

- ***What is the relative proportion of residency compared to anadromy in the population?***

The overwhelming majority of *O. mykiss* observed and samples during this study were residents, however there was a high retention of the alleles associated with anadromy (Nuetzel et al. submitted 2019). The expected heterozygosity (0.3421) and observed heterozygosity for Topanga Creek was 0.3351. The mean observed heterozygosity amongst all southern California populations (after removing hatchery-introgressed individuals) and hatchery strains in the analytical baseline was 0.3323 and 0.3086, respectively amongst individuals from all southern California populations and hatchery strains that were included in the baseline for genetic assignment. Of the 427 samples tested from Topanga Creek, 67.71% had a frequency of anadromous allele at OmyR04944 and 66.78% had a frequency of anadromous allele at SH114448-87, both of which are high as compared to the frequency of anadromous alleles observed in other southern California native populations, even though they are lower than Malibu (18 samples) of which 85.29% had a frequency of anadromous allele at OmyR04944 and 81.25% of anadromous allele at SH114448-87). The frequency of the allele associate with anadromy at this locus is quite variable across the southern California baseline populations and occurs at a mean frequency of ~41.3% across all Fillmore Hatchery strains.

- ***Can juveniles be recruited into the population within critical habitat (e.g., pools that provide summer thermal refuge), or must they move to find other habitat within the creek that is perhaps less suitable?***

During the drought relatively few juveniles were recruited into the population within remaining refugia pools. Based on fish distribution analysis (Dagit et al. 2018a), it appears that large (> 250 mm) *O. mykiss* are positively correlated with deep pool habitat, while juvenile (<250 mm) *O. mykiss* are negatively correlated with deep pool habitat. In addition, the presence of large *O. mykiss* is correlated with fewer juvenile *O. mykiss*. Overall, it appears that resident large *O. mykiss* are using the larger pools, and juveniles may be displaced to other shallow areas of the stream where adults are less likely to be present, and these areas were relatively scarce during the drought. Increased connectivity and restored flows in winter-spring of 2017 supported limited additional juvenile recruitment which declined again during low flows of 2018. Above average rainfall in 2019 supported a pulse of recruitment in Topanga although no anadromous adults were observed.

Recommendations

Given the extremely low numbers of anadromous adults observed in the Santa Monica Bay, and the declining number of resident *O. mykiss* during the 2012-2018 drought, we recommend the following studies be considered. Additional information on each recommendation is found in Section 5.

- Continue long-term population monitoring to document changes over time.
- Restore fish passage in all potential *O. mykiss* creeks within the Santa Monica Bay.
- Restore Topanga, Trancas, and other coastal lagoons.
- Remove Rindge Dam in Malibu Creek and other upstream barriers.
- Consider developing a genetically informed broodstock program to preserve genetic diversity.
- Continue regular and comprehensive sampling of lagoons to determine residency and growth prior to smolting and habitat availability.
- Continue efforts to monitor, minimize or avoid water quality impairments, especially increased water temperature.
- Support restoration of riparian canopy lost in the drought and Woolsey Fire (2018).
- Further investigate the impacts of invasive species such as the red swamp crayfish on *O. mykiss*.
- Further investigate potential causes of seasonal and annual growth patterns (e.g., food availability, rainfall, density).
- Install an instream antenna array in Malibu and Topanga Creeks to check for tagged anadromous adults.
- Generate and maintain a strong public outreach and education program to support restoration actions that will lead to the recovery of the species.

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INTRODUCTION

Historically, southern steelhead trout (*Oncorhynchus mykiss*) utilized many of the small coastal creeks within the Santa Monica Bay, but passage restrictions and upstream development, access has been restricted since the early 1900's. The southern coastal systems are characterized by sometimes lengthy periods of relative stasis, interspersed with random catastrophic events like wildfires, earthquakes, drought, and high flow years that can dramatically alter habitat availability and quality. Since 2000, Arroyo Sequit, Malibu and Topanga Creeks are the last remaining creeks used by *O. mykiss*. The southern steelhead population was federally listed as endangered as far south as Malibu Creek in 1997. The steelhead in Topanga Creek were protected in the southern range expansion of the Southern California Coast Evolutionarily Significant Unit (ESU; now Distinct Population Segment, DPS) in July 2002. Monitoring the distribution and abundance of *O. mykiss* in these creeks has been identified as an important way to provide critical management information for the *Southern California Steelhead Recovery Plan* (NMFS 2012). Both Malibu and Topanga Creek are listed as Core 1 populations by the Recovery Plan, and Arroyo Sequit is listed as Core 2. The 19 years of snorkel survey and migration trapping data from Topanga Creek (2001-2019), along with the 15 years of snorkel survey data from Arroyo Sequit and Malibu Creeks (2005-2019), provides the only continuous data set available in the Santa Monica Bay.

Topanga Creek is also identified as a focal watershed representative of small coastal streams in the southern steelhead Distinct Population Segment by CDFW and NMFS. Documenting abundance patterns in the Santa Monica Bay provides information required to meet the NOAA criteria for understanding population growth rate and related parameter guidelines, as well as diversity guidelines detailed in the Viable Salmonid Populations and the Recovery of Evolutionary Significant Units (McElhaney et al. 2000). This data is also contributing to the CDFW Coastal Monitoring Program (Adams et al. 2011).

Topanga is one of the lesser-impacted creeks in the Santa Monica Bay, with little variation to historic flow conditions. Monitoring in Topanga between June 2001 and November 2019 documented changes related to both extreme low and high flow conditions, impacts of the seven-year drought, and a small (55 acre) fire in lower Topanga during the study period. Restoration of the lower Topanga floodplain (also known as the former Rodeo Grounds Berm area) in 2008 increased spawning habitat by almost 1000 meters and extended above-surface channel flow for an additional two months per year prior to 2014, and again following the rains in spring 2019. Between 2001 and 2005, *O. mykiss* were documented between the ocean and 4.4 river kilometers (rkm), although from June-December they were typically restricted to the reach between 1.68-4.4 rkm. A suite of storm events in January-February 2010 allowed adult fish to migrate above the natural boulder barriers, once thought to be the limit of anadromy at 5.3 rkm Grotto Pool, resulting in the extension of creek utilized by *O. mykiss* to the upper state park boundary at 6.0 rkm. Between 2012-2018, the distribution contracted due to drought when even some of the lower gradient groundwater fed refugia, pools dried down, forcing the remaining fish upstream of 3.6 rkm (Dagit et al. 2017a).With the higher rainfall in 2019, base flow was maintained from January through June.

Monitoring in Malibu Creek from June 2005 to June 2019 documented abundance and distribution for this important Core 1 habitat. During that time, the creek experienced a die-off of all observed aquatic species in summer 2006, (including *O. mykiss* that turned yellow (Dagit et al. 2009), wildfire in 2007, tremendous recruitment of young of the year in 2008 along with observed anadromous adults, and another population decline in summer 2009. Between 2012-2017, abundance declined substantively, from an average of 126 in 2012 to a single sighting of one anadromous adult in 2017. A single fish was observed once in 2018 prior to the November 2018 Woolsey Fire, and no *O. mykiss* were observed at all in 2019 following the fire.

In 2010, concern about water quality impacts associated with two die-off events and the drought resulted in the installation of continuously recording YSI 6600 sondes (temperature, DO, pH, conductivity, turbidity, flow, chlorophyll a) in both Malibu and Topanga, which provided insight into what parameters may have contributed to the problems observed in Malibu (Dagit et al. 2015a). A Troll 9500 sonde was then permanently installed in 1.043 rkm Start Pool in Malibu Creek in 2012 where it provided daily data until the floods of 2017 destroyed the housing and cables. Efforts by RCDSMM and California Department of Parks and Recreation (CDPR) Angeles District to repair it were completed and the sonde was redeployed in August 2017. It was functional until removed and retired in October 2019.

Monitoring in Arroyo Sequit Creek also started in 2005. Despite its small size, Arroyo Sequit had extensive high-quality habitat for *O. mykiss* both as refugia pools in the main stem, as well as in the upper reaches prior to the Woolsey Fire (2018). Between 2014-2016, a small check dam and two instream road crossings were removed. A single anadromous adult was observed upstream of all these barriers in January 2017. An additional anadromous *O. mykiss* was also observed further upstream at the culvert pool, suggesting that the upstream refugia pools located on private property and outside the study area may have provided habitat during the drought.

While snorkel surveys have inherent biases and inconsistencies related to visibility, they provide a relatively reliable, cost effective and non-invasive picture of fish distribution and abundance. The purpose of this study is to build upon existing data gathered in our complimentary Lifecycle Monitoring efforts (Dagit et al. 2018a) to provide a better picture of *O. mykiss* life history characteristics in southern California. This information will be used to enhance ongoing restoration planning efforts, with a focus on the larger landscape-scale projects needed to fully optimize *O. mykiss* recovery in the Santa Monica Bay.

1.1. Project Background

Rather than repeat what has already been published, this report incorporates some of the more basic information as background, summarizes previously reported results and adds information gathered between May 2017 and November 2019. The work reported here compliments work conducted under separate grants which ended in 2018. Those grants funded the Lifecycle and DIDSON Monitoring programs which included mark-recapture, tissue sampling, weir trapping, as well as the installation and maintenance of an instream antenna and DIDSON camera.

Data gathered between 2001 and November 2019 is summarized in the following reports produced as part of the grant process:

Dagit, R., D. Alvarez, R. Dauksis, B. Demirci, H. Nuetzel, Stillwater Sciences, and J. C. Garza. 2018a. Comprehensive Lifecycle Monitoring Report for *O. mykiss* in Topanga Creek, California. Prepared for California Department of Fish and Game Contract No. P1550012, RCD of the Santa Monica Mountains, Topanga, CA

Dagit, R., D. Alvarez, S. Contrares, and R. Dauksis. 2018b. Santa Monica Bay Anadromous adults and juvenile steelhead monitoring. Final Report prepared for CDFW Contract No. P1250013. Prepared by Resource Conservation District of the Santa Monica Mountains, Topanga, CA.

Dagit, R., K. Adamsek, D. Alvarez, R. Dauksis, S. Kwon, E. Montgomery. 2017. Steelhead Monitoring in the Santa Monica Bay January 2015- April 2017. Prepared for California Department of Fish and Game Contract No. P1450012, RCD of the Santa Monica Mountains, Topanga, CA

Dagit, R., K. Adamsek, E. Montgomery, J. Mongolo, Stillwater Sciences and J. C. Garza. 2016. Updated Lifecycle Monitoring of *O. mykiss* in Topanga Creek, California. Prepared for California Department of Fish and Game Contract No. P01350010, RCD of the Santa Monica Mountains, Topanga, CA

Dagit, R. K. Adamsek, S. Albers, E. Montgomery, and A. Sanchez. 2015. Topanga Creek Steelhead Monitoring March 2011-December 2015. Prepared for California Department of Fish and Wildlife, Contract P105009. Resource Conservation District of the Santa Monica Mountains, Topanga, CA.

Krug, J., R. Dagit, Stillwater Sciences, J.C. Garza. 2014. Lifecycle monitoring of *Oncorhynchus mykiss* in Topanga Creek, California. Final Report. Prepared for CA Department of Fish and Wildlife, Contract No. PO950013. January 2014.

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Dagit, R., and K. Reagan. 2006. Southern Steelhead Trout Topanga Creek Monitoring Summary June 2001-September 2005. Prepared for the California Department of Fish and Game Contract No P0350019. February 2006. Resource Conservation District of Santa Monica Mountains, Topanga, CA.

Dagit, R., K. Reagan, and C. Swift. 2004. Topanga Creek Watershed Southern Steelhead Trout Monitoring March 2003-2004. Prepared for CA Department of Fish and Game, March 2004. Resource Conservation District of the Santa Monica Mountains, Topanga, CA.

Dagit, R., K. Reagan, and C. Swift. 2003. Topanga Creek Watershed Southern Steelhead Trout: Preliminary Watershed Assessment and Restoration Plan Report. Prepared for CA Department of Fish and Game, March 2003. Resource Conservation District of the Santa Monica Mountains, Topanga, CA.

Additionally, portions of this data have been published in peer reviewed journals as follows:

Nuetzel, H., R. Dagit, S. Jacobson, and J. C. Garza. (submitted October 2019). Genetic assignment and parentage analysis of steelhead (*Oncorhynchus mykiss*) in the Santa Monica Bay, California. Bulletin of the Southern California Academy of Sciences

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1.2. Objectives

This study attempts to build upon previously collected information to provide a:

- Consecutive multi-year database of *O. mykiss* abundance in three critical streams of the Santa Monica Bay including number and seasonal distribution of adults, intermediates and juveniles, survival rates, spawning data, and migration movement data.
- Information on genetic relatedness both within the watershed and regionally.
- Description of habitat suitability and availability changes related to rainfall, sediment delivery, storm events, drought and wildfires, and estimations of how many *O. mykiss* could be supported within the presently accessible reaches of each creek, with preliminary information on possibilities for further upstream expansion.
- Evaluation of factors that influence mortality rates, limitations impacting recruitment and spawning opportunities on a year-to-year basis and development of a plan to reduce variability and prevent and/or minimize local extirpation.
- Objective, measurable, abundance data necessary to develop recovery goals for inclusion in the NMFS Recovery Plan (2012).
- Lagoon/ocean interface configuration, especially during potential migration opportunities.

Additionally, we hope to better understand the dynamics of dispersal and abundance patterns within the Santa Monica Bay sub-population in order to answer questions relevant to addressing the needs identified by the Coastal Monitoring Program (Adams et al. 2011) such as:

- Does population persistence in a representative small southern California coastal stream, such as Topanga Creek, rely solely on local recruitment?
- What is the role of anadromous individuals in maintaining long-term population sustainability?
- What are the sizes and/or ages of *O. mykiss* smolts leaving Topanga Creek?
- How many smolts outmigrate and under what flow conditions?
- How are *O. mykiss*, both juveniles and adults, using available habitat?
- What are the seasonal and age specific growth patterns?
- What is the relative proportion of residency compared to anadromy in the population?
- Can juveniles be recruited into the population within critical habitat (e.g., pools that provide summer thermal refuge), or must they move to find another habitat within the creek that is perhaps less suitable?

1.3. Study Areas

1.3.1. Arroyo Sequit Creek

The project area extends from the ocean interface of Arroyo Sequit Creek upstream to the boundary of Leo Carrillo State Park as shown in Figure 1.1. The study reach includes all of the currently accessible parts of the documented historic range of *O. mykiss* according to initial records in the 1800’s to present; downstream of the current limit of anadromy at the Mulholland Highway culvert. Upstream of the public lands, the ownership along the creeks is a mosaic of primarily private lands, interspersed with some public land, and is impractical to include at this time due to road and streambank degradation issues reducing habitat suitability, as well as accessibility. The entire Arroyo Sequit Watershed lies within the Triunfo Pass and Newbury Park Quadrangles.

Parcels in the 7,551-acre Arroyo Sequit watershed average 40 acres in size and are regulated by the Los Angeles and Ventura County General Plans, and the Santa Monica Mountains Local Coastal Plan (2014), all of which restrict development density, especially in relation to septic system limitations. Current development is approximately 3% in the Arroyo Sequit Watershed, and includes primarily single-family dwellings, ranch type facilities, numerous seasonal and year-round camp facilities, as well as public open space managed by county, state and federal park agencies. Future development is expected to be primarily single-family homes and potentially expanded camp facilities.

Access to Arroyo Sequit is available at numerous locations within the public right of way or within Leo Carrillo State Park, primarily along the road shoulder of Pacific Coast Highway and Mulholland Highway. It is possible to park legally at most of these locations along the shoulder, walk down the bank and enter the creek channel. Access to the small remnant lagoon at Arroyo Sequit is similarly accessible via State Park parking lots.

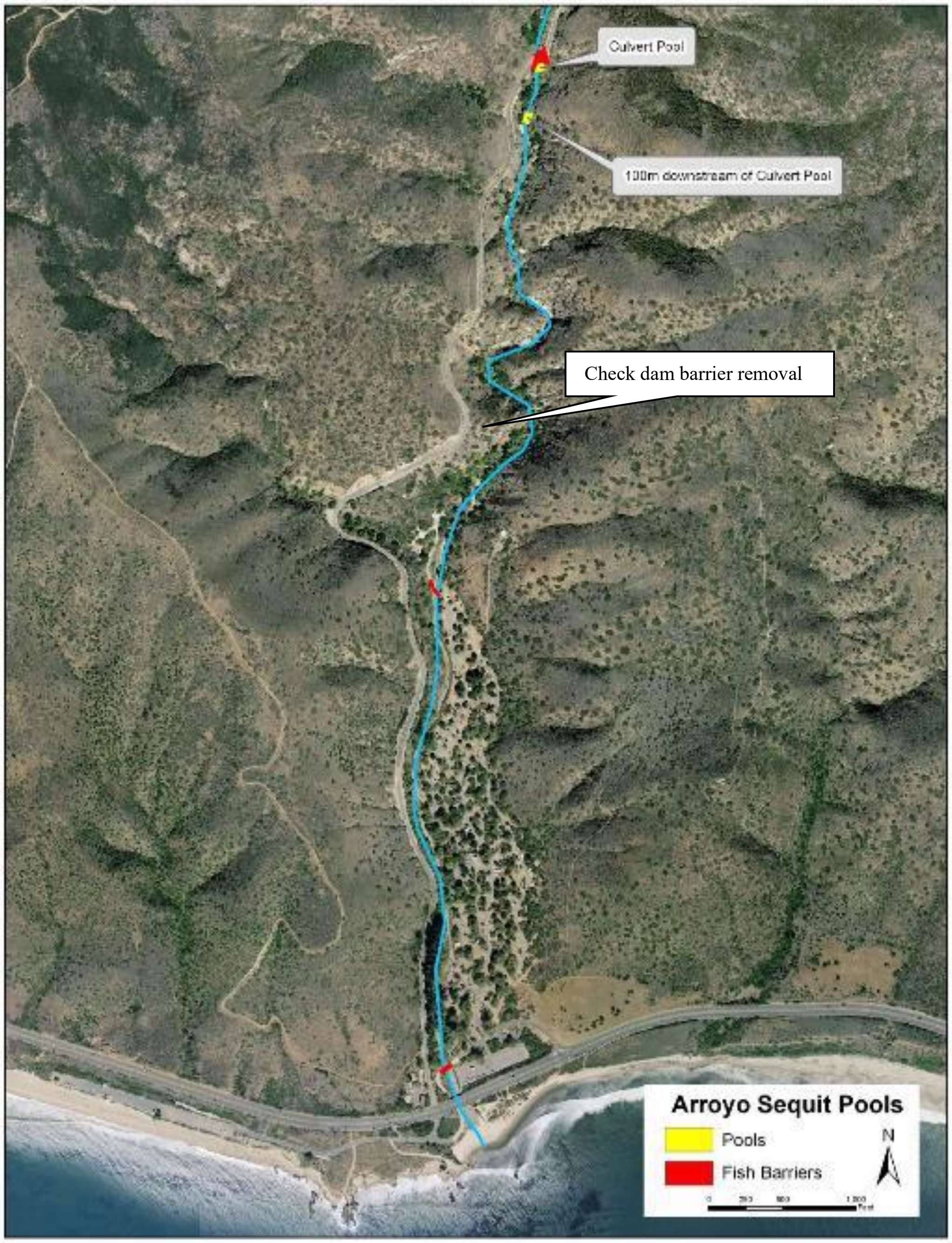


Figure 1.1. Map of Arroyo Sequit Watershed study area showing barriers removed by 2016.

1.3.2. Malibu Creek

The project area extends from the ocean interface of Malibu Creek upstream to Rindge Dam, as shown in Figure 1.2 and 1.3. This reach includes all of the currently accessible parts of the documented historic range of *O. mykiss* since Rindge Dam was installed in 1926. Upstream of the public lands, ownership along the creeks is a mosaic of primarily private lands, interspersed with some public lands, and is impractical to include at this time due to dam, road and streambank degradation issues reducing habitat suitability, as well as accessibility. The entire Malibu Creek Watershed lies within Malibu Beach, Calabasas, Thousand Oaks, Newbury Park, Point Dume, and Triunfo Pass Quadrangles.

Of the 70,352 acres in the Malibu Creek Watershed, approximately 31% (21,809 acres) are dedicated public open space. The study area comprises the lower 2,510 acres (3.6%) from Rindge Dam to the ocean. Single-family residential dwellings covering approximately 5,000 acres dominate existing development. However, 400 acres of commercial facilities and 860 acres of multi-family dwellings occur throughout the watershed. The Malibu Creek Watershed has a small amount of agriculture and animal husbandry totaling approximately 1,700 acres. It is anticipated that future development will be the continued sub-development and incremental construction of single-family homes on existing undeveloped lots. Development in the Malibu Creek Watershed (approximately 15% overall) is managed by numerous jurisdictions, including parts of unincorporated Los Angeles County, the cities of Agoura Hills, Calabasas, Hidden Hills, Thousand Oaks and Westlake Village in the upper watershed, as well as the City of Malibu in the proposed study area. Each city/county has its own land use regulations and restrictions. The City of Malibu Local Coastal Plan was certified by the Coastal Commission in 2002.

Access to Malibu Creek is available at numerous locations within the public right of way or within Malibu Creek State Park, primarily along the road shoulder of Malibu Canyon Rd. at some pullouts. It is possible to park legally at most of these locations along the shoulder, walk down the bank and enter the creek channel. There is also access directly into Malibu Lagoon from Pacific Coast Highway, and from the beach parking areas.

Figure 1.2. Map of Malibu Creek Watershed study area below Rindge Dam also showing upatream tributaries and barriers.

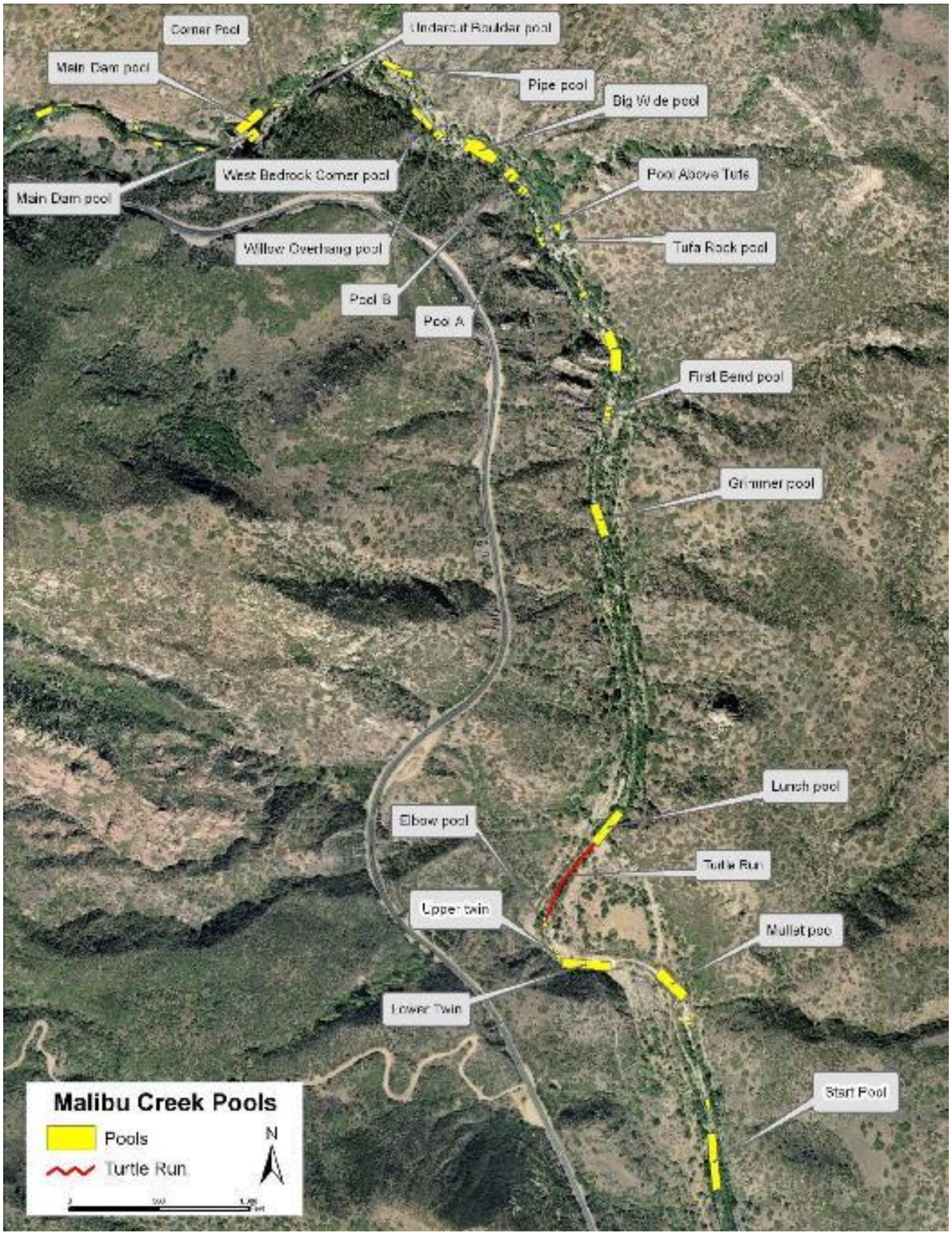


Figure 1.3. Pools in the Survey Reach of Malibu Creek.

1.3.3. Topanga Creek

The project area in Topanga Creek extends from the ocean interface upstream six river kilometers (rkm) to the boundary of Topanga State Park, as shown in Figure 1.4 and 1.5. This reach of the creek is both the current and documented range of *O. mykiss* from initial records in the 1930's to present. Upstream of the parkland, the ownership along the creek is a mosaic of primarily private lands, interspersed with some public land, and is impractical to include at this time due to road and streambank degradation issues reducing habitat suitability, as well as accessibility. The entire Topanga Creek Watershed lies within three quadrangles, including Calabasas, Canoga Park, and Malibu Beach.

Of the 12,400 acres in the Topanga Watershed, 9,205 acres are dedicated public open space. The remaining 3,195 acres are privately held. Existing development includes two residential sub-divisions and a mobile home park at the northern end of the watershed, three small commercial areas (under 20 acres each) along Topanga Canyon Blvd., and individual residential development located in areas of historic small lot sub-divisions or on private lots throughout the canyon. It is anticipated that future development will be the continued incremental construction of single-family homes on existing undeveloped lots. Most parcels in Topanga are under 40 acres and regulated by Hillside Management Criteria, the Santa Monica Mountains North Area Plan, and the Santa Monica Mountains Local Coastal Plan (2014), all of which restrict development density, especially in relation to septic system limitations.

Access to Topanga Creek is available at numerous locations within the public right of way, or within Topanga State Park, primarily along the road shoulder of Topanga Canyon Blvd. at mile markers 0.5, 1.0, 1.5, 2.02. 2.4, 2.75 and 3.25. It is possible to park legally at most of these locations along the shoulder, walk down the bank and enter the creek channel. There is also access directly into Topanga Lagoon from Topanga Beach and along Pacific Coast Highway just west of the intersection with Topanga Canyon Blvd. (State Highway 27).

Figure 1.4. Map of Topanga Creek Watershed study area.

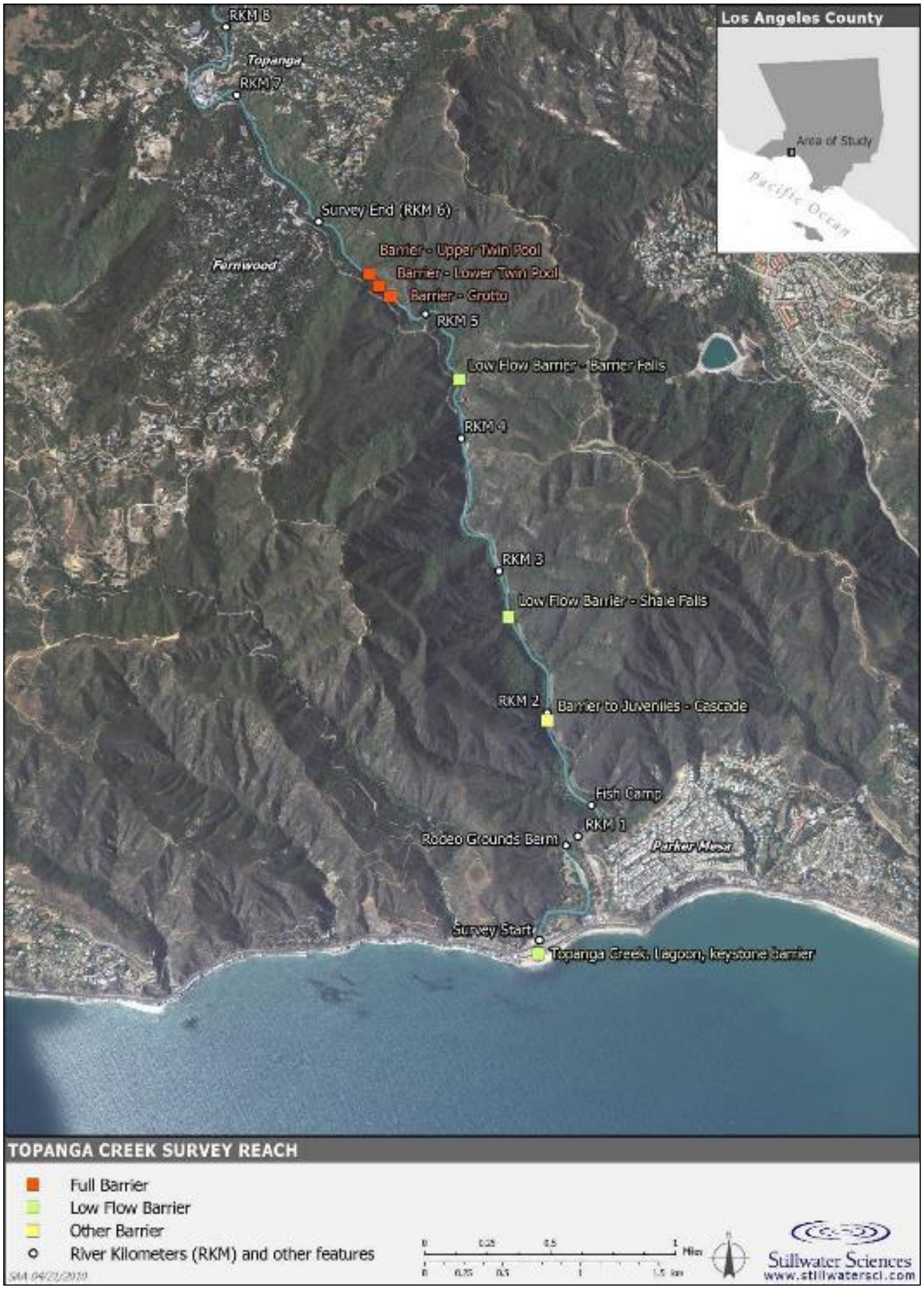


Figure 1.5. Topanga Creek Study Reach.

2. METHODS

2.1. Fish Surveys

Permits necessary for conducting this research are held by Dagit (CDFW Scientific Collecting Permit 000604, and NOAA NMFS Endangered Species Act Section 10 Permit #15390). CDFW Region 5 personnel approved the methodology and were notified of survey dates in advance throughout the course of the study.

2.1.1. Steelhead/Rainbow Trout (*O. mykiss*) Population Assessment

2.1.1.1. Objective

Identify *O. mykiss* population distribution, relative abundance, sizes, and age structure.

2.1.1.2. Methodology

Focused snorkel surveys were conducted monthly within the reaches of each creek where most *O. mykiss* were confined as a result of either low water levels, creating low flow barriers to movement, or in Malibu, below Rindge Dam (0-4 rkm), an impassable barrier for species. Snorkeling in Arroyo Sequit begins just upstream from the ocean and continues to the limit of anadromy (0-2.6 rkm) when the creek was connected, but during most surveys low flow conditions disconnected reaches so we instead targeted specific pools and wetted reaches. Following high flow events in 2005, 2010 and 2011, snorkel surveys in Topanga Creek were expanded to include the reach from 0-6.0 rkm, although this was constracted to 5.3 rkm Grotto Pool since 2013 due to drought, although focused surveys of fish trapped in pools continued throughout the study. See Appendix A for a summary of dates and reaches surveyed. All fish activity was noted, in addition to observations about overall creek conditions.

Great effort was expended in training field crews to make sure that snorkel teams were reliably documenting fish in a consistent way as per O'Neal (2007). A team of at least two people (one or more snorkeling and one recording and observing from the bank with polarized sunglasses) walked the creek, snorkeling in all possible locations of any habitat type with enough depth to support fish. Snorkel training events were held annually and when new divers joined the team. All divers were trained to recognize the different species of fish.

Young of the year *O. mykiss* without clear parr marks were not counted, to avoid counting Arroyo Chub by mistake. Size of fish were estimated and provided to the data recorder independently, to have repeated counts to verify numbers of fish in each size class (Table 2.1). If there were any inconsistencies between divers, a repeat pass was made.

Numbers of *O. mykiss*, size and life stage/ maturation were recorded according to both size class and the Juvenile Steelhead Life-Stage Rating Protocol developed by the IEP Steelhead Project Work Team. Habitat characteristic data including habitat type, maximum and average depth, percent canopy cover, dominant substrate, percent cover with algae, percent of instream cover, and shelter value were noted at each location where *O. mykiss* were observed. Presence of any invasive species such as crayfish, New Zealand Mud Snails, or bullfrogs was also noted.

Table 2.1. Life-stages of Steelhead Trout (*O. mykiss*).

Life Stage	Description
Young of the year Juvenile	<100 mm Fork Length
Parr	darkly pigmented, distinct parr marks, no silver coloration, scales firmly set
Intermediate	101-249 mm Fork Length
Silvery parr	parr marks visible but faded, intermediate degree of silvering
Smolt	parr marks faded or absent, bright silver or nearly white color, scales easily shed
Adult	>250 mm Fork Length, no parr marks, well developed coloration, including dark spots above the lateral line, scales not easily shed.

2.1.2. Spawning and Rearing Surveys

During snorkel surveys, observers looked for and recorded any evidence of spawning activity or redds. Using the survey protocol developed by NMFS (2012) and updated by McLaughlin and Christianson (2016), data on location, length, width, depth, substrate size, presence of adult fish or young of the year, and approximate age of the redd was recorded. Data was submitted to NMFS and CDFW at the end of each season in compliance with our permits. Since 2011 we have surveyed Topanga twice per month from January-May. Malibu was surveyed once a month coinciding with snorkel events, from the Cross Creek Road Bridge up to Rindge Dam. Arroyo Sequit was also surveyed once a month coinciding with snorkel events. All records are included in Appendix B.

In addition, availability, distribution, area and suitability of spawning gravel in Topanga Creek was noted during monthly snorkel surveys. Length and width of gravel beds, degree of embeddedness and water depth were recorded during January – April. A more systematic evaluation of embeddedness according to CDFW Rapid BioAssessment Protocol (Ode 2007) was done as part of the macro-invertebrate sampling each spring.

2.2. Genetic Analysis

2.2.1. Objective

To identify relatedness within the Topanga population of *O. mykiss* to the regional anadromous populations both up and down the coast.

2.2.2. Methodology

Material was collected opportunistically from carcasses in Arroyo Sequit, Malibu, and Topanga Creeks. Samples were also collected systematically from all captured *O. mykiss* in Topanga as part of the Lifecycle Monitoring project from 2008-2017.

All fin clips were dried in Rite in the Rain paper, placed in envelopes with associated data (fork length, condition, direction of travel, time and date), and sent to the NMFS Genetic Tissue Laboratory, in Santa Cruz, CA.

Samples were collected via electrofishing, weir trapping, and opportunistic carcass collection, and therefore include representatives from various age and size classes. Tissue samples were digested in Proteinase K lysis buffer and extracted on a QIAGEN BioRobot 3000, following the DNeasy 96 Tissue Kit protocol (QIAGEN Inc., Hilden, Germany).

2.2.2.1. SNP Loci and Genotyping

All individuals were genotyped using a panel of 95 Single Nucleotide Polymorphism (SNP) loci (Aguilar and Garza 2008; Campbell et al. 2009; Abadía-Cardoso et al. 2011). The 95 SNP markers selected for genotyping here demonstrated consistent levels of polymorphism, including higher mean minor allele frequencies common amongst *O. mykiss* populations throughout southern California, which is conducive to performing phylogenetic, genetic stock identification, and parentage-based analyses in the species (Abadía-Cardoso et al. 2011). One additional locus was used to infer genetic sex but was removed before performing any such analyses. See Abadía-Cardoso et al. (2013) for pre-amplification and genotyping protocol conditions.

2.2.2.2. Matching Samples

After genotyping, and prior to performing any downstream analyses, we used the Microsatellite Toolkit (Park 1999) to compare all individuals against each other to identify duplicate samples across years. Individuals that matched for at least 85 of 95 loci, and which differed at a maximum of two alleles were accepted as duplicates. We recovered 69 occurrences of duplicate sampling across all years, the majority of which involved individuals re-sampled two to three times in Topanga Creek. One individual, however, was re-sampled five times from 2009 through 2013. Only one representative individual from these matching clusters was then retained for all downstream analyses.

2.2.2.3. Analytical SNP Loci

We ultimately used genotype data from 90 of the 95 loci to perform population genetic and assignment analyses. Two of the five removed loci map to a genomic region (Omy5) found to be closely associated with the anadromous or resident phenotype in *O. mykiss* (Hecht et al. 2012; Pearse et al. 2014). This explicit link between genotype and phenotype implies that these two markers are subject to selection and were therefore not included in any population-level assessments of allele frequencies or heterozygosity. We do, however, separately report the allele frequencies at these loci to determine the potential for anadromy within Topanga Creek and nearby watersheds. Two of the remaining three excluded loci were removed due to increased susceptibly to genotyping error. Lastly, one locus was removed as it was not present in the southern California *O. mykiss* SNP baseline (Clemento et al. 2009; Abadía-Cardoso et al. 2016) used in this study, and therefore cannot be considered when comparing genetic diversity and estimating relatedness of the focal populations to southern California populations and hatchery strains. Any individuals missing data at more than 10 of these 90 loci were not included in any downstream analyses.

We used genotype data from 92 of the 95 loci to perform pedigree reconstruction analyses. The two loci vulnerable to high genotyping error rates, and one Omy5 locus were dropped. Only one of the two Omy5 loci was removed prior to parentage and family structure analyses given that these loci can still provide unbiased information relevant to inheritance; however, linkage between these loci suggests using both loci would be redundant. Additionally, since parentage inference and sibling relationship (sibship) estimation does not require we reference any baseline genetic data, we could include the single locus not present in the southern California baseline. Any individuals missing data at more than 10 of these 92 loci were not included in any downstream analyses.

2.2.2.4. Population Genetic Structure and Ancestry

The population structure and ancestry of Arroyo Sequit, Malibu, and Topanga Creeks were assessed using several methods. First, we utilized the software STRUCTURE (Pritchard et al. 2000) to investigate ancestry patterns at a population and individual level. STRUCTURE uses a clustering method, where the user specifies the number of clusters (i.e. populations), *K*, each of which is defined by locus-specific allele frequencies (Pritchard et al. 2000). Individuals are then probabilistically assigned to whichever cluster most closely aligns with their genotype without prior knowledge of any individual's geographic sampling location or population affiliation. Individuals can be assigned to several clusters if their genotypes suggest admixture between two or more identified clusters. We performed four separate runs, each constrained by a different number of clusters (i.e. k = 2, k = 3, k = 4, and k = 5), and each run was repeated five times.

The results were visualized using the software CLUMPP (Jakobsson and Rosenberg 2007) and DISTRUCT (Rosenberg 2004). This analysis was performed twice, with the first set of results being used to identify individuals in the baseline that demonstrated significant hatchery introgression. Baseline individuals, outside of the hatchery strains, with >12.5% proportional assignment to the cluster representing hatchery lineage were assumed to not appropriately represent the genetic profile of their respective basin and were therefore removed from the baseline for all subsequent analyses. With these individuals removed, the STRUCTURE analysis was re-run with the same parameters described above.

After removing these hatchery-introgressed individuals from the baseline, phylogeographic trees were also constructed using D_A distance estimation (Nei et al. 1983) and the neighbor-joining method (Takezaki and Nei 1996), within the web version of POPTREEW (Takezaki et al. 2014). Markers for which genotype data was missing for an entire population were removed, leaving 89 loci for phylogenetic analyses. Arroyo Sequit was not included as only one individual passed the missing data criterion, rendering any interpretation of population-level ancestry unreliable. Allele frequencies were bootstrapped 1,000 times to evaluate statistical support for resulting branching patterns.

Individual genetic assignment was also implemented in the software rubias (Moran and Anderson 2018). This software applies a novel parametric bootstrap approach to the traditional

Bayesian inference from the conditional genetic stock identification model, which corrects for bias in reporting units, or populations, that are more well-represented in the reference (Moran and Anderson 2018). We conducted a mixture analysis, in which individuals from the study populations were assigned to a southern California reference population, and a self-assignment analysis.

In the self-assignment analysis, Topanga Creek, Malibu Creek and Arroyo Sequit Creek were included in the reference, and all individuals were assigned back to these reference populations using a leave-one-out approach, which simply means the individual being assigned is removed from the reference during assignment. Assignments from the mixture and self-assignment analysis were filtered by posterior probability ≥ 0.95.

2.2.2.5. Parentage and Family Structure Analysis

First, the cohort, or birth year, for every individual was estimated using know age-length relationships and scale-age data when available (Krug et al. 2012). Parent-offspring trios were then reconstructed for each cohort separately using the program SNPPIT (Anderson 2010) and assuming a genotyping error rate of 0.005. SNPPIT identifies the most likely pair of parents for each offspring and reports confidence in each assignment as a false discovery rate (FDR), which is effectively the rate at which one may anticipate recovering false assignments given the data (Anderson 2012). Potential parent and offspring pools were constructed, such that all individuals born in the six years prior to the offspring cohort were considered potential parents. For example, if individuals born in 2017 were being analyzed as offspring, all individuals born in 2016, 2015, 2014, 2013, 2012 and 2011 would be considered potential. Constructing offspring and parent pools in this manner considers known reproductive and life history patterns for *O. mykiss* in southern California, while also accommodating for potential errors in age estimates. Furthermore, this approach also ensured the single representative of any duplicate sample cluster was always included as the maximum time frame over which the same individual was re-sampled was five years.

We performed two runs of SNPPIT, with the first being uninformed of any individual metadata, while the second was constrained by sex. We compared the results of each run to address and correct minor metadata errors, such as incorrect age estimates. Resulting trios were filtered by a False Discovery Rate (FDR) ≤ 0.05, which effectively means one may expect five in every 100 assignments passing filter to be inaccurate. The parent-offspring trios that passed this filtration criterion were then analyzed to assess age at spawning. Additionally, any individuals that were assigned as parents to offspring from multiple birth cohorts, were considered putative iteroparous spawners.

Finally, full sibling (FullSib) relationships were estimated in COLONY 2.0.6.4 amongst individuals within the same estimated cohort (Jones and Wang 2009). Unlike SNPPIT, COLONY2 can infer family relationships without establishing parent-offspring relationships, which allows for a less constrained assessment of full-sibling family groups. The input parameters for each run in COLONY2 were as follows: both sexes polygamous and dioecious; no sibship size prior or full sibship scaling; full likelihood estimation with medium run length and high precision; and no updating of allele frequencies. The allelic dropout rate and genotyping error rate were estimated at 0.0025 each. All FullSib families were filtered by Inclusive Probability (P(Inc.)) ≥ 0.90. The inclusive probability indicates how likely it is that a given family can be split into two or more additional families, such that a low P(Inc.) value would suggest the family has inaccurately grouped individuals into a FullSib family. Additionally, we did not consider FullSib families with less than three members, as previous analyses have demonstrated inferred sibships of size two to be unreliable (Garza et al. 2014).

2.2.2.6. Genetic Diversity Statistics

Finally, observed and expected heterozygosity were estimated for the focal and southern California baseline populations using the Microsatellite Toolkit (Park 1999). This analysis was performed after population genetic structure and sibsip analysis so that: 1) any hatchery-introgressed individuals identified in the STRUCTURE analysis could be removed from baseline native populations, and 2) full-sibling family groups did not disproportionately affect population-level genetic statistics. In addition to duplicate samples, estimates of allele frequencies and heterozygosity can also be skewed by the inclusion of full sibling (FullSib) family groups. Therefore, only one individual from all FullSib groups recovered by COLONY2, which were larger than two and with I(P(Inc.)) ≥ 0.90, was then included in population-level estimates of allele frequencies and heterozygosity.

Genetic analysis was completed under the supervision of Dr. Carlos Garza (NMFS). Results of that effort are provided in Appendix J.

2.3. Instream Habitat Survey

2.3.1. Objective

Document the amount, type and relative quality of *O. mykiss* habitat, describe any physical limitations, and identify problem areas and potential restoration sites.

2.3.2. Methodology

Due to the drought, Arroyo Sequit Creek was dry during much of the study period. Mapping was only possible in April 2019 and conditions were greatly impacted by sedimentation following the Woolsey Fire (2018).

Malibu Creek was mapped in October 2017 and May 2019. This habitat mapping builds on a survey done in 2004 that only documented refugia pools and low flow barriers (CalTrout 2006).

Topanga Creek was surveyed in October and November 2017 and May 2019 to build on previous surveys done in June 2001, October 2002, September 2003, September 2004, June 2005 and September 2006 from the lagoon mouth at Topanga State Beach, upstream to the confluence of Dix Creek just below the town of Topanga (5.9 rkm). The results of these surveys are found in Appendix E.

Physical stream characteristics were measured using meter tapes and mapping was done visually. GPS data was collected at each 100 meter cross section for specific unique locations, and at low flow passage barriers. Data was collected using the Habitat Inventory Data Form provided in Flosi et al. (2010). Additionally, a Stream Channel Type Work Sheet was completed at every 100 meter interval.

Level IV Habitat Types as defined by Flosi, et al. (2010) were modified slightly to accommodate the needs of the creek conditions in the Santa Monica Bay. We added fields for lagoon and road crossings in the creek channel (Arizona Crossings). Additionally, due to low water levels and narrow channels, we found that it was sometimes difficult to distinguish between step pools (4.4) and step runs (3.4), as they are quite similar. Another issue was classifying riffles, several of which were more stepped. These were categorized as high gradient riffles (1.2). Undercut banks are unusual but undercut areas under boulders are common. This field was used to represent both types of potential cover.

Data on habitat type by percent of total length, mean reach width in centimeters by habitat type, mean reach depth in centimeters by habitat type, max reach depth in centimeters by habitat type, mean reach shelter value by habitat type, and percent canopy cover by habitat type were documented. Additionally, summaries of adult, intermediate, and juvenile *O. mykiss* habitat suitability were also documented.

A list of seven substrate size classes was used to visually estimate and classify percent cover of each habitat unit. At each 100-meter location, the bottom was touched at 0.5-meter intervals across the channel width, and substrate described for each site.

Shelter Value ranges were from 0-3, with higher values indicating greater presence and quality of shelter (0 = no shelter, 1 = fair shelter, 2 = good shelter and 3 = excellent shelter). The following nine cover types were visually evaluated and assigned a percentage of the unit covered (% undercut bank, % small woody debris, % large woody debris, % root mass, % terrestrial vegetation, % aquatic vegetation, % bubble curtain, % boulders, and % bedrock ledges). Since some cover types can overlap, the total cover could total more than 100%. We considered the entire length of the unit when assigning a percentage of cover. These elements provide *O. mykiss* with protection from predators, separation of territorial areas, and refugia providing slower water where fish can rest, conserve energy, or provide necessary habitat for macro-invertebrates.

Data was inputted into an Excel database and then adjusted to be imported into ArcView. Quality Assurance/Quality Control consisted of two separate reviews of the input data by the authors. Any questions or discrepancies were identified and rectified. Data was also used to create maps using ArcGIS to visualize the habitat types throughout the length of the creeks.

Detailed results from habitat mapping surveys can be found in Appendix E.

2.4. Lagoon/Ocean Interface Monitoring

Monthly and storm-event related monitoring of the lagoon/ocean interface of Arroyo, Malibu and Topanga lagoons documented passage opportunities and constraints. Seining and/or snorkel surveys were conducted to record number of individuals, species, and estimated or measured length when conditions were suitable. The physical condition of the lagoon was photographed. These photos are summarized in Appendix C.

2.4.1. Seine Methodology

Spot seines were conducted in Arroyo Sequit (when there was water present), Malibu Creek twice annually (once in open and once in closed condition), and in spring and fall in Topanga Creek.

Spot samples were conducted at several random locations within Arroyo Sequit and Topanga. A 3.2 m x 1.2 m x 3 mm mesh net was used to seine starting parallel to the shore, and then pivoting into the shore. At least three passes were used at each lagoon, with more as needed to sample the entire wetted area.

Data collected included:

- Numbers of each species, standard length, reproductive status of individuals and their characteristics, observations of any parasites or lesions;
- Location of the seine, direction of pull, distance seined, habitat characteristics including substrate, algal cover, shelter, etc.;
- Water quality observations including, depth, temperature, dissolved oxygen, salinity, pH, and in the case of creek channels, flow;
- Weather conditions including air temperature, wind speed and direction, cloud cover, precipitation.

All captured fish were removed from the net and placed in buckets filled with clean, cool water, measured and released.

In Malibu Lagoon, a total of six sample sites were selected post construction in 2012 (Figure 2.1, Table 2.2) to provide an overview of all potential habitat types in the lagoon, except for the deep thalweg in the center (which was too deep to seine effectively). Seining was conducted in conformance to the pre- and post-project monitoring plan protocol, as noted in the Draft Malibu Lagoon Monitoring Plan, the Lagoon Restoration and Enhancement Project Monitoring Plan, and the Lagoon Restoration and Enhancement Quality Assurance Project Plan.

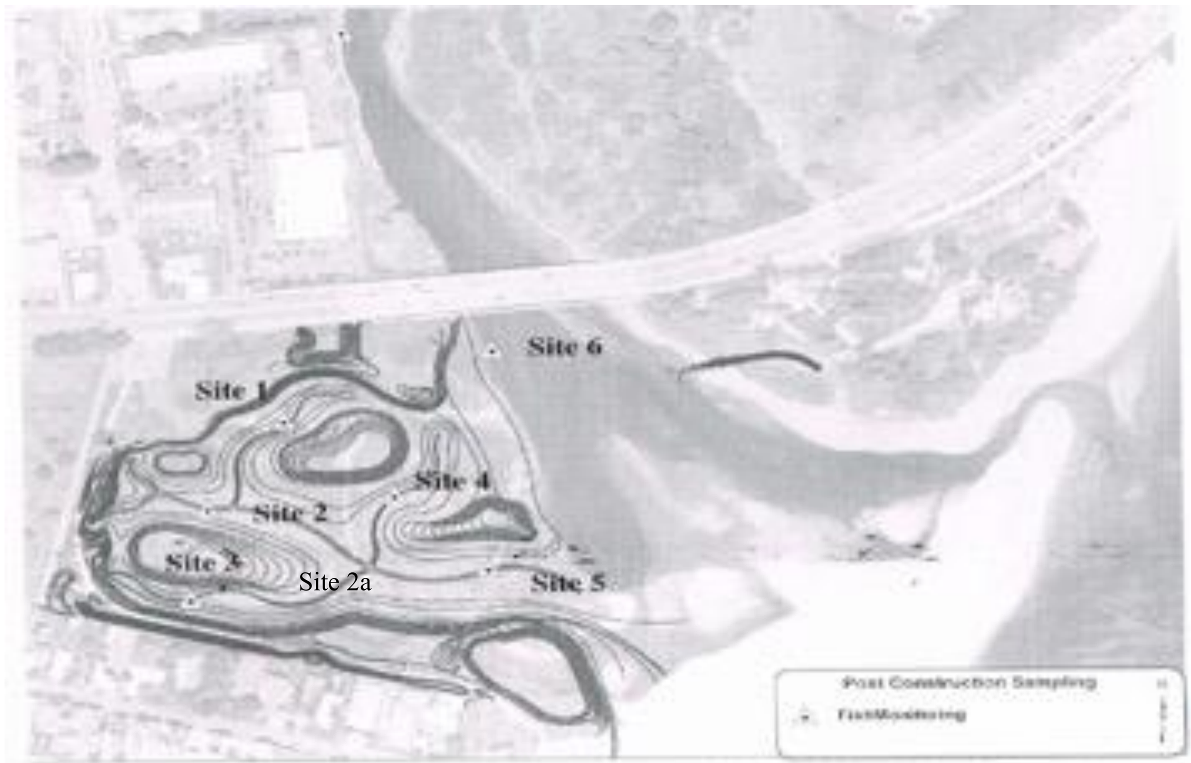


Figure 2.1. Map of Permanent Monitoring Sites, Malibu Lagoon Restoration (established in January 2013 and revised in May 2014

Table 2.2. GPS Coordinates for permanent monitoring sites Malibu Lagoon Restoration (decimal degrees).

Site	Latitude	Longitude
1	34.02.032	-118.41.054
2	34.01.983	-118.41.084
2a	34.01.970	-118.41.058
3	34.01.958	-118.41.086
4 (not sampled)	34.01.947	-118.40.963
5	34.02.000	-118.41.006
6	34.02.049	-118.40.974

Blocking Net Sampling Method for Permanent Stations

A meter tape was laid out along the shoreline at the water's edge extending for 10 meters. Two 10 m x 2 m blocking nets were pulled out perpendicular from the shore. Then the two nets were pulled together to form a triangle, trapping any fish inside. Two teams with 2 m x 1 m seines walked carefully to the apex of the triangle and pulled from the shore to the apex, from the apex towards the shore and randomly throughout the blocked area. Seines were beached at the water's edge and all contents examined. All fish were moved into buckets of clean, cold water standing by each net. Types of algae were noted. Fish were identified, photographed and Fork Length measured, then they were released outside of the blocked area. Seining continued until no fish were caught in three consecutive hauls. Number of hauls was recorded along with total numbers and size class of each species.

Spot Survey Sampling Methods for the Main Lagoon
Using 2 m x 1.25 m seines, two teams pulled parallel to shoreline along beach bank, from west to east, as well as parallel to the east bank of the lagoon from just upstream of PCH Bridge to the beach.

2.5. Water Quality and Temperature Monitoring

2.5.1. Water Temperature Monitoring

2.5.1.1. Objective

To document summer water temperature changes, and identify any limitations for spawning, rearing, or growth of resident *O. mykiss*.

2.5.1.2. Methodology

In Arroyo, Malibu and Topanga Creeks, continuously recording thermometers (Stowaway Tidbits-20-70°C) were installed in pools from April-October. The loggers were set to record data at 30-minute intervals. Sites were randomly selected to reflect a subset of canopy cover, substrate, habitat type, depth conditions, and proximity to known seeps or springs both in known fish refugia. Loggers were installed in one-two pools in Arroyo Creek (2009-2019), seasonally in six-eight pools in Malibu Creek (2008-2019), and seasonally in six pools in Topanga Creek (2005-2019).

Data was downloaded monthly during snorkel surveys using Boxcar Pro or HOBOware software and analyzed using Microsoft Excel. Methods are described in further detail in Dagit and Krug (2011). Water and air temperatures were graphed over time for all years and annual mean, maximum and minimum temperatures were assessed and compared (Appendix D). Proportion graphs were made to show the proportion of time a pool was at a certain temperature (Appendix D). We focused the proportion graphs on years that have overlapping data from the hottest time of year (July-October in most cases) since we were most interested in the amount of time *O. mykiss* were exposed to extreme temperatures. If the temperature in a pool was above 23°C for any amount of time, the total amount of time (hours) above 23°C was calculated as well. These data are also found in Appendix D.

In Malibu Creek, a continuously recording Troll 9500 probe measuring dissolved oxygen, temperature, conductivity, pH and pressure was deployed in 2012 by the NPS Santa Monica Mountains National Recreation Area Mediterranean Research Learning Center (NPS) in partnership with California Department of Parks and Recreation and the RCDSMM Steam Team volunteers. The RCDSMM staff maintained and calibrated the instrument at least monthly. Solar panels and batteries provide power. Due to vandalism concerns, the equipment was secured in a locked metal box, and the cable and probe hidden, although it was stolen between Sep 12 and Oct 17, 2012 and replaced with funding from the Los Angeles County Fish and Game Commission. A second Troll 9500 sonde donated in 2012 by California State University Channel Islands (CSUCI) was redeployed on Nov 11, 2012. The probe was encased in a PVC tube and secured to the stream bottom to prevent tampering. The locked metal box was vandalized again in October 2013, but no data was lost. During summer 2016, the pool where the sonde was located dried and it was removed. The dissolved oxygen probe was damaged and funding to provide a replacement was provided by Las Virgenes Municipal Water District. Then in the high flows of winter 2017, the housing and cable were damaged and subsequently repaired. The DO probe failed again in summer 2019 and the sonde was removed and retired since there is no funding for continued maintenance and monitoring. RCDSMM staff and volunteers have uploaded the data monthly to a laptop in the field and maintain the database at the RCDSMM office. A summary of all data is found in Appendix E.

A summary of habitat conditions and temperature monitored locations and dates are summarized below by site (Tables 2.3-5)**.**

2.5.1.3. *Arroyo Creek*

Table 2.3. Habitat characteristics of temperature monitored pools in Arroyo Creek from 2018 snorkel survey data.

Location	Habitat type	Canopy cover (%)	Max depth (cm)	Avg depth (cm)	Shelter value	Substrate
Fish West Bedrock Boulder Pool (1.625 RKM)	Step pool	13	73.5	35	1.5	boulder
Culvert Pool (Water and Air) (2.640 RKM)	Pool DRY	43	80	35.8	1.5	gravel

2.5.1.4. *Malibu Creek*

Table 2.4. Habitat characteristics of temperature monitored pools in Malibu Creek from 2018 snorkel survey data.

Location (distance upstream from ocean)	Habitat type	Canopy cover (%)	Max depth (cm)	Avg depth (cm)	Shelter value	Substrate
Start Pool* (Water and Air) (1.07 RKM)	mid-channel pool	10.6	100	59	1.5	sand
Lunch Pool (1.996 RKM)	mid-channel pool	15.4	185	110	2	sand
Grimmer (2.671 RKM)	mid-channel pool	7	255	158	2	sand
Tufa West (3.322 RKM)	side channel	11	142	73	1.75	boulder
Big Wide (3.579 RKM)	mid-channel pool	8	243	108	2	gravel/sand
West Bedrock (3.714 RKM)	mid-channel pool	10	106	50	1.5	sand
Big Boulder (3.864 RKM)	mid-channel pool	5.5	283	165	2.5	sand

*Start Pool dried completely in August 2016.

2.5.1.5. Topanga Creek

Table 2.5. Habitat characteristics of temperature monitored pools in Topanga Creek from 2018 snorkel survey data.

Location (distance upstream from ocean)	Habitat type	Canopy cover (%)	Max depth (cm)	Avg depth (cm)	Shelter value	Substrate
Topanga Lagoon (0 RKM)	lagoon	9.3	101	66	1.5	sand
Ski Pole Pool+ (Water and Air) (2.0 RKM)	mid-channel pool	38	68	32	1.5	sand
Ken2 Pool*+ (2.6 RKM)	pocket pool	60	90	55	2	sand
Engine Pool (3.5 RKM)	step pool	23	67	44	1.5	boulder
Sycamore Tree* (3.94 RKM)	mid-channel pool	63	54	33	1.25	boulder
Noel Pool* (4.0 RKM)	mid-channel pool	36	200	109	2.5	sand
Josh Pool (4.36 RKM)	deep scour pool	48	208	116	2	sand
Grotto Pool (5.275 RKM)	deep scour pool	11	222	145	2.5	sand

*Ken2 Pool,Sycamore Tree and Noel pools have a documented seep/spring nearby.
+ Ski Pole Pool and Ken2 Pool were disconnected both up and downstream July – Sept 2016.

2.5.2. Flow Monitoring and Storm Events

There is no flow gauge or recording system for Arroyo Sequit. Flow in Malibu Creek was recorded by LA County at the stream gauge above Rindge Dam (F435), and data provided by the county. Flow in Topanga Creek was recorded by a Los Angeles County stream gauge located at the 2.02 mile bridge (F54). This gauge has been intermittently functional during this study period and only records high flows. A summary of flow data is found in Appendix F.

2.5.3. Precipitation Monitoring

Precipitation was measured by Los Angeles County gauges located at the Lechuza Fire Station (Site 352b) in Arroyo Sequit; at the Monte Nido Fire Station upstream of the dam in Malibu Creek (Site 435); and at the Topanga Fire Station (Site 318). A summary of wet spells and annual rainfall is found in Appendix F.

2.6. Macroinvertebrate Monitoring

2.6.1. Objective

To determine the community assemblage, species richness and relative abundance of macro-invertebrates in the Arroyo Sequit, Malibu, and Topanga Creek Watersheds.

2.6.2. Methodology

The California Rapid Bioassessment Procedure (Ode 2007) was used from 2003-2012 in Topanga Creek, and starting in 2013 the SWAMP Bioassessment Procedure (Fetscher et al. 2009) was used. A 1ft^2 kick net sample was collected every 15 m along a 150 m transect, alternating along the way between 25%, 50% and 75% from right bank, for a composite sample of 11 kicks. All samples were preserved either in 90% ethanol and were archived at the RCDSMM until processed.

Annual stream survey samples were also collected from nearby creeks, such as Arroyo Sequit (AS19), Cold Creek (CC2, CC3, CC11), Solstice (SC14), and Malibu (MC1, MC15) from 2000-2014 by the Heal the Bay (HTB) Stream Team and processed by Sustainable Land Stewards International (SLSI). In 2003 BMI samples were collected using the California Rapid Bioassessment Protocol; from 2005-2007, sampling was conducted using the US EPA targeted riffle composite (TRC) procedure (Ode 2007), and starting in 2008, sampling was conducted using the Reach Wide Benthos (RWB) of the SWAMP protocol (Ode 2007). All data from this effort is published in Task 3 (Dagit et al. 2018b). The 2019 samples from Topanga Creek have not yet been analyzed.

2.6.2.1. Sample Processing and Analysis

Each sample was strained and, in most cases, processed entirely. Using a dissecting microscope, organisms were sorted and identified to the lowest practical taxon (family, genus, or species level) when possible. Identifications were confirmed using the California Aquatic Bioassessment Laboratory (ABL). Processors also referred to Heal the Bay's benthic macroinvertebrate data from other nearby creeks within the Santa Monica Bay 2000-2016. A second processor and/or supervisor checked a subsample of each sample to ensure completeness, and accuracy of identification. When identification was not possible, photographs were sent to Dan Pickard at CDFW ABL or identified to the lowest taxonomic level possible and recorded as non-distinct (n.d.) within that taxon. Data was recorded on a standardized processing sheet and transferred into an Excel database. Processing was evaluated for overall error by randomly selecting a subset of 10% of all samples having more than 500 individuals by assigning a random number to each sample. Ten percent of those samples' vials were then re-identified by another processor, and identification outcomes were compared. This resulted in an overall error of <10% to be applied to BMI data reporting.

Processed samples were assessed according to the Southern California Coastal Index of Biotic Integrity (Ode et al. 2005). For this index, seven metrics are used to assess ecosystem health: EPT taxa, Coleoptera richness, predator taxa richness, % non-insect taxa, % tolerant taxa

(TV>7), % intolerant individuals (TV<3), and % collector-gatherer + collector-filterer (CG+CF) individuals. Information regarding tolerance values and functional feeding groups was obtained on CAMLnet (Ode 2003). These seven metrics were scored and adjusted to a 100-point scale according to Ode et al. (2005) in order to provide a single measure of overall ecosystem health (Table 2.6). As this metric was designed for sub-samples of 500 individuals, samples with less than 500 are denoted in tables.

Table 2.6. SCC-IBI metric scoring as adapted from Ode et al. (2005).

Total IBI score	Score of biotic integrity
0-20	Very Poor
21-40	Poor
41-60	Fair
61-80	Good
81-100	Very Good

2.7. Invasive Species Monitoring

Monitoring for invasive species was a part of every field effort, including snorkel surveys, redd surveys and trapping events. Although exact numbers were not often collected, presence in a given location was noted. New Zealand Mud Snails have still not colonized Arroyo Sequit but were observed in a 250 m reach of Topanga Creek from July-November 2016, but not since 2017. Since this invasive exotic was established in Malibu Creek in 2006, the RCDSMM has implemented decontamination procedures in order to prevent spread. In addition to using different wetsuits, shoes, and backpacks, any gear used in Malibu Creek or the infected reach in Topanga was cleaned well and decontaminated by freezing for at least 72 hours. A full discussion of decontamination procedures is found in Appendix H QA/QC Plan.

2.8. Data Management and Analysis

2.8.1. Objective

To develop a Microsoft Excel database for snorkel survey and temperature data, as well as a relational database and an integrated Geographic Information System (GIS) incorporating all relevant themes to create a comprehensive tool for watershed assessment and *O. mykiss* population monitoring.

2.8.2. Snorkel Survey Methodology

Field data was collected using bound Rite in the Rain field notebooks and printed data sheets. At the end of each field day, all pages were reviewed for completeness and then photocopied. Data was entered into an Excel spreadsheet by date, location identification (along the reach), habitat type, estimated maximum and average depth, percent canopy cover, dominant substrate, percent algal cover, shelter value and instream cover, followed by the number and size class of any *O. mykiss* observed. Data was entered into an Excel spreadsheet with two levels of review to ensure accuracy. First, when entering the initial data, the supervisor compared the entries to the field data sheet to confirm completeness and accuracy. The second level of review was performed by RCDSMM supervisors. The collection, processing, and entry of all data were performed in accordance with the Santa Monica Bay Quality Assurance/Quality Control Plan guidelines described in Appendix H.

Abundance of *O. mykiss* was estimated based on the total number of individuals of both juveniles (<100 mm FL), intermediate (100-250 mm FL), and adults (>250 mm FL) observed during snorkel surveys. Annual abundance was compared by plotting total counts during each survey from 2001 to 2019 for a 3.6 rkm stretch of Topanga Creek common to all surveys (1.7-5.3 rkm). However, within each survey the distance of Topanga Creek observed varied, based on environmental or safety conditions (e.g., dry or excessively turbid reaches were not surveyed).

The data collected in Arroyo Sequit and Malibu Creeks during this monitoring period (May 2017 - November 2019) built upon that assembled since 2005, and in the Topanga Creek Watershed since 2001, which was presented in previous reports. This data is archived at the RCDSMM office, and metadata information is provided on-line at the CERES web site (www.ceres.ca.gov) for data prior to 2011 and CDFW BIOS METADATA Site from 2011-present. Precipitation and stream gauge data were provided courtesy of the Los Angeles County Department of Public Works.

2.8.3. Redd Data Management

A template was provided by CDFW Coastal Monitoring Program that is based on the field data collected using the NMFS Redd Survey Protocol (2012) which was updated by CDFW (2017). Data was entered at the end of each field day and then compiled at the end of the spawning season. Data for the year was provided to CDFW.

2.8.4. Genetic Analysis Data Management

Any tissue samples collected were immediately sent to Dr. Carlos Garza. All pertinent data (size, location, etc.) was maintained on an excel spreadsheet at the RCDSMM and sent to NMFS and CDFW. As samples were processed, additional data management coordinated the NMFS and RCD identifications so further analysis could be accomplished.

2.8.5. Instream Mapping Data Management

As was done in previous reports, the summary data tables and graphs were organized according to the Level IV ranking, except we start in each case with the lagoon. This allows for easier comparison of habitat types over time. The CDFG style tables follow standards set in Flosi and Reynolds (1994: updated 2010). Habitat characteristics summarized included length, width, depth, shelter value, substrate, and habitat type.

Following data input from field forms into the EXCEL database, analysis of the different habitat characteristics was completed. Habitat type and length data was also imported into ArcGIS. This data was applied to stream layers in order to visualize habitat type at every length of the stream. Maps were then generated in order to compare habitat type distribution over time for each creek.

2.8.6. Lagoon/Ocean Interface Monitoring Data Management

Observations were entered into the field notebooks and then into the table for lagoon openings. Photographs were taken to document condition and labeled in folders by site and date. Seining notes were copied from field notes into an EXCEL database.

2.8.7. Water Quality and Water Temperature Monitoring

Hobos were uploaded monthly to the shuttles and downloaded to the computer using Hoboware software. The first level of QA/QC was done by reviewing the hobo file graphs for each pool to check that each tidbit was functioning properly. Hobo files were converted to .csv files, imported into Excel and the raw data for each site was pasted into the appropriate excel file. The data for each site was then pasted into an excel file where outliers and any erroneous data were removed for graphing and later analysis.

Water temperatures were graphed over time for all years and annual maximum, average, and minimum temperatures were compiled and compared. Data was pooled to obtain average maximum, mean, and minimum temperatures for the creek as a whole for each year in order to identify if there have been any significant changes over time in response to decreased precipitation levels associated with drought (2012 – 2018). To determine whether average mean, minimum or maximum temperatures varied across years for each site, a one-way ANOVA was performed. If there was a significant difference ($p<0.05$), a two-sample t-test was used to identify significant differences by comparing one year to another. Two-sample t-tests were also used to compare pools within each site, and to compare Malibu Creek with Topanga Creek. As the drought ended with above normal rainfall in 2019 no additional analyses were done.

To examine the frequency of potentially critical water temperatures (those greater than 23˚C) we counted the number of occurrences of temperatures greater than 23˚C and greater than 25˚C during the period of logging in each pool for each year. To correct for differences in deployment periods and duration, the number of occurrences were standardized to a sample size of 100 logging days.

To examine the relationship between average maximum and minimum temperature, precipitation, habitat characteristics, and *O. mykiss* abundance and distribution for each site (Malibu and Topanga) during the drought from 2011-2018, a Pearson correlation was performed. For any pair of variables with a correlation coefficient (r) > 0.20 or < -0.02, a regression analysis was performed to determine the strength of the relationship and its statistical significance. A result was considered statistically significant when the p-value was < 0.05. The relationship between precipitation, potentially lethal temperatures and their potential effect on *O. mykiss* abundance and distribution was addressed with correlation and regression analyses as described previously.

The USEPA (2003) uses the calculation of Seven-Day Average Daily Maximum (7-DADM) for the application of total maximum daily loads (TMDLS) in relation to temperature. 7-DADM is the highest average temperature recorded in any period of seven sequential days in a year. 7-

DADM values were calculated for four pools in Malibu Creek and four pools in Topanga Creek pools in 2005-2019.

2.8.8. Quality Assurance Quality Control Plan

The design, collection, processing, and entry of all data were performed in accordance with the Quality Assurance/Quality Control Plan guidelines described in Appendix H.

2.8.9. CDFW Coastal Monitoring Program

We are still awaiting direction from CDFW on how the snorkel survey data will be incorporated into the ACCESS database for CMP. All red survey data has been uploaded to CDFW.

2.8.10. BIOS Metadata

In compliance with CDFW requirements, an updated metadata summary has been provided using the BIOS format. This information (abstract, purpose, date, point of contact, data type, field definitions, access constraint, use constraints, data distribution, progress, and update frequency) is provided in Appendix G.

3. RESULTS

Results are presented by watershed in alphabetical order.

3.1. ARROYO SEQUIT CREEK

3.1.1. *O. mykiss* Population Assessment

Two main refugia pools have been the only locations (2.47 rkm Old Trout Pool and 2.64 rkm Culvert Pool) where *O. mykiss* have been observed in the past but with restored connectivity in winter 2017, two anadromous *O. mykiss* were observed in another newly restored pool slightly upstream of the 1.625 rkm Fish West Bedrock Pool (Table 3.1) . In 2014, a single resident fish was observed in February, but there was no connection to the ocean and the fish was never observed again. We suspect that it may have been poached. The main 2.64 rkm Culvert Pool dried up in early summer 2014 for the first time since monitoring began in 2005 and it remained dry for much of 2015-2018. During 2015-2016 no fish were observed at all. Though fully connected in the winter of 2017 which allowed access for two anadromous steelhead adults, Arroyo Sequit dried down by the summer months and the culvert pool subsequently dried down by the end of the year. The last anadromous adult was relocated from that pool to Topanga Creek in November 2017. The year 2018 was a below average water year so the reach remained dry with minimal surface water in the 1.625 rkm Fish West Bedrock Pool and no water in the 2.64 rkm Culvert Pool. Following the Woolsey Fire (2018), the winter rains carried a significant sediment load into the lower watershed, resulting in minimal passage opportunities as surface flows were extremely shallow. The pool never recovered in 2019.

Table 3.1. Summary of all sightings of trout Arroyo Sequit 2005-2019.

YEAR	Average Total Juvenile <100mm	Average Total Intermediate 100-250mm	Average Total Adult >250mm	Average Total	Size Range mm	Smolts	Anadromous Adults	WY Rainfall in**
2004*	0	0	0	0 (n=1)	0	0	0	
2005	0	0	3	2 (n=7)	300-355	0	0	22.86
2006	0	0	0	0 (n=12)	0	0	0	13.26
2007	0	0	0	0 (n=6)	0	0	0	13.26
2008	0	0	0	0 (n=0)	0	0	0	12.44
2009	0	0	0	0 (n=2)	0	0	0	13.46
2010	0	0	0	0 (n=4)	0	0	0	21.65
2011	0	0	0	0 (n=12)	0	0	0	28.19
2012	0	0	0	0 (n=12)	0	0	0	14.83
2013	0	0	0	0 (n=11)	0	0	0	8.99
2014	0	0	1	1 (n=12)	400	0	1	5.87
2015	0	0	0	0 (n=12)	0	0	0	17.5
2016	0	0	0	0 (n=13)	0	0	0	9.09
2017	0	0	2	1 (n=4)	250-500	0	2	29.02
2018	0	0	0	0 (n=11)	0	0	0	10.94
2019	0	0	0	0 (n=5)	0	0	0	23.66

*Snorkel data only August 2004
**Rain data courtesy of Los Angeles County, Lechusa Station; Rain data is water year

3.1.2. Spawning and Redd Survey Data

No spawning or redds were observed in Arroyo Sequit Creek from 2005 - 2019. Spawning gravel was present prior to the Woolsey Fire (2018) and embededness ranged from 10-50%, depending on season. Post-fire there is little to no suitable spawning gravel present in the survey reach.

No young of the year have been observed in this creek.

3.1.3. Genetic Information

Due to a small number of samples (Table 3.2), it was not possible to further examine the role of Arroyo Sequit in the regional context. It was not clear if both fish observed in 2017 were anadromous or not and it was possible that a resident fish from upstream migrated down to the culvert pool, although this fish did exhibit anadromous coloration. Figure 3.1 shows photographs of both individuals.

Table 3.2. Summary of genetic tissue samples from Arroyo Sequit.

Inferred Population 1	Proportional Assign	NMFS_ID	COLLECTION DATE	Collect Month	Collect Year	Scale.Age. RCDSMM	Est age	Est_ cohort	LENGTH (mm)	Genetic sex
NA	NA	M043922	8/27/1997	Aug	1997	NA	NA	NA	NA	NA
NA	NA	M043923	8/27/1997	Aug	1997	NA	NA	NA	NA	Female
NA	NA	M043924	8/27/1997	Aug	1997	NA	NA	NA	NA	Female
NA	NA	M043925	8/27/1997	Aug	1997	NA	NA	NA	NA	Female
NA	NA	M102212	9/12/2017	Sept	2017	5+	5	2012	360	Female
SYnzSCrz	0.844567	M103709	11/21/2017	Nov	2017	NA	4	2013	350	Male

It was only possible to analyze one tissue samples collected in Arroyo Sequit and it was not possible to report heterozygosity for Arroyo Sequit Creek given the limited sample size.

Figure 3.1. Adult *O. mykiss* observed in Arroyo Sequit Creek in 2017.

3.1.4. Instream Habitat Mapping

Surveys were conducted in 2019 on April 15, 16, and 18. During this time the length of the stream starting at the PCH Bridge over Arroyo Sequit lagoon (34.04544, -118.934504) to 500 m past the culvert at Mullholand Hwy (34.06874, -118.93063) were mapped.

Prior to 2019, Arroyo Sequit could not be mapped due to drought conditions, as the creek was mostly dry. Following the Woolsey Fire (2018) and the 2019 rains, the creek had enough flow to allow for a mapping event which provides a baseline for asssessing post-fire recovery.

The habitat consisted mostly of riffles with little to no canopy or shelter as well as increased sedimentation due to rain events, as the entire watershed was serverly burned in the Woosley Fire (2018). The overall distribution of habitat types indicates high gradient riffles (33.93%) and step runs (28.57%) are the dominant habitat types, with no instances of main channel pools and only few scour pools (7.14%) or step pools (3.57%). Analysis of habitat type by length shows a dominance of shallower habitat types such as riffles (76.05%) and step runs (18.7%). By length, only 1.33% of the stream was composed of scour pools (Figure 3.2).

Analysis of width dimensions showed that the maximum width was 8 m at a boulder formed scour pool and the minimum width was 1 m at a root-wad formed scour pool. The average width of the stream was 2.7 m. The dominant substrates for Arroyo Sequit were gravel and sand, which is likely the result of increased sedimentation following the Woolsey Fire and increased 2019 rain events.

Overall, canopy cover averaged 13% for the study area. The lack of canopy can be attributed to the Woolsey Fire, as many trees were burned. The maximum depth was 55.5 cm at a step pool, and the minimum depth was 5 cm at a low gradient riffle. The average depth was 40.3 cm. Mean shelter value did not exceed 1.5 (fair) with the average being 1 (poor). Pool habitats such as scour pools and step pools had the highest shelter values while the shallower habitats such as riffles had the lowest.

Summaries and further analysis of the data can be found in Appendix E.

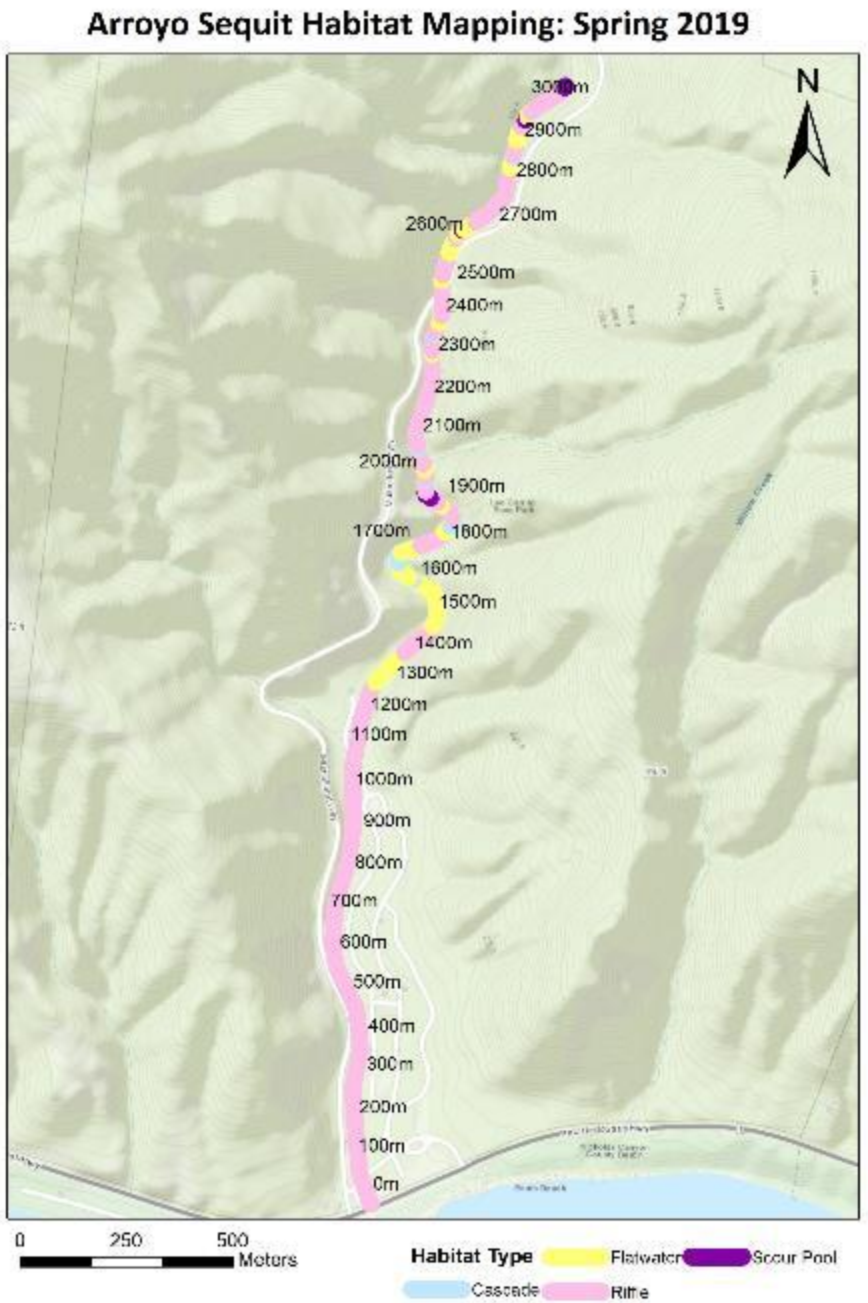


Figure 3.2. Summary of habitat type distributions for Arroyo Sequit Creek (2019).

3.1.5. Lagoon/Ocean Interface Monitoring

The sand berm at the mouth of Arroyo Sequit Creek enters the ocean at a cove protected by rock outcrops. The creek was connected to the ocean for brief time windows associated with rain events, although the berm quickly reformed, limiting migration opportunities. Most of the time the creek was connected for fewer than five days each year (Table 3.3). The rains during the winter 2017 provided almost continuous connectivity at the ocean, especially during high tides from January to April, but the flow levels extending from the lagoon upstream were extremely variable and had become almost impassable for much of the creek by March 2017. No connection was made during 2018. Following the Woolsey Fire (2018), the rains in 2019 provided ocean connection but no passage opportunities as the sediment built up in the lagoon and throughout the creek restricted depth to less than 20 cm for much of the time, with almost no pool habitat.

The rain gauge with information relevant to the Arroyo Sequit area is located at the Lechuza Fire Patrol Station (LACO 352b) and maintained by Los Angeles County Department of Public Works.

Table 3.3. Lagoon Openings and Passage Opportunities at Arroyo Sequit Creek. Data from Lechuza Fire Patrol Station (Site 454).

Water Year	Rainfall Total	Dates Berm Open	Estimated Number of Passable Days
2004-2005	22.86	January – February	5-10
2005-2006	13.26	17-28 February, 1 March- 10 April, 18-22 May	<5
2006-2007	13.26	Only with storms	<5
2007-2008	21.32	December – February	<5
2008-2009	13.46	No data	ND
2009-2010	21.65	December and March	~20
2010-2011	29.02	January – May	~5-10
2011- 2012	8.99	March	<5
2012-2013	5.87	Storm event only	<5
2013-2014	17.5	Storm event only	<5
2015-2016	9.09	Storm event only	<5
2016-2017	29.02	January – April, June	~50
2017-2018	10.94	Disconnected	0
2018-2019	25.16	February-April	0 (connected for ~ 50)

The natural hydrologic regime remains fairly intact, which resulted in the creek flowing subsurface in several reaches from early spring through winter prior to the Woolsey Fire (2018). Several important refugia pools formerly retained water throughout the year, refreshed by seeps. The heavy sedimentation following the fire and drought have resulted in minimal surface flow in 2019. Photographs illustrating the lagoon conditions over time are found in Appendix C.

3.A.3 Seine Results

For most of the study period, seining was not possible as the lagoon was either too shallow and no fish were observed, or it was dry.

However, seining was conducted on 27 January 2017, although no fish were observed. On 23 June 2017 there was a storm event that resulted in a brief period of ocean connection. Spot seines were pulled and we captured approximately 300 juvenile topsmelt (*Atheriniops affinis*) and California killifish (*Fundulus parvipinnis*) (Figure 3.3). As the water dried down, these fish were lost. No tidewater gobies were observed.

Figure 3.3. Topsmelt and killifish captured in Arroyo Sequit Lagoon June 2017.

3.1.6. Water Temperature, Flow and Water Quality Monitoring

3.1.6.1. Water Temperature Monitoring

A Stowaway TIDBIT continuously recording thermometer was deployed in the 2.64 rkm Culvert Pool under Mulholland Highway (Table 3.4). The pool was fairly stable until summer 2014 when it completely dried up. As a result, we moved the TIDBIT to the single remaining pool (1.62 rkm Fish West Bedrock Boulder Pool) in the creek located upstream from the check dam for summer of 2014-2019. Overall, annual temperatures did not exceed 23 ˚C in 2.64 rkm Culvert Pool 2009-2013, and generally ranged 16 ˚C to 22 ˚C during the hottest period of August through September (Figures 3.4-3.7). In 1.62 rkm Fish Bedrock Pool in 2014-2016, temperatures neared 25˚C by early summer (Figures 3.4, 3.8). Between April and August of 2019, a total of 65 days were above 23 ˚C in Fish Bedrock Pool (Figure 3.7). Five of these days contained periods of four hours or less where temperatures reached 25 ˚C. These temperature results show 2019 as having the warmest water temperatures in Arroyo Sequit since 2014 (Figure 3.8). Air temperatures in Arroyo Sequit also appeared to have increased from 2014-2018 (Figure 3.9).

Table 3.4. Summary of temperature monitored locations and dates in Arroyo Creek, 2009-2019.

Pool	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fish West Bedrock Boulder Pool (Water) 1.62 rkm	ND	ND	ND	ND	ND	*May 07- 13 Nov	ND	04 April-31 Oct	15 April – 9 Nov	5 Mar – 15 Oct	4 Apr – 6 Nov
Fish West Bedrock Boulder Pool (Air) 1.62 rkm	ND	ND	ND	ND	ND	ND	ND	04 April-31 Oct	ND	ND	ND
Culvert Pool (Water) 2.64 rkm	27 Jul-19 Oct	ND	12 Apr-09 Nov	13 Mar-16 Nov	13 Apr-07 Nov	*03 Apr-07 May	08 Apr-	DRY	15 Apr – 9 Nov	5 Mar – 15 Oct	ND

Pool	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Culvert Pool (Air) 2.64 rkm	ND	ND	ND	13 Mar-16 Nov	13 Apr-07 Nov	03 Apr-13 Nov	08 Apr-	DRY	15 Apr – 9 Nov	5 Mar – 15 Oct	ND

*5/7/14 - water hobo moved to fish west bedrock boulder pool because culvert pool was completely dry
2016-water and air hobos placed at FWBBP (culvert pool dry at beginning of season)

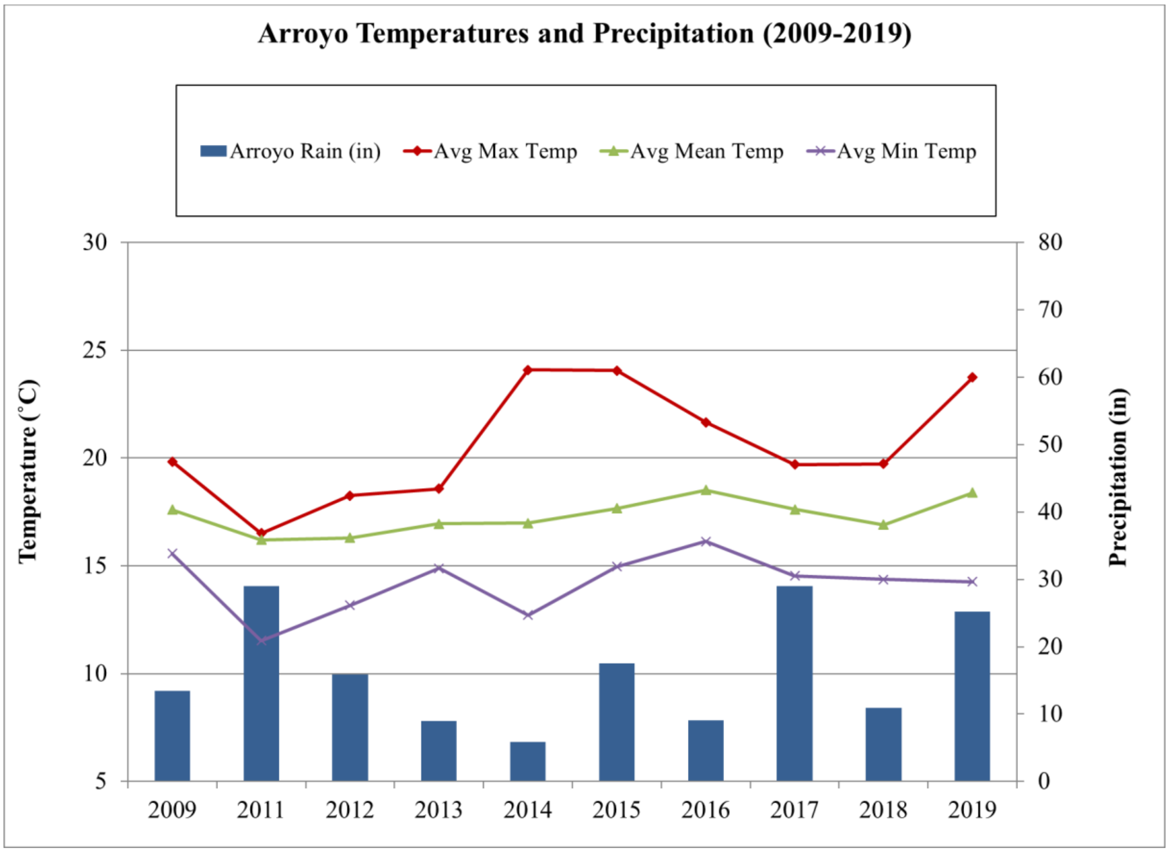


Figure 3.4. Arroyo Sequit water temperatures (Culvert Pool) and rainfall (2009-2019). Starting in 2014 the logger was placed in FWBB (Fish West Bedrock Boulder Pool) due to Culvert Pool being dry.

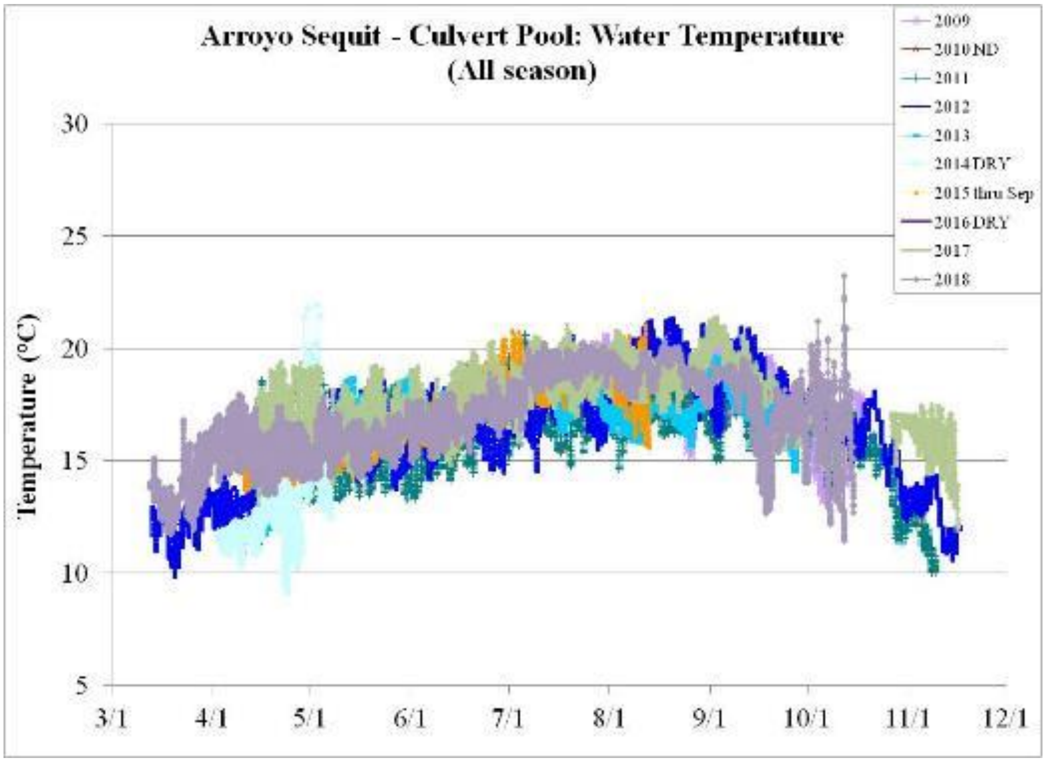


Figure 3.5. Water Temperature in the Culvert Pool, Arroyo Sequit Creek.
*2014- no data shown for 2014 because on 5/7/14 the water hobo tidbit was moved to 1.62 rkm Fish West Bedrock Boulder Pool because Culvert Pool was completely dry. The air hobo remained at the culvert pool all 2014 season.

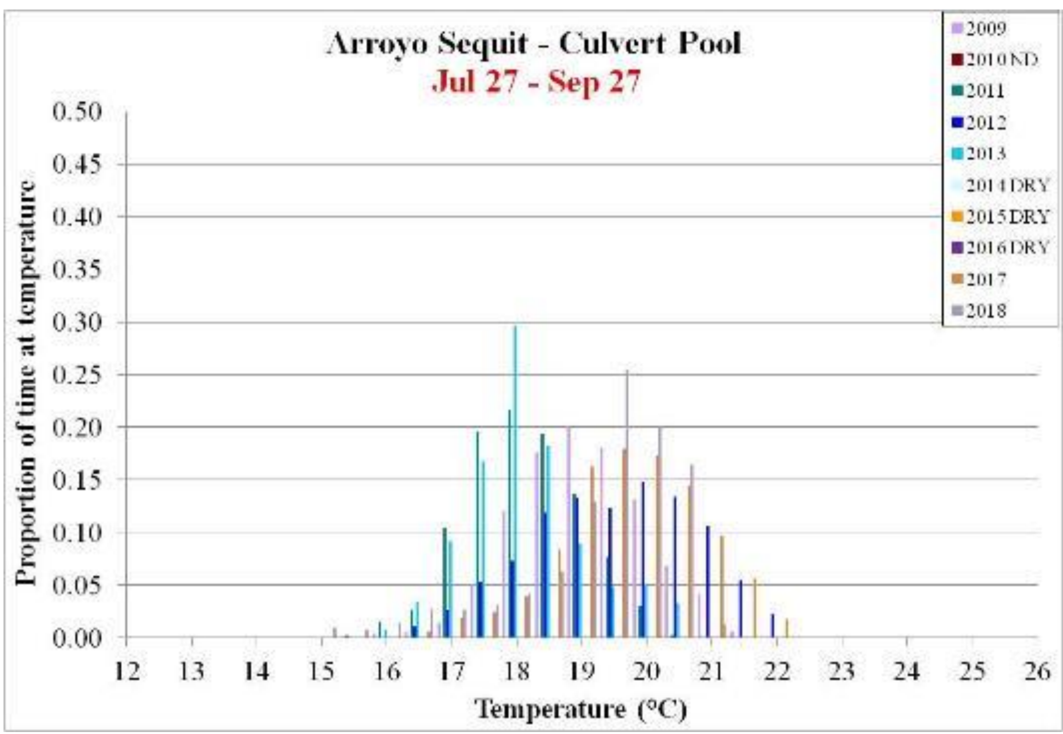


Figure 3.6. Proportion of time at each temperature for the hottest months from August through September. *2014 data not continuous - not included.

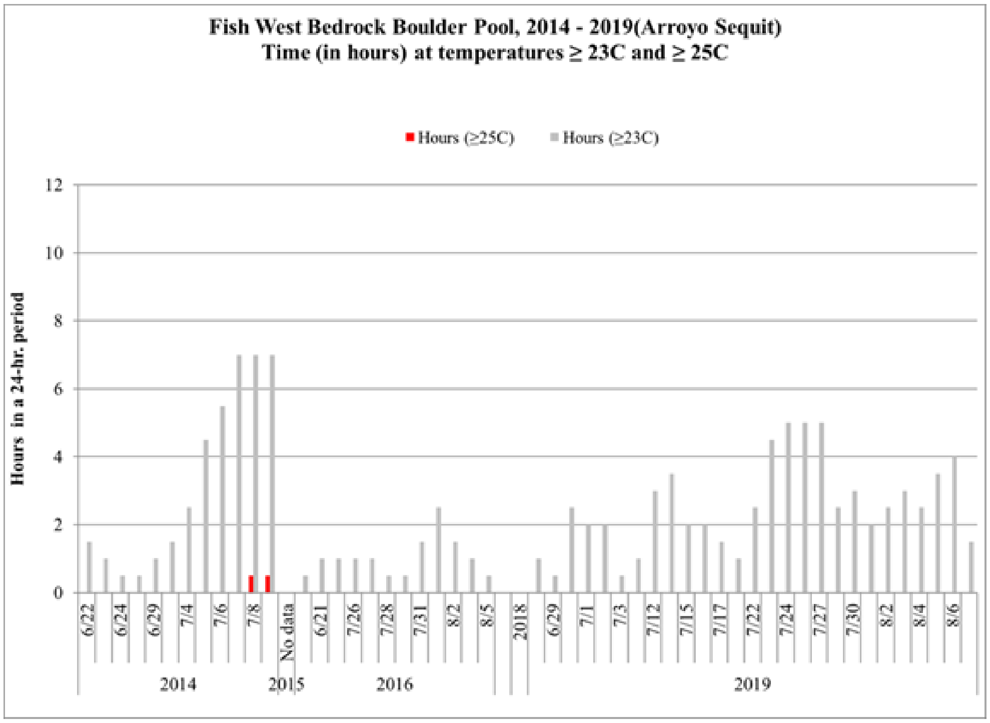


Figure 3.7. Water Temperature in the Fish West Bedrock Boulder Pool, above check dam, Arroyo Sequit Creek. (On 5/7/14 the water hobo tidbit was moved from Culvert Pool to Fish West Bedrock Boulder Pool because Culvert Pool was dry.)

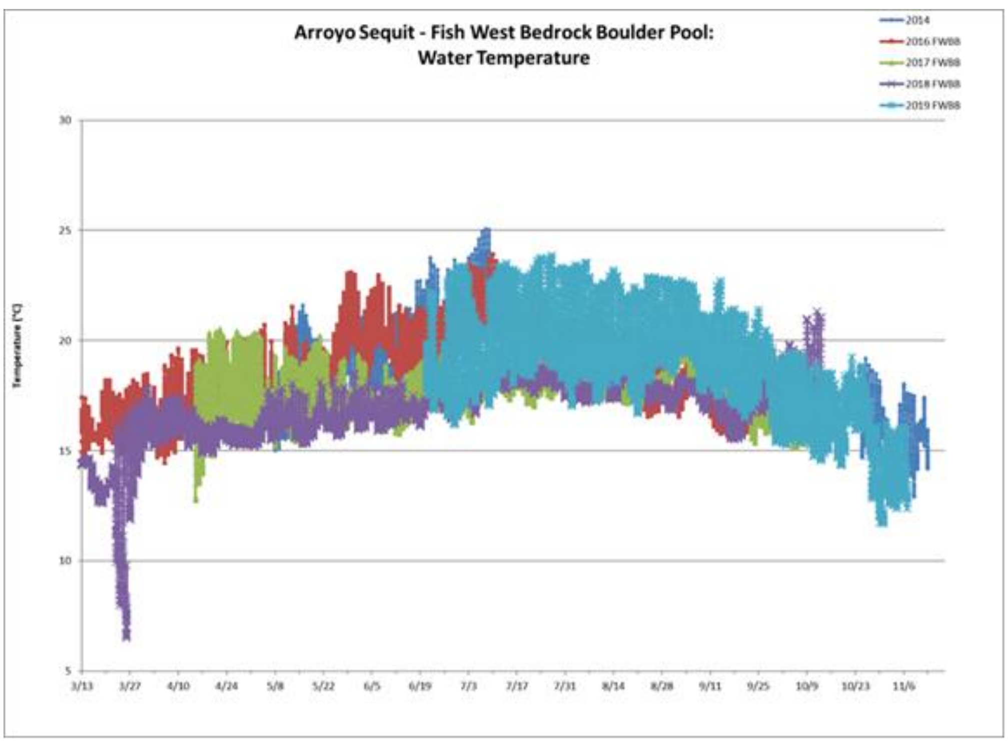


Figure 3.8. Water temperature in Fish West Bedrock Boulder Pool, Arroyo Sequit Creek from 2014-2019.

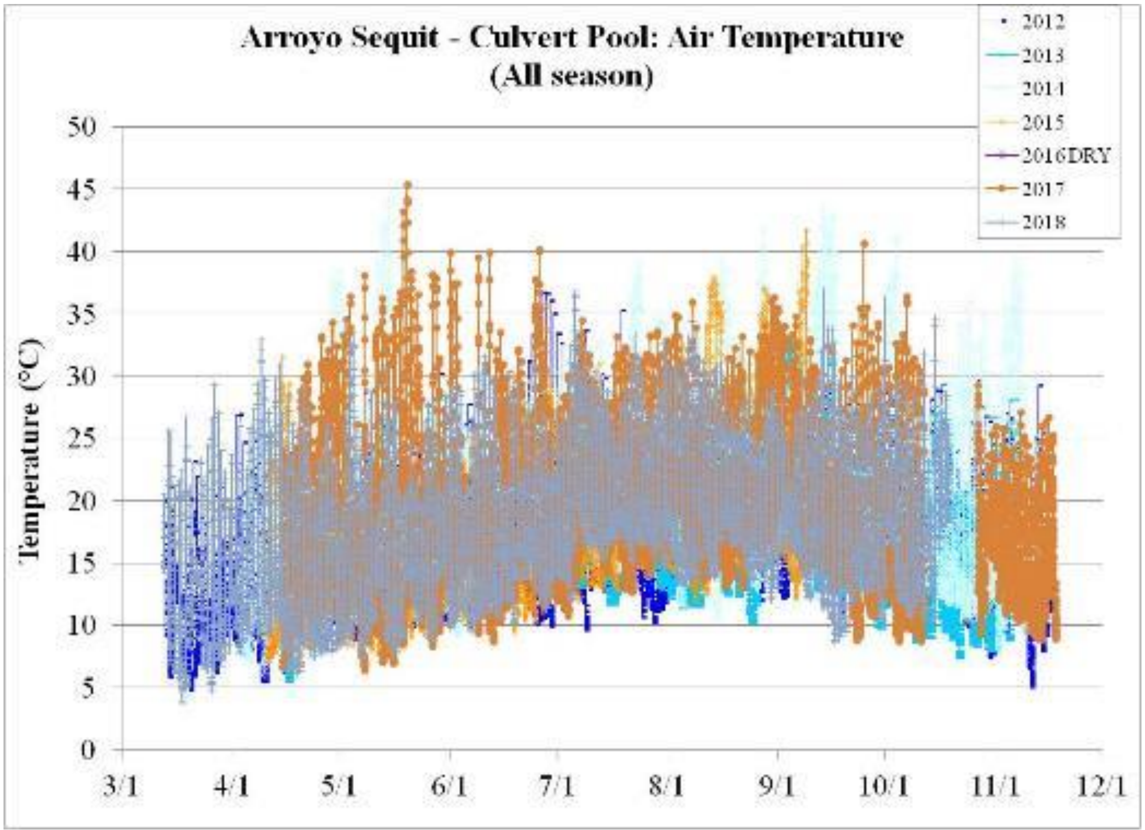


Figure 3.9. Air temperatures at the Culvert Pool 2012-2018.

3.1.6.2. *Precipitation and Flow*

There are no flow measurements available for Arroyo Sequit Creek. Rain data is collected at the Lechuza Station by Los Angeles County and is summarized in Appendix F.

3.1.6.3. *Water Quality*

Water quality parameters (dissolved oxygen, temperature, nitrates, nitrites, ammonia and orthophosphate) were recorded by the Heal the Bay Stream Team using monthly grab samples until 2016 (Table 3.5 and 3.6). Samples were collected at AS19, located near the 2.64 rkm Culvert Pool under Mulholland Highway. There is no further water quality data available for this system.

Table 3.5. Water Quality summary 2011-2014 Courtesy of Heal The Bay.

Variable	Average Value	Highest value	Lowest value
Dissolved oxygen (mg/l)	8.06	10.38	3.10
Turbidity (NTU)	0.73	7.83	0
Conductivity (uS)	1030	1542	773
Nitrates (ppt)	0.04	0.86	0.00
Phosphates (ppt)	0.14	0.39	0.00
Ammonia (ppt)	0.08	1.12	0.00

Table 3.6. Water Quality summary AS19 2015-2016 Courtesy of Heal The Bay.

Variable	Average Value	Highest Value	Lowest Value
Water Temperature °C	15.85	19.2	11.35
Dissolved oxygen (mg/l)	7.39	9.70	6.45
Turbidity (NTU)	0.04	0.08	0
Conductivity (uS)	1217	1453	1038
Nitrates (ppt)	0.04	0.20	0
Phosphates (ppt)	0.12	0.02	0

3.1.7. Benthic Macroinvertebrates

Macroinvertebrate sampling was conducted by the Heal the Bay Stream Team in Spring 2011-2016. Using the metrics developed by the Index of Biological Integrity for the Santa Monica Mountains (Ode et. al. 2005), Arroyo Sequit ranked Good in 2011, Fair in 2012, Poor in 2013 through 2016 during the drought. No data has been collected since 2016.

3.1.8. Invasive Species Monitoring

To date, no invasive aquatic species have been detected in Arroyo Sequit.

3.2. MALIBU CREEK

3.2.1. *O. mykiss* Population Assessment

Figure 3.10 summarizes the abundance of *O. mykiss* observed in Malibu Creek between June 2005 and November 2019. Data was not collected between November 2008 and June 2009 due to a suspension of funding. Between January 2015- April 2017, we observed as few as one individual in December 2016 and March 2017, to a high of 84 individuals, mostly young of the year, in April 2015 (Table 3.7). Overall abundance has declined steadily since 2013. A single anadromous adult was observed in March 2017, but this gravid female died with 18 mature eggs. In 2018 a single adult (not possible to determine if anadromous) was observed. No *O. mykiss* have been observed in 2019.

Visiblity is extremely variable in Malibu Creek. Both flow and algal density affect the turbidity levels. Although every effort is made to be consistent with level of diver effort and skill, these factors can impact probablity of detection and abundance accuracy.

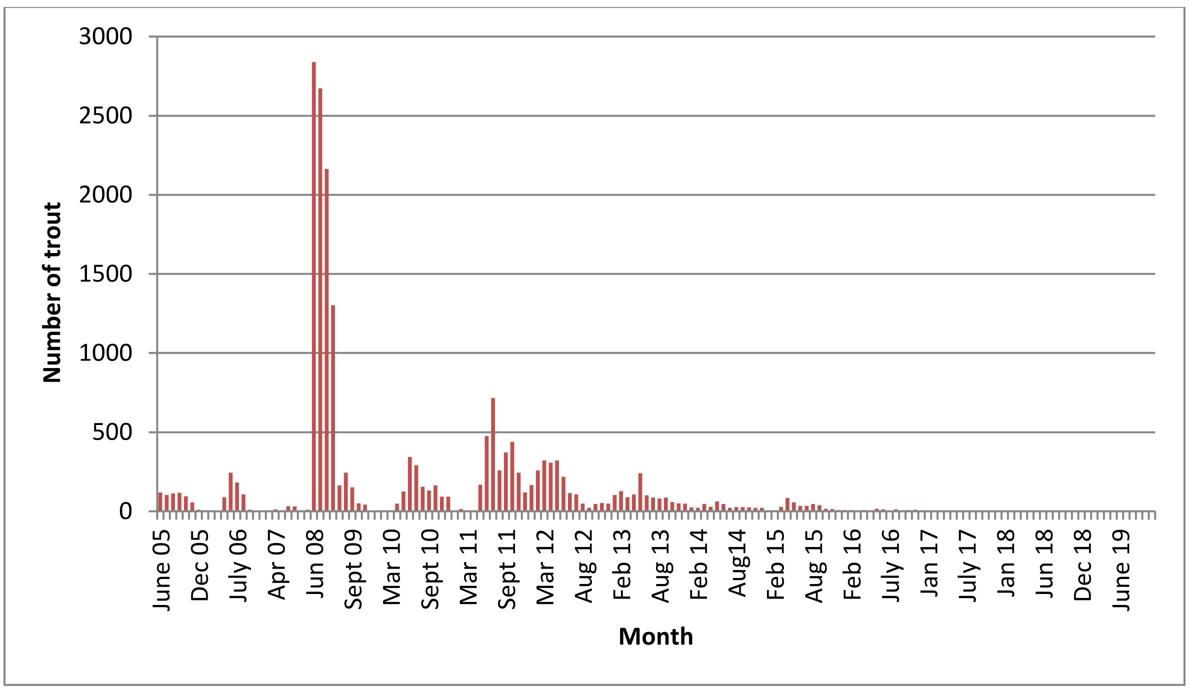


Figure 3.10. Total *O. mykiss* observed in Malibu Creek 2005-November 2019.

Table 3.7. Average number of *O. mykiss* observed per month by size class in Malibu Creek 2005-2019 (n=# survey months).

YEAR	Average Total Juvenile <100mm	Average Total Intermediate 100-250mm	Average Total Adult >250mm	Average Total of fish observed	Range mm	Average Smolts	Anadro-mous Adults	WY Rainfall in**
2004*	217	6	7	34 (n=1)	101-355	0	0	22.86
2005	40	31	16	12 (n=7)	101-432	0	0	53
2006	23	36	21	10 (n=8)	101-432	0	1	13.26
2007	1	5	6	2 (n=8)	101-600	0	2	19.72
2008	1819	419	7	561 (n=4)	76-711	0	4	14.35
2009	10	113	7	26 (n=5)	76-508	0	1	24.68
2010	73	77	10	18 (n=9)	51-432	0	2	22.29
2011	186	86	9	28 (n=10)	56-610	0	2	24.37
2012	47	98	11	12 (n=13)	101-660	2	3	15.87
2013	42	46	11	8 (n=12)	56-610	3	3	8.62
2014	8	16	7	3 (n=12)	25-864	2	5	6.37
2015	15	13	4	3 (n=12)	25-660	0	3	16.06
2016	0	3	4	1 (n=12)	76-813	0	2	9.84
2017	0	3	3	1 (n=12)	228-584	0	1	24.8
2018	0	0	1	0 (n=12)	305	0	0	10.63
2019	0	0	0	0 (n=12)	0	0	0	27.17

*Snorkel data only September 2004
**Rain data courtesy of Los Angeles County, Malibu; Rain data is water year

3.2.1.1. Distribution

The distribution of *O.mykiss* throughout the creek varied seasonally (Figure 3.11). When the numbers of fish observed increased, the number of locations where they were found also increased. Since there is no habitat mapping data before Fall 2017, it was difficult to assign specific locations to the runs, riffles or step pools where fish were observed, although we have attempted to use GPS coordinates in order to estimate river kilometers. Several larger, stable pools were mapped and named during the study and these names are used as references to compare numbers of fish present in a given location over time.

Step pools and larger mid-channel pools were the dominant habitat where *O. mykiss* were found, although the high gradient riffles and step runs were also used when smaller size classes were abundant in the spring and early summer.

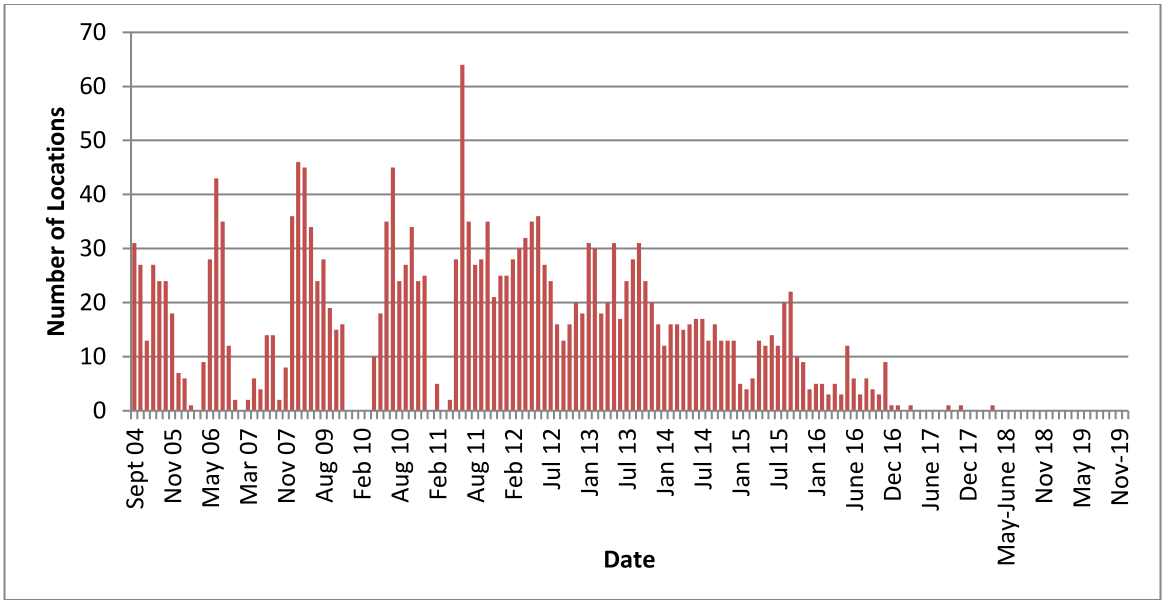


Figure 3.11. Number of locations used by *O. mykiss* in Malibu Creek 2004-November 2019.

3.2.1.2. Disease and Mortality

Notes on presence of diseased or dead individuals were made during snorkel surveys and carcasses retrieved when possible (Table 3.8 and 3.9). During July through October 2006, snorkel surveys documented the crash of the steelhead trout population in Malibu Creek below Rindge Dam (Figure 3.12). That information is reported in Dagit and Abramson (2007) and Dagit et al. (2009a) and not repeated here.

Figure 3.12. *O. mykiss* caught in Malibu Creek June 2006.

No diseased or dead individuals were observed between January 2015 - December 2016. A single female anadromous adult was found and died in March 2017. No diseased or dead anadromous were found in 2018. No *O.mykiss* were observed as of November 2019.

Table 3.8. Observations of Diseased *O. mykiss* in Malibu Creek 2005-2019.

Date	**Number of Diseased Individuals**	**Notes**
2004	0	No diseased individuals were observed in 2004
2005	0	No diseased individuals were observed in 2005
2006	119	07/18/2006 - to 07/19/2006 37 trout with yellow discoloration were observed. All measured <15cm 08/2006 – The number of discolored trout increased to 75 09/2006 – 7 trout with discoloration observed
2007	1	One adult trout exhibited same yellow color and sluggish movement as the previous years
2008	0	No diseased individuals were observed in 2008
2009	0	No diseased individuals were observed in 2009
2010	0	No diseased individuals were observed in 2010
2011	2	08/2011 – 10” in Long Pool 12/2011 - 9", above Grimmer
2012	4	01/2012 - 7 and 8" in step pool, no size for individual in Rusty Van Pool 02/2012-7" just above Cross Creek Road
2013	4	01/2013 – 11” run below Big Wide Pool 07/2013 – 9” step above First Bend Pool, 12" run below Big Wide 08/2013 - 8" Jeep Pool
2014	0	No diseased individuals were observed in 2014
2015	0	No diseased individuals were observed in 2015
2016	0	No diseased individuals were observed in 2016
2017	0	No diseased individuals were observed in 2017
2018	0	No diseased individuals were observed in 2018
2019	0	No diseased individuals were observed in 2019

Table 3.9. Observations of Dead *O. mykiss* in Malibu Creek 2005-2019.

Date	Number of Dead Individuals	Notes
2004	3	09/2/2004 - 3” found in Tufa Pool 09/03/2004 – 70mm FL found in step pools below Ringe Dam and 490mm FL found in plunge pool below Ringe Dam
2005	0	No dead individuals were observed in 2005
2006	119	07/18/2006 - to 07/19/2006 37 trout with yellow discoloration were observed. All measured <15cm 08/2006 – The number of discolored trout increased to 75 – 150mm FL trout collected at Big Wide pool 09/2006 – 7 trout with discoloration observed – 160mm, 285mm, and 140mm FL fish collected at step pools below Ringe Dam, Big Boulder Pool, and step pools below Ringe Dam, respectively.
2007	0	No dead individuals were observed in 2007
2008	0	No dead individuals were observed in 2008
2009	2	08/18/2009 - One found decomposed in Start pool; another 17” found recently dead in Big Wide Pool
2010	0	No dead individuals were observed in 2010
2011	0	No dead individuals were observed in 2011
2012	10	04/10/2012 - 11” Found dead in Big Wide Pool, collected otoliths, scales, and fins. 270mm FL, nothing found in stomach. 07/10/2012 – 6” found in Grimmer pool, collected and put into Freezer. 8” found dead in Big Wide, collected and put into freezer. 8” found dead in West Bedrock, too decomposed to collect. Three 7-8” trout found dead in Broken Pipe Pool, collected and put in freezer. 7” trout found dead in Big Boulder Pool, collected and put into freezer. 8” found dead in Railroad Track Pool, too decomposed to collect. 8” found dead in Dam Pool, too decomposed to collect.
2013	3	03/7/2013 - 6 and 8" found in Lower Twin, no samples collected. 09/11/2013 - 9" run below Grimmer Pool, collected otoliths and tissue
2014	2	02/5/2014 - 17" found in Start Pool. Too decomposed to collect. 07/8/2014 - Too decomposed to get size, head only in run below Grimmer Pool
2015	0	No dead individuals were observed in 2015
2016	0	No dead individuals were observed in 2016
2017	1	3/7/2017 - 23” FL anadromous found below Grimmer Pool, ~6yo, had not spawned. Collected.
2018	0	No dead individuals were observed in 2018
2019	0	No dead individuals were observed in 2019

3.2.1.3. Creek Conditions Above Rindge Dam

Following the die-off in Malibu Creek in 2006, we added a 500 meter reach of creek from the top of 4.12 rkm Rindge Dam upstream to provide observations on any differences in physical condition above and below the dam. The notes from these events are found in Appendix A. No die-offs or disease has been observed upstream of 4.12 rkm Rindge Dam to date.

3.2.2. Spawning and Redd Survey Data

Redd data for Malibu Creek between 2010-2012 was recorded and compiled by Rick Bush, NMFS. Since 2012, redd data has been collected monthly concurrently with snorkel surveys. Spawning gravel has not been mapped in Malibu Creek. Amount of spawning gravel was noted in pools where *O. mykiss* were observed during snorkel surveys. Embeddedness ranged seasonally from 10-50%. Table 3.10 summarizes these observations.

Table 3.10. Observations of redds and anadromous adults observed in Malibu Creek 2004-2019.

YEAR	Number of Redds	Locations of Anadromous Adults	# Anadromous Adults
2005	0	NA	0
2006	3	NA	1
2007	0	Big Wide Pool, Big Boulder Pool, BFF Pool, Dam Pool	2
2008	0	Big Boulder Pool, Dam Pool	4
2009	0	Big Wide Pool	1
2010	6	Start Pool	2
2011	2	Start Pool, Dam Pool	2
2012	1	Grimmer Pool, Big Wide Pool, West Bedrock Pool, Upper Twin Pool	3
2013	1	Step pool below pipes, Pipe Pool, Broken Pipe, Railroad Track, Willow overhang, Big Boulder	3
2014	1	Run above Lunch, Grimmer, Step above Grimmer Turtle Run, Big Wide, West Bedrock Pool, Malibu Lagoon	5
2015	0	Giant Carp (3), Dam pool, Lower Twin, Turtle Run, Grimmer, Big Elbow Pool Below Start, 200m Above Bridge At Cross Creek (9 observations of 3 individuals)	3
2016	0	Step below West Bedrock (West), First Bend	2
2017	0	Below Grimmer Pool	1
2018	0	NA	0
2019	0	NA	0

Although spawning observations are scarce, we documented the abundance of young of the year *O. mykiss* when they were present (Table 3.11). Variability year to year is quite marked, which could be a result of difficulty in seeing these small fish, especially when algae growth is abundant, as well as the relative fecundity of anadromous vs. resident fish. Predation by non-natives is also a potential impact on young of the year recruitment.

Table 3.11. Yearly peak of Young of the Year observed in Malibu Creek 2001-2019.

DATE	Peak count of Trout <100mm observed	Annual Water Year Rainfall Total (in.)
August 2005	72	53
May 2006	73	13.26
June 2007	8	19.72
July 2008	2331	14.35
August 2009	24	24.68
June 2010	242	22.29
July 2011	560	24.37
May 2012	181	15.87
May 2013	193	8.62
May 2014	29	6.37
April 2015	76	16.06
May 2016	4	9.84
2017	0	24.8
2018	0	10.63
2019	0	27.17

3.2.3. Genetic Information

Between 2004 and 2017, a total of 20 tissue samples were collected in Malibu Creek (Table 3. 12). It was not possible to infer a population assignment for five individuals and it was not possible to determine sex for two individuals. We observed a nearly equal distribution of males (8) and females (10) over the sampled years. The four samples collected in 2006 were from fish that turned yellow (See Figure 3.11 above) and cause of death was never conclusively determined. Both clustering-based methods and phylogeographic tree construction display strong evidence that Malibu Creek is of predominately coastal steelhead lineage, although that is based on a very limited sample size.

It is not possible to infer regional population dynamics based on the limited sample size (n=5); however they express an expected heterozygosity of 0.3836 and an observed heterozygosity of 0.4083, as compared to the mean expected heterozygosities (0.3293) and mean observed (0.3323) amongst individuals from all southern California populations and hatchery strains that were included in the baseline for genetic assignment. Of the 18 samples tested, 85.29% had a frequency of anadromous allele at OmyR04944 and 81.25% had a frequency of anadromous allele at SH114448-87, both of which are high as compared to the frequency of anadromous alleles observed in other southern California native populations (calculated in MS Toolkit, Park 1999).

Table 3.12. Summary of genetic tissue samples from Malibu Creek 2004 -2017. No additonal samples collected.

Inferred Population 1	Proportional Assign	NMFS ID	COLLECTION DATE	Collect Month	Collect Year	Scale.Age. RCDSMM	Est age	Est cohort	LENGTH (mm)	Genetic sex
ArGrMain	0.962828	M020030	9/3/2004	Sept	2004	NA	4	2000	490	Male
SYnzMain	0.984587	M020029	9/3/2004	Sept	2004	NA	0	2004	70	Female
ArGrMain	0.551881	M027330	9/26/2006	Sept	2006	NA	3	2003	285	Female
SYnzMain	0.994137	M027328	8/17/2006	Aug	2006	NA	0	2006	150	Male
ArGrMain	0.966523	M027329	9/26/2006	Sept	2006	NA	1	2005	160	Female
ArGrMain	0.999607	M027331	9/26/2006	Sept	2006	NA	0	2006	140	Male
SYnzMain	0.981634	M103800	8/18/2009	Aug	2009	NA	NA	NA	390	Female
NA	NA	M041445	8/18/2009	Aug	2009	NA	4	2005	390	Female
NA	NA	M041446	8/18/2009	Aug	2009	NA	1	2008	176	Male
SYnzMain	0.999906	M103791	5/27/2011	May	2011	NA	NA	NA	NA	gender???
NA	NA	M065432	4/10/2012	April	2012	NA	2	2010	270	gender???
NA	NA	M103784	7/10/2012	July	2012	NA	NA	NA	NA	Male
SYnzMain	0.996584	M103789	7/10/2012	July	2012	NA	NA	NA	NA	Male
SYnzMain	0.963455	M103785	7/10/2012	July	2012	NA	NA	NA	NA	Female
SalTjara	0.368684	M103786	7/10/2012	July	2012	NA	NA	NA	NA	Female
SYnzMain	0.937564	M103787	7/10/2012	July	2012	NA	NA	NA	NA	Male
SYnzMain	0.716363	M103788	7/10/2012	July	2012	NA	NA	NA	NA	Male
NA	NA	M097899	3/11/2014	Mar	2014	NA	5?	2008	670	Female
ArGrMain	0.999512	M103799	3/11/2014	Mar	2014	NA	NA	NA	670	Female
SYnzMain	0.881337	M102213	3/18/2017	Mar	2017	5+	5	2011	550	Female

3.2.4. Instream Habitat Mapping

Instream habitat mapping surveys were conducted in fall 2017 on 10/31/2017, 11/3/2017, and 11/21/2017 and in spring 2019 on 4/24-26/2019, and 5/9/2019. The 2019 survey followed the Woolsey Fire (2018) and rains of 2019. The Woolsey Fire did not directly burn anything downstream of Rindge Dam, but a significant portion of the upper watershed was burned. The length of the stream starting at 0 rkm Cross Creek Bridge (34.04301, -118.68423) to 4.12 rkm Ringe Dam (34.06509, -118.69798) was mapped.

The most prevalent habitat unit in 2017 was mid channel pools (38.57% of length) while in 2019 the most prevalent habitat unit was step runs (23.08% of length) (Figure 3.13). Additionally, in 2019, there was an increase in scour pools as well as shallower habitat types such as high gradient riffles and cascades.

Average width increased in 2019 (11.2 m) compared to 2017 (8.2 m). The dominant substrate composition in both 2017 and 2019 were boulders and sand. Mean canopy cover increased in 2019 (16.32%) compared to 2017 (10.88%). The mean depth increased in 2019 (71.8 cm) compared to 2017 (48.6 cm). Lastly, mean shelter value also increased slightly in 2019 (1.2) compared to 2017 (1.1). Mid channel pools had the highest shelter value ratings for both years, followed by scour pools and runs. In 2017, large woody debris were seen in a few locations throughout the reach. By the mapping event of 2019, no large woody debris was seen, as it was all washed away by the rains.

Summaries and further analysis of the data can be found in Appendix E.

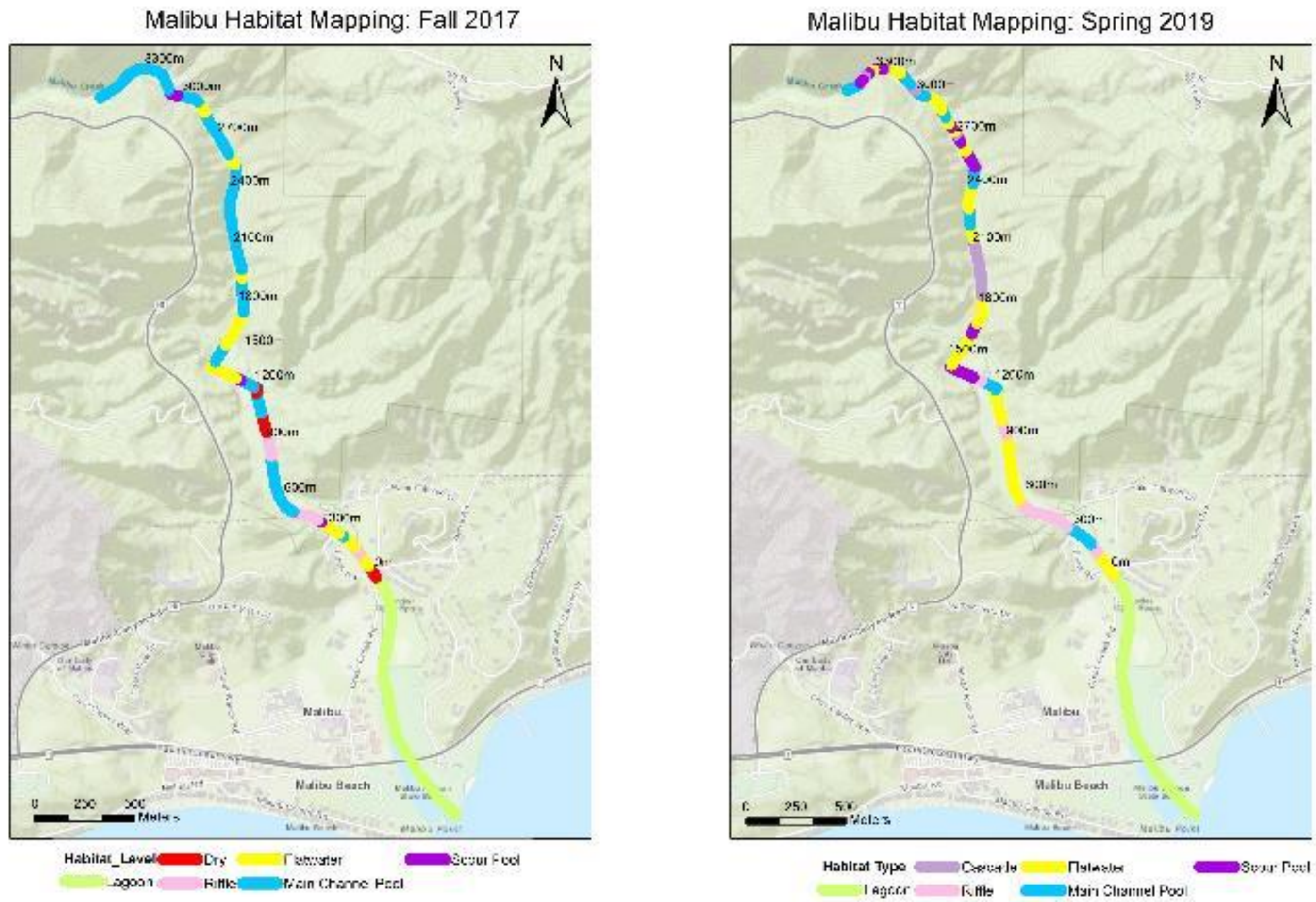


Figure 3.13. Summary map showing changes in habitat type distribution over time.

3. B. 1. Physical Conditions of Malibu Creek

Habitat conditions in Malibu Creek were mapped and pool dimension data was collected by the snorkel team in March 2007. At that time, it was not possible to characterize the segments of reach in-between pools due to the lack of consecutive and complete instream mapping data, even though steelhead were observed using step pools, step runs and high gradient riffles. However, the pool data does provide a way to compare the quality and quantity of available habitat used by steelhead between watersheds.

Conditions were mapped again in October/November 2017 and in April/May 2019. These mapping events follow the Woolsey Fire that occurred in Winter 2018 and the drought that occurred in California between 2012 and 2018. Between these two surveys, a single fish was observed in Malibu Creek, but it was not possible to determine if it was anadromous. Regardless if fish were present, data was still taken at pools that possessed suitable habitat and had contained *O. mykiss* in the past.

3.2.4.1. Pool Characteristics Statistical Analysis Results

For each of the mapping events, data was taken on the physical characteristics of pools and other habitat types. Pool volume in m^3 was calculated for fifteen pools that in the past contained suitable habitat for *O. mykiss* (Table 3.13).

The most dramatic change in pool volume was observed in the 4.12 rkm Dam Pool. The pool shrank due to sedimentation of the pool after the fire that occurred in October 2007 (Figure 3.14) but increased almost tenfold following the rains in 2017, followed by subsequent sedimentation impacts in 2019 following the Woolsey Fire (2018).

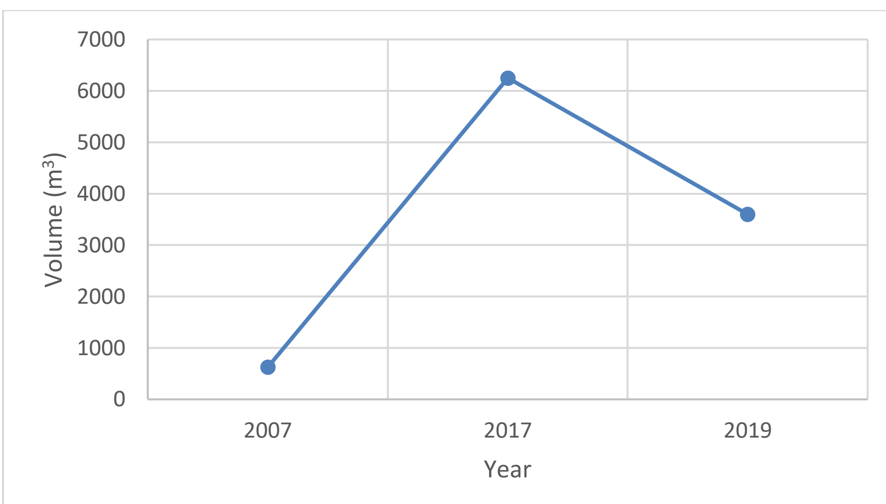


Figure 3.14. Change in volume (m^3) for 4.12 rkm Dam Pool between 2007 – 2017 - 2019.

Table 3.13. Pool Dimensions in Malibu Creek, March 2007, October-November 2017, April-May 2019.

Pool Name	Year	Length (cm)	Avg Width (cm)	Avg Depth (cm)	Pool Volume (m3)	% Change 2007 to 2017	% Change 2017 to 2019
Start Pool 1.0 rkm	2007	29500	800	180	4248		
	2017	26000	1500	85	3315	-22%	
	2019	25600	1300	67	2229.76		-33%
Mullet Pool1.4 rkm	2007	8700	2000	150	2610		
	2017	10600	1500	85	1351.5	-48%	
	2019	9000	1400	65	819		-39%
Lower Twin Pool 1.6 rkm	2007	9000	2500	500	11250		
	2017	7400	1000	100	740	-93%	
	2019	9000	1200.00	150.00	1620		119%
Upper Twin Pool 1.7 rkm	2007	3100	700	120	260.4		
	2017	2700	800	60	129.6	-50%	
	2019	4800	800	85	326.4		152%
Turtle Run 1.78 rkm	2007	10500	1000	180	1890		
	2017	16900	750	52.5	665.4375	-65%	
	2019	18700	1000	57	1065.9		60%
Lunch Pool 1.9 rkm	2007	6500	2500	350	5687.5		
	2017	5500	1500	135	1113.75	-80%	
	2019	6100	1200	150	1098		-1%
Grimmer Pool 2.6 rkm	2007	6100	3000	400	7320		
	2017	9000	2000	250	4500	-39%	
	2019	6600	2300	140	2125.2		-53%
First Bend Pool 3.0 rkm	2007	4700	1200	150	846		
	2017	5900	1700	100	1003	19%	
	2019	4600	1500	115	793.5		-21%
Big Wide Pool 3.08 rkm	2007	9200	2500	300	6900		
	2017	6500	1500	100	975	-86%	
	2019	5400	1700	150	1377		41%
West Bedrock Pool 3.7 rkm	2007	5500	2500	250	3437.5		
	2017	5800	800	70	324.8	-91%	
	2019	7100	900	50	319.5		-2%
Broken Pipe Pool 3.8 rkm	2007	5500	1500	180	1485		
	2017	6200	1000	100	620	-58%	
	2019	4700	100	110	51.7		-92%
Big Boulder Pool 3.86 rkm	2007	3000	1200	300	1080		
	2017	3600	800	210	604.8	-44%	
	2019	4800	1200	175	1008		67%
Railroad Track Pool 4.0 rkm	2007	2000	800	150	240		
	2017	2000	700	55	77	-68%	
	2019	2800	800	90	201.6		162%
Willow Overhang Pool 4.09 rk	2007	1600	1700	100	272		
	2017	1000	400	60	24	-91%	
	2019	1700	600	80	81.6		240%
Dam Pool 4.12 rkm	2007	2500	2500	100	625		
	2017	10000	2500	250	6250	900%	
	2019	10000	1800	200	3600		-42%

Between 2007 and 2017, pool volume generally decreased due to the drought (Figure 3.15). However, between 2017 and 2019 the pool volume generally increased (Figure 3.16). This was due to the increased rainfall that occurred between 2017 and 2019, as well as the elimination of any dry sections in the creek.

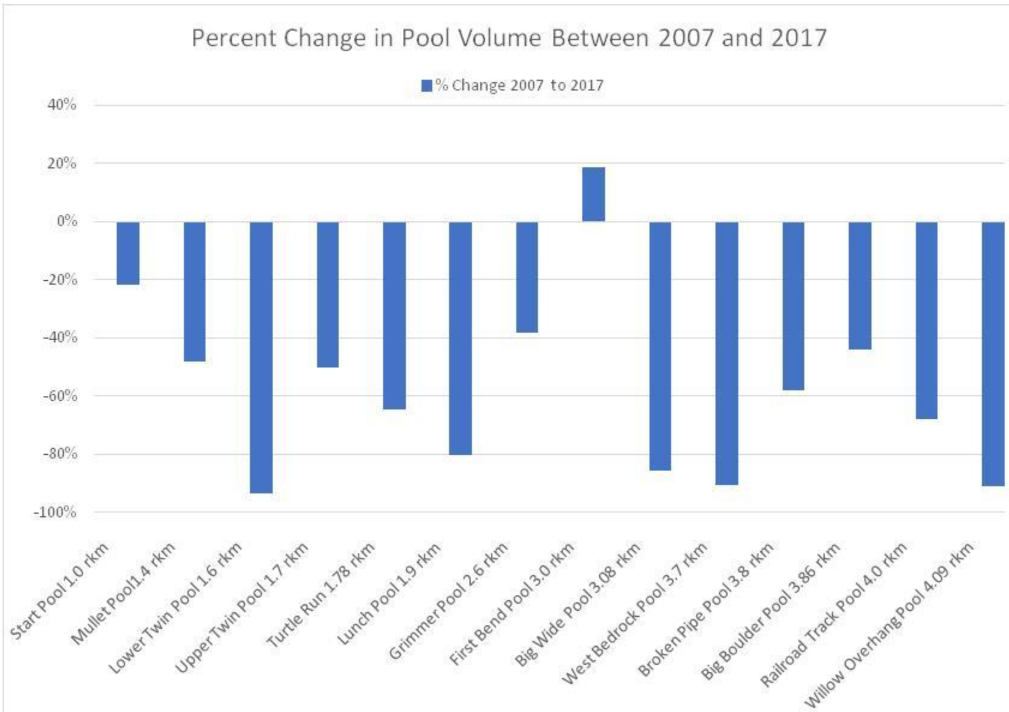


Figure 3.15. Percent change in pool volume between 2007 and 2017.

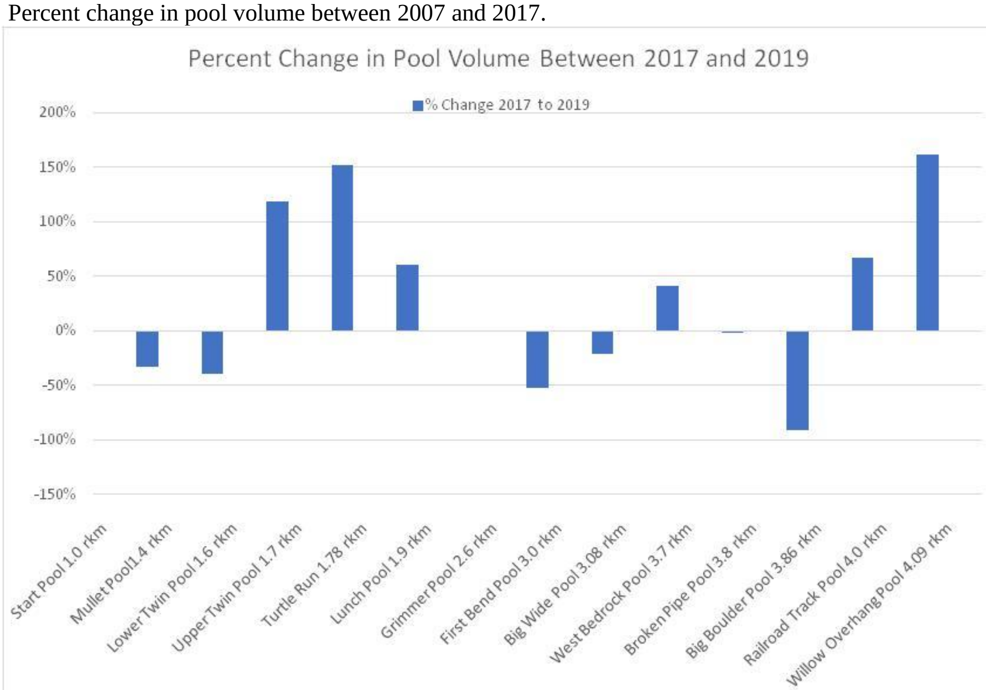


Figure 3.16. Percent change in pool volume between 2007 and 2019.

3.2.5. Lagoon/Ocean Interface Monitoring

Malibu Creek enters the ocean at Malibu Lagoon. Due to the release of millions of gallons of water per day from the Tapia Water Reclamation Plant between November 16 and April 14 each year, as well as run-off from hundreds of acres of impervious surfaces in the upper watershed, Malibu Creek remains connected to the ocean for much of the time between November and June each year (Table 3.14). No upstream releases are permitted from April 15 – November 15, and it is during this time that the sand bar at the beach reforms to close the lagoon, unless breached by a rain event, or illegally by surfers.

The closest rain station is located in Monte Nido (LACO 435), along the Cold Creek tributary to Malibu Creek. The stream flow gauge for Malibu Creek (LACO #F130-R) is located just downstream of the outlet of the Tapia Water Reclamation Plant and managed by Los Angeles County Department of Public Works. USGS installed another flow gauge at the Cross Creek Road bridge following the 2007 fire. Data from that gauge was available online in real time until it was closed in 2011.

In 2012, a restoration of Malibu Lagoon was completed, which has increased the area of water signficantly but the amount of time the lagoon is connected to the ocean appears to be consistent with previous observations.

Table 3.14. Summary of Migration Opportunities in Malibu Creek*

Water Year	Rainfall Total (inches)	Dates Entrance Open	Estimated Number of Passable Days
2004-2005	53		
2005-2006	13.26	April – May 06	>300
2006-2007	19.72	August 06- April 07	~145
2007-2008	14.35	October 07 – June 08	>200
2008-2009	24.68	July – August 08; November 08- June 09	>200
2009-2010	22.29	October 09- June 10	>200
2010-2011	24.37	December 10 - June 11	>200
2011- 2012	15.87	October 11- June 12	>200
2012-2013	8.62	November 12 - May 13	>200
2013-2014	6.37	Nov 25 - 8 May	>200
2014-2015	16.06	December 04-March 2015	>200
2015-2016	9.84	December 16 – April 2016	>200
2016-2017	24.8	November 2016; January-April 2017	105
2017-2018	10.63	December 3,2017 – May 9,2018	~150
2018-2019	27.17	November 22, 2018 – July 2 2019	>200

*Data from Los Angeles County Dept of Public Works, Lifeguards and RCDSMM

3.B.3 Malibu Lagoon Seine Results

Seining was conducted on 20 June 2005 from 0900-1600 and subsequently twice per year between 2012 -2019 according to the pre-and post-project monitoring plan protocol outlined in the Draft Malibu Lagoon Monitoring Plan. A total of six stations were sampled during each event, and spot surveys were done in the thalweg and at an additional five locations within the lagoon (Table 3.15). It was not possible to seine in the main body of the lagoon as it was too deep.

Table 3.15. Summary of Fish and Invertebrates captured/observed 2005-2019.

		Survey 6/1/2005 open	Relocation June 2012 open	Survey 1/8/2013 open	Survey 5/15/2014 closed	Survey 12/11/2014 open	Survey 5/27/2015 closed	Survey 1/12/2016 open	Survey 6/1/2016 closed	Survey 3/3/2017 open	Survey 7/26/2017 closed	Survey 1/30/2018 open	Survey 6/19/2018 closed	Survey 2/20/2019 open	Survey 7/17/2019 closed
Native Fish Species															
Steelhead trout	*O.mykiss*				1 observed										
Unidentified goby larva (<5 cm)			2		500~						8	1			6
Tidewater goby larva (<5cm)	*Eucyclogobius newberryi*				13				17	12	10		5	5	7
Tidewater goby adult (6-8cm)	*Eucyclogobius newberryi*	473	8				41								
Arrow goby (<5 cm)	*Cleavlandia ios*				5										
Bay goby?	*Lepidogobius lepidus*				2										
CA Halibut	*Paralichthys californicus*								2						
CA killifish juveniles (<5cm)	*Fundulus parvipinnis*		306						1	1					300
CA killifish (5-10 cm)	*Fundulus parvipinnis*	46	16		5										17
Long-jawed mudsucker (<5 cm)	*Gillichthys mirabilis*	1	8		5		3		11	2	4	3	10	50+	18
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*		11				22	5	52		13		1		4
Topsmelt larva (<5 cm)	*Atherinops sp*		1	3			176	6	1289	35	2618	276	3128		
Topsmelt juvenile (6 cm)	*Atherinops sp*	244			24		60		133	48	933	264	15		784
Topsmelt adult (16 cm)	*Atherinops sp*						6				56		2		228
Unidentified smelt larva (<5 cm)	*Atherinops sp*		101		15,293		2244	64					2400		317
Staghorn sculpin (<5 cm)	*L. armatus*			17	11			1		130	1	8	12	28	
Staghorn sculpin (5-10 cm)	*L.armatus*		3						5	4	2		2	5	
Staghorn sculpin (10-15cm)	*L.armatus*														
Opaleye	*Girella nigricans*										2				
Diamond turbot	*Hypsopsetta guttulata*			7	1				5						
Spotted turbot	*Pleuronichthys ritteri*											12			
Garabaldi (28 cm FL) dead dropped	*Hypsypops rubicundus*														
Northern anchovy <5 cm	*Engraulis mordax*		5					180	1		423				
Northern anchovy 5-10 cm	*Engraulis mordax*										239			1	
Striped mullet	*Mugil cephalus*	observed		observed	observed	7	1		observed	observed		1			
Mullet juveniles <5cm	*Mugil sp.*													82	
Unidentified fish larva							991		3		52				
Non-Native Fish Species															
Mosquitofish Juveniles (<5cm)	*Gambusia affinis*						13	6	10	1	271		7		58
Mosquitofish Adults (5-10cm)	*Gambusia affinis*	65	4072			2	3				3				8
Carp	*Cyprinus carpio*	1			observed						1				
Mississippi silversides	*Menida audens*			1		970	9	15	16		650	1	17		578
Largemouth Bass															1
Invertebrates															
Oriental shrimp	*Palaemonetes sp.*			37	209	43	10	5	58	89	280	7	442	12	5
Hemigraspus crabs			6		8	1	20	1	1	2	2		2		12
Water boatman juveniles			6,000+		2504						14			50+	600+
Amphipods			2500+												
Isopods			2500+									3			
Ctenophore sp (<2 cm)				3											
Salp sp (<2 cm)				3											
Sea hare (5-10 cm)	*Aplysia californica*			2											
Segmented worm <2 cm)				3											
Gastropoda							4								
Water scavenger larva	*Hydrophilidae*						1								
Dragonfly											16		1	1	
Caddisfly											8		1	1	
Crayfish	*Procambarus clarkii*									1					

3.2.6. Water Temperature, Flow and Water Quality Monitoring

Table 3.16 summarizes the deployment history of Stowaway TIDBIT continuously recording thermometers in Malibu Creek from 2009-2019. Between 5-10 pools were selected annually to represent typical refugia locations where *O. mykiss* were consistently observed. A few of these pools are over three meters deep, however only one pool (3.86 rkm Big Boulder) seemed to have thermal stratification and we deployed both surface and bottom thermometers to see if there was any notable difference in temperature from 2013-2016. Temperatures ranged between 13-27ºC, but there was minimal difference between the surface and bottom readings. With lower pool levels in 2017-2019, we deployed only a single hobo in that pool.

Malibu Creek temperature data for years 2011-2019 are presented, which included the most complete data set. Due to equipment malfunction there is less than 30% complete data for 2009 and 2010. Complete individual pool data is provided in Appendix D. In addition to examining the temperature patterns over time for each pool location, we also compiled all pool data into composite annual and monthly maximum, average, and minimum temperature for the creek as a whole, in order to identify if there were any significant changes in response to decreased rainfall levels associated with drought.

Table 3.16. Summary of temperature monitored locations and dates in Malibu Creek, 2008-2019.

Pool	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Start 1.0 rkm (water)	ND*	29 Jul-30 Oct	09 Sept-26 Oct	23 May-06 Oct	14 Mar-13 Nov	17 Apr-31 Dec	01 Jan-13 Nov	09 Apr-31 Oct	30 Mar-08 Nov	15 Apr-6 Nov	9 Mar-17 Oct	2 April – 5 Nov
Start 1.0 rkm (air)	ND	ND	ND	ND	17 Oct-31 Dec	01 Jan-13 Nov	01 Jan-13 Nov	09 Apr-31 Oct	30 Mar-08 Nov	15 Apr-6 Nov	9 Mar-17 Oct	2 April - 5 Nov
Lower Twin 1.6 rkm	13 Jun-Jul-24	ND	ND	ND	ND	ND	ND	ND	ND	15 Apr-6 Nov	9 Mar-17 Oct	ND
Lunch 1.9 rkm (water)	ND	04 Aug-30 Oct	09 Sept-26 Oct	23 May-10 Nov	17 May-13 Nov	17 Apr-11 Sept	02 Apr-12 Nov	09 Apr-31 Oct	30 Mar-08 Nov	15 Apr-6 Nov	9 Mar-17 Oct	2 April – 5 Nov
Lunch 1.9 rkm (air)	ND	04 Aug-30 Oct	ND	ND	17 Apr-13 Nov	17 Apr-11 Sept	02 Apr-12 Nov	ND	ND	ND	ND	ND
Grimmer 2.6 rkm	ND	29 Jul-30 Oct	09 Sept-26 Oct	23 May-06 Oct	14 Mar-13 Nov	17 Apr-13 Nov	02 Apr-10 Nov	09 Apr-31 Oct	29 Mar-09 Nov	15 Apr-6 Nov	9 Mar-17 Oct	3 April -6 Nov
Tufa West 3.3 rkm	ND	ND	ND	ND	ND	17 Apr-12 Nov	29 Apr-10 Nov	09 Apr-31 Oct	29 Mar-09 Nov	15 Apr-6 Nov	9 Mar-17 Oct	3 April - 6 Nov
Big Wide 3.5 rkm	ND	ND	ND	ND	17 Jul-13 Nov	17 Apr-12 Nov	*02 Apr-04 Aug	ND	29 Mar-13 Dec	15 Apr-6 Nov	9 Mar-17 Oct	3 April - 6 Nov
West Bedrock 3.7 rkm	ND	ND	ND	ND	17 Jul-13 Nov	ND	04 Jun-10 Nov	**07 Apr-lost	ND	15 Apr-6 Nov	9 Mar-17 Oct	3 April - 6 Nov
Broken Pipe 3.8 rkm (surface +bottom)	ND	ND	ND	ND	17 Jul-13 Nov	ND	ND	ND	ND	ND	ND	ND
Big Boulder 3.86 rkm (surface +bottom)	ND	ND	ND	ND	17 Jul-13 Nov	17 Apr-12 Nov	02 Apr-10 Nov	09 Apr-31 Oct	29 Mar-13 Dec	15 Apr-6 Nov	9 Mar-17 Oct	3 April - 6 Nov
Dam 4.12 rkm	13 Jun-10 Sept	29 Jul-21 Oct	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mott Rd.	ND	ND	09 Sept-26 Oct	ND	ND	ND	ND	ND	ND	ND	ND	ND

* ND = logger was not deployed in this location for this year
*Big Wide tidbit failed, not replaced
**West Bedrock tidbit lost, not recovered

3.2.6.1. *Overall Malibu Creek Temperature Patterns*

Daily fluctuations in average maximum, mean, and minimum temperatures were examined for all pools (Figure 3.17), which confirmed that although some pools are cooler or warmer than others, daily temperature patterns throughout the creek are relatively homogenous, even between isolated pools. Air temperature appeared to be the strongest driver of water temperature in both Malibu and Topanga Creek.

Annual average maximum, mean, and minimum temperatures 2011-2019 of 1.0 rkm Start Pool (max=21.0˚C, mean=18.6˚C, minimum=16.7˚C) were significantly cooler ($p<0.05$) than the larger 1.9 rkm Lunch (max=23.8˚C, mean=20.7˚C, minimum=17.74˚C), 2.6 rkm Grimmer (max=22.6˚C, mean=20.1˚C, minimum=17.44˚C), and 4.12 rkm Dam Pool (2011-2018: max=21.6˚C, mean=20.7˚C, minimum=20.0˚C) (One-tail T-test, $p< 0.05$). 1.9 rkm Lunch Pool maximum, mean, and minimum temperatures were significantly warmer that other pools (One-tail T-test, $p< 0.05$).

Maximum and average depths of 1.0 rkm Start Pool were less than 1.5 meters until the pool dried down in June 2016, and the banks were stabilized by clusters of cattails (*Typha latifolia),* tules (*Shoenoplectus acutus*) and willows (*Salix sp.*). During the summer months in 2011-2019, the reaches upstream and downstream both flowed subsurface, disconnecting and isolating the pool. Cooler temperatures in 1.0 rkm Start Pool could be a result of either cooling as the water flows subsurface downstream from 2.6 rkm Grimmer, to 1.9 rkm Lunch, then to 1.0 rkm Start Pool; or it is possible that there is groundwater seep input into 1.0 rkm Start Pool, or a combination of both. 1.0 rkm Start Pool has the greatest canopy cover and is far longer than wide. 1.9 rkm Lunch and 2.6 rkm Grimmer are both wide pools with less canopy shading. Although there was year-round data available from the 1.0 rkm Start Pool data sonde except for in summer 2016-2017, only the summer months comparable to other pools were used in the analysis. No data on seeps and springs for Malibu Creek is available. Graphs of 1.0 rkm Start Pool temperature are provided in Appendix D.

1.9 rkm Lunch and 2.6 rkm Grimmer Pools are defined by bedrock banks with cascades delimiting the upstream ends of the pool, and step pool complexes on the downstream ends, providing potential spawning gravel in the pool tails. These pools are over three meters deep and bank vegetation is limited due to the rock outcrops. Although deeper, these pools had consistently higher temperatures overall, ranging from 12.4 – 28.4ºC, but proportionately having more time above 20ºC. Graphs of Lunch and Grimmer temperature are provided in Appendix D.

There were no significant correlations between rainfall and either average max, mean, or minimum temperatures (Figure 3.17).

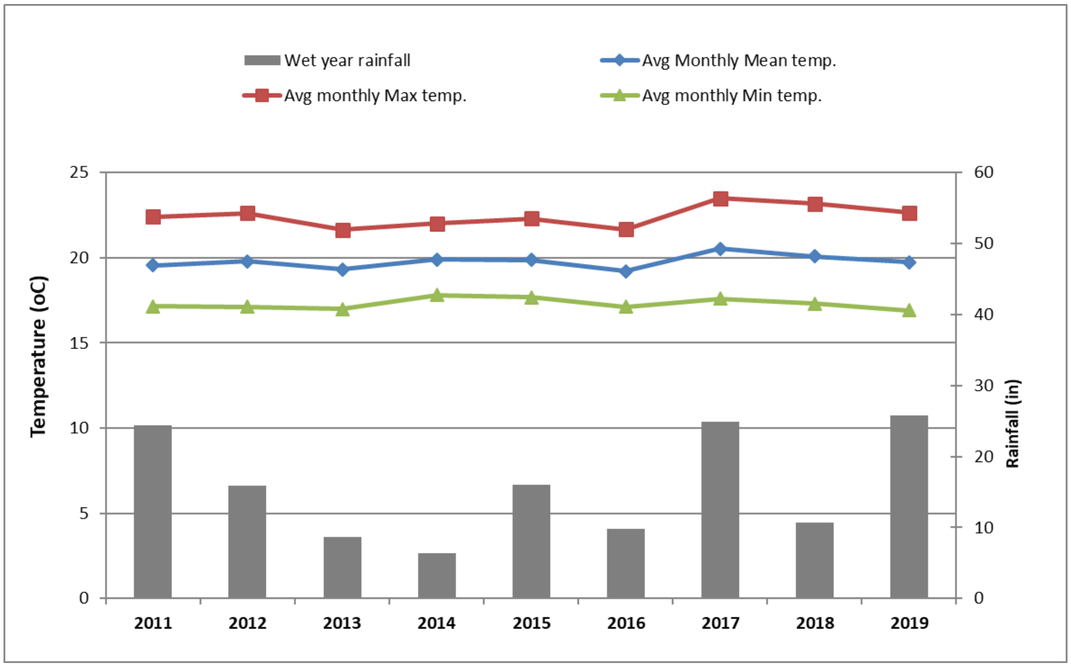


Figure 3.17. Malibu Water Temperatures and Precipitation (2009-2019).

3.2.6.2. Average Maximum Temperatures by Pool

Average monthly maximum temperatures were less than 27ºC in Malibu Creek, but varied by pool and year (Figure 3.18). Mean monthly maximum temperatures oscillated inter-annually; at 2.6 rkm Grimmer Pool monthly maximum in July ($z = 2.403$) and August ($z = 2.103$) increased significantly in the period 2011-2018 with estimated rates of increase of 1.4 and 1.0ºC/year. Warmest monthly maximum occurred in years 2015, 2017, 2018, and 2019. From 2018-2019 a trend of decreasing maximum temperatures was observed in Lunch (2019: 23.25ºC) and Grimmer Pools (2019: 22.22ºC). Start Pool showed an opposite trend of increased average maximum temperature (2019: 22.40ºC).

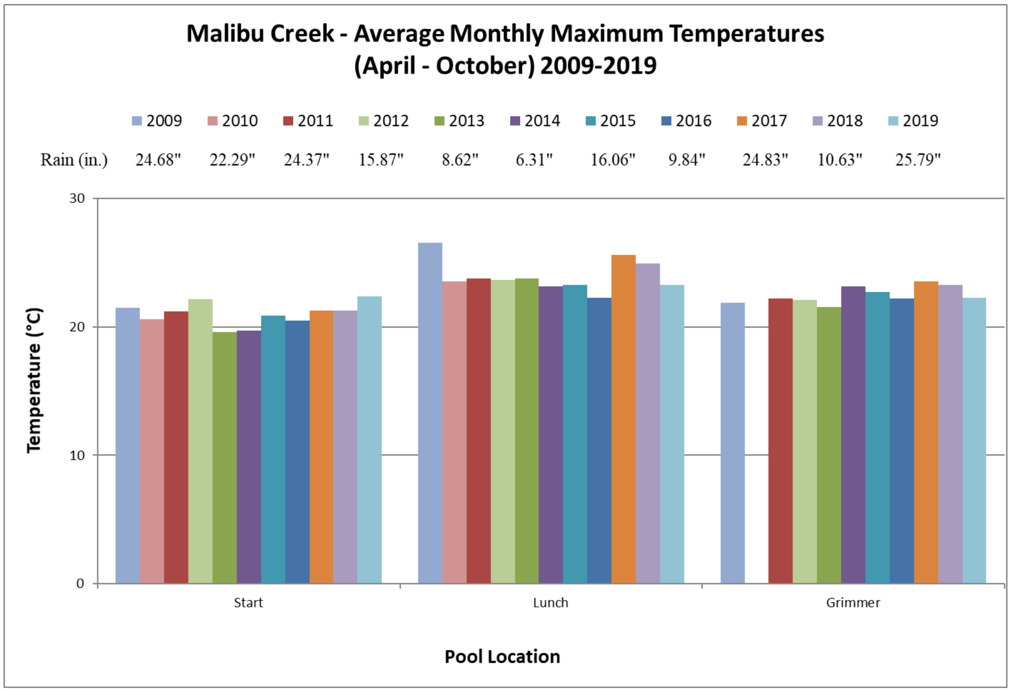


Figure 3.18. Average Maximum Water Temperature in Malibu Creek 2009-2019.

Average monthly maximum temperatures were less than 27°C in Malibu Creek, but varied by pool and year (Figure 3.18). Mean monthly maximum temperatures oscillated inter-annually; at 2.6 rkm Grimmer Pool monthly maximum in July ($z = 2.403$) and August ($z = 2.103$) increased significantly in the period 2011-2018 with estimated rates of increase of 1.4 and 1.0°C/year. Warmest monthly maximum occurred in years 2015, 2017, 2018, and 2019.

3.2.6.3. Correlation of precipitation to days with temperatures >23° and 25°C

In Malibu Creek, the monitored pool most downstream behaved differently from the upstream pools (Table 3.17). 1.0 rkm Start Pool (located furthest downstream and usually connected only by sub-surface flow) rarely exceeded 23°C, while the next upstream 1.9 rkm Lunch Pool consistently had temperatures exceeding both 23 and 25°C almost all years. 2.6 rkm Grimmer Pool was more variable, but also experienced days with temperatures exceeding both 23 and 25°C. In 2019, Malibu Creek received the greatest rainfall since 2005 at 25.79 inches. However, number of days when water temperature >23°C and >25°C in Malibu did not correlate to precipitation amounts in the period 2009 to 2019. Lunch Pool had the greatest number of days >23°C, and Start Pool had by far the fewest. Most temperature records >25°C are from Lunch Pool, except in 2017 and 2018 when Grimmer Pool also exceeded 25°C 18 and 41% of days. Overall, the amount of time each of the three pools reached temperatures over 23°C decreased in 2019.

Table 3.17. Total number of days with temperatures greater than 23 and 25°C in three pools in Malibu Creek, from June through October (n=number of days logger deployed).

MALIBU	2009*	2010*	2011	2012	2013	2014	2015	2016	2017	2018	2019
Precipitation (in)	24.68	22.29	24.37	15.87	8.62	6.37	16.06	9.84	24.83	10.63	25.79
Start Pool 1.0 rkm days >23 °C (n)	0 (94)	0 (48)	0 (128)	15 (123)	0 (152)	0 (153)	1 (126)	5 (66)	1 (95)	0 (84)	3 (217)
Lunch Pool 1.9 rkm days >23 °C (n)	28 (63)	4 (48)	69 (153)	54 (138)	54 (102)	54 (99)	68 (152)	30 (129)	88 (90)	72 (109)	31 (217)
Grimmer Pool 2.6 rkm days >23 °C (n)	3 (84)	n.d.	18 (153)	21 (153)	7 (152)	62 (153)	60 (153)	45 (153)	76 (153)	61 (108)	23 (217)
Start Pool 1.0 rkm days >25 °C (n)	0 (94)	0 (48)	0 (128)	0 (123)	0 (152)	0 (153)	0 (126)	0 (66)	0 (95)	0 (84)	0 (217)
Lunch Pool 1.9 rkm days >25 °C (n)	14 (63)	0 (48)	11 (153)	15 (138)	7 (102)	2 (99)	0 (152)	0 (129)	73 (90)	46 (109)	1 (217)
Grimmer Pool 2.6 rkm days >25 °C (n)	0 (84)	n.d.	0 (153)	0 (153)	0 (152)	1 (153)	0 (153)	0 (153)	28 (153)	44 (108)	0 (217)

*Due to equipment problems data collected in 2009 and 2010 were only 30% complete.

Number of days during the drought when water temperature >23°C and >25°C in Malibu did not correlate to precipitation amounts in the period 2009 to 2018 (Figure 3.19). Lunch Pool had the greatest number of days >23°C, and Start Pool had by far the fewest. Most temperature records >25°C are from Lunch Pool, except in 2017 and 2018 when Grimmer Pool also exceeded 25°C 18 and 41% of days.

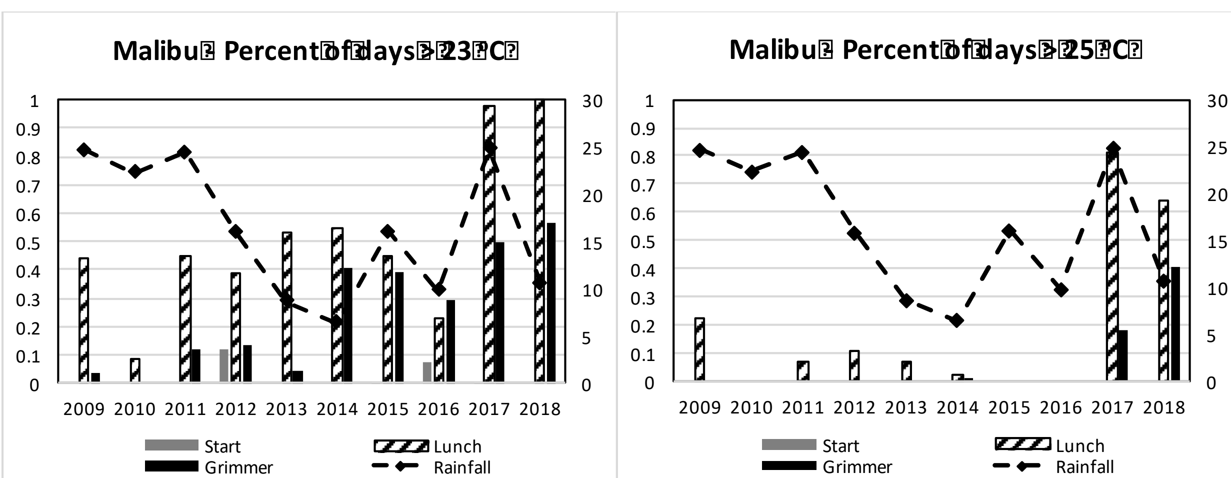


Figure 3.19. Percent of days with temperatures > 23 and 25 °C in Malibu Creek.

7 Day Average Daily Maximum by Pool (7-DADM)

The calculation of Seven-Day Average Daily Maximum (7-DADM) temperatures is suggested for use by USEPA (2003), particularly for the application of total maximum daily loads (TMDLS) in relation to temperature. 7-DADM is the highest average temperature recorded in any period of 7 sequential days in a year. Water temperature 7-DADM was calculated for Start, Grimmer, Lunch, and Dam Pools in Malibu Creek between June – October 2011 and 2019. Due to equipment failure, data for 2009 and 2010 data in Malibu is less than 30% complete and thus not included in the analysis. No temperature data was available for Dam Pool in 2019.

Results from Malibu Creek indicated 7-DADM for Start Pool fluctuated wildly yet was coolest overall, ranging from 24.5ºC (9/9-9/15, 2012) to 20.2ºC (6/24-6/30 2013), with no significant trend in 7-DADM magnitude over time. 7-DADM was highest overall in Lunch Pool, ranging from 24.2ºC (7/17-7/23, 2016) to 27.6ºC (8/28-9/3, 2017), with no significant trend overtime. Grimmer 7-DADM ranged from 23.3 (8/18-8/24, 2012) to 26.0ºC (7/24-7/30, 2018). A significant upward trend was identified 2011-2019 in Grimmer 7-DADM by Mann-Kendall test statistic ($z = 1.98$, $p < 0.05$). Dam Pool 7-DADM ranged from a high of 25.5ºC (8/9-8/15, 2012) to a low of 22.9 (7/11-7/17, 2015) with no significant trend. The earliest 7-DADM occurred was June 24th (Start, 2013), and latest, September 12th (Start 2014, Lunch 2012, 2014). There was no trend over time in the seasonal timing of 7-DADM occurrences from 2011 to 2019 (Figure 3.21).

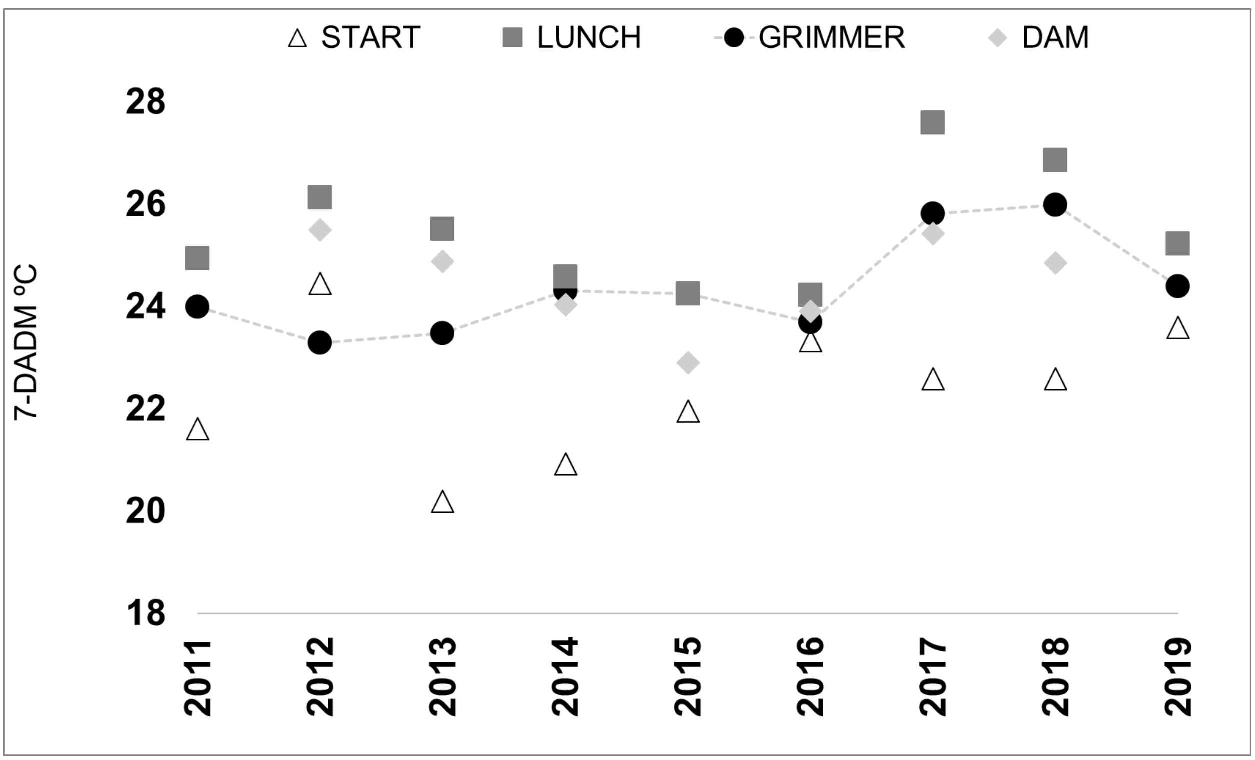


Figure 3.20. 7 Day Average Daily Maximum Temperatures Malibu Creek.

Number of days when water temperature >23ºC and >25ºC in Malibu did not correlate to precipitation amounts in the period 2009 to 2016. Lunch Pool had the greatest number of days

>23ºC, and Start Pool had by far the fewest. Most temperature records >25ºC are from Lunch Pool.

3.2.6.4. *Average Mean Temperature*

Average temperatures remained consistent overall and did not significantly change during the drought 2012-2018. Mean temperatures in Lunch and Grimmer Pools were close to 20ºC (Figure 3.21), which is at the upper end of the preferred temperature range to support foraging and growth in *O. mykiss* (Spina 2007). In 2019, mean temperatures in the upstream pools (Lunch and Grimmer Pool) decreased while the downstream pool (Start Pool) increased.

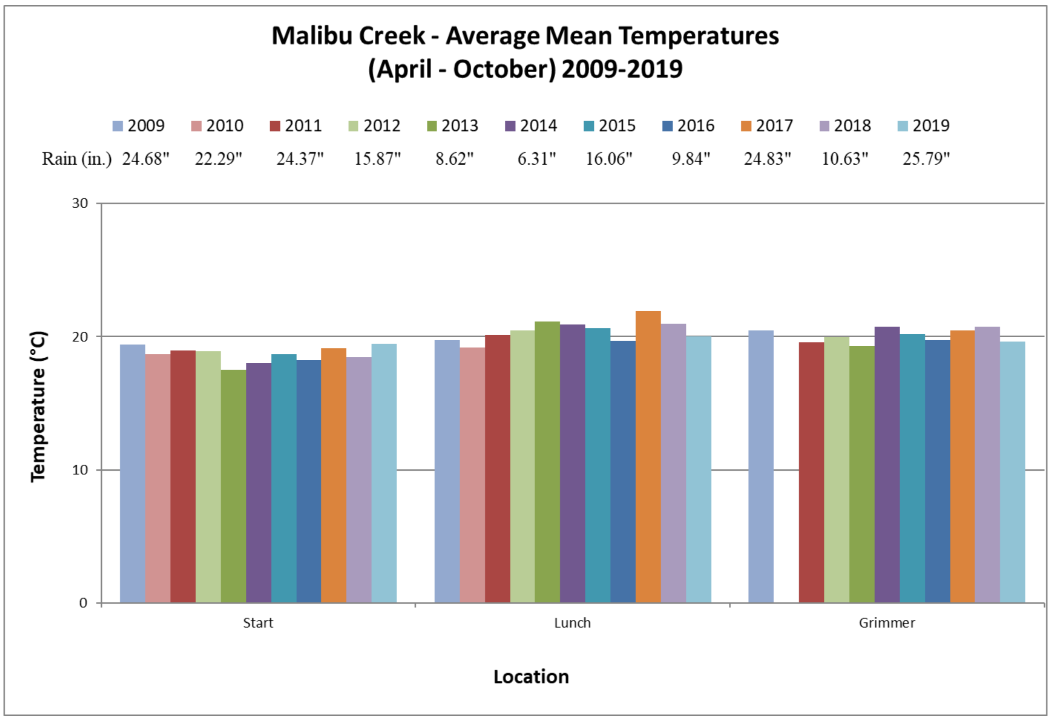


Figure 3.21. Average Mean Water Temperature in Malibu Creek 2009-2019.

3.2.6.5. *Average Minimum Temperature*

Average minimum temperatures were less than 23.5ºC in Malibu Creek, but varied by pool and year (Figure 3.22). In 2019, average minimum temperatures increased in the downstream Start Pool (17.05ºC) and decreased in the upstream Lunch (16.73ºC) and Grimmer Pools (16.91ºC).

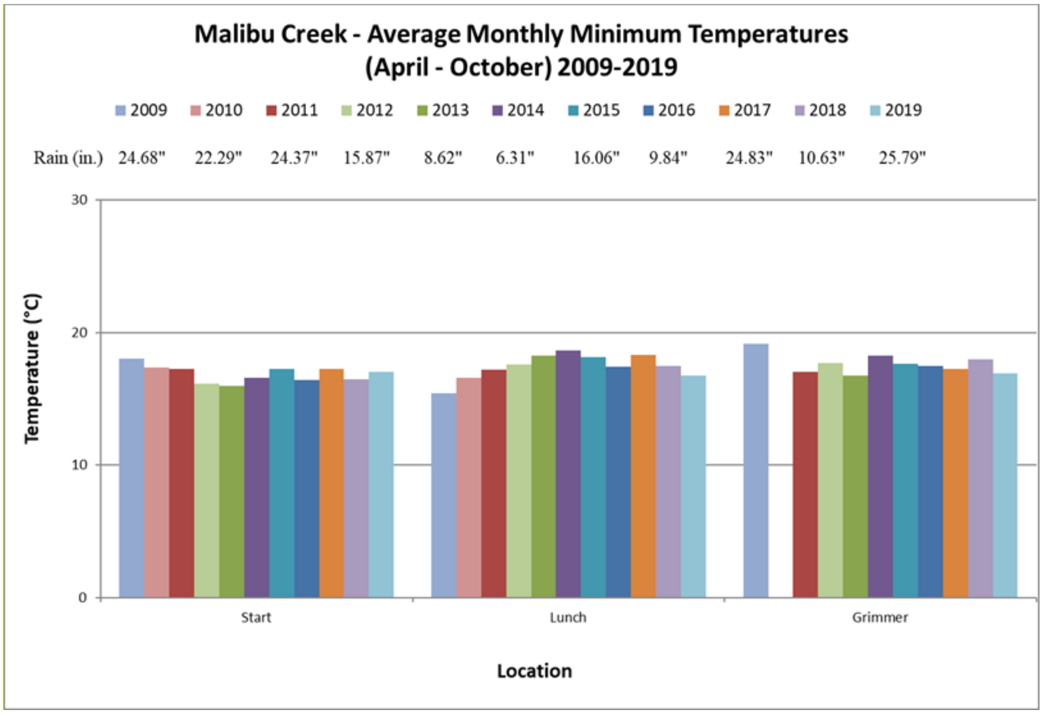


Figure 3.22. Average Minimum Water Temperature in Malibu Creek 2009-2019.

Mean monthly minimum temperatures increased over the period 2011-2018 in Lunch Pool in July ($z = 2.254$), and Dam Pool in July ($z = 2.703$) and August ($z = 2.103$). Sen's Test estimated rate of change at these sites ranged from 0.9 to 1.0°C/year MnwT. Warmest monthly minimum occurred in years 2015, 2016, 2017, and 2018.

3.2.6.6. Pool and environmental conditions

Analysis comparing the three pools (1.0 rkm Start, 1.9 rkm Lunch, 2.6 rkm Grimmer) for which we have the longest data series (2011-2019) in Malibu Creek revealed that water temperature correlated with pool dimensions and canopy cover. Pool characteristics were not compared to water temperature due to the small sample set (n=4). However, it can be noted that cooler maximum temperatures were observed in pools with greater canopy cover (1.0 rkm Start and 2.6 rkm Grimmer), and warmer minimum temperatures in shallower pools (1.0 rkm Start and 1.9 rkm Lunch) (Table 3.19).

Table 3.19. River kilometer (rkm), pool temperature, dimension, and canopy cover of of Malibu Creek temperature monitored pools 2011-2019.

POOL	rkm	MAX T (daily mean °C)	MIN T (daily mean °C)	pool length (m)	pool width (m)	pool depth (cm)	pool volume (m^3)	% canopy
START	1.0	21	16.7	139	10	60	792	18
LUNCH	1.9	23.8	17.7	64	13	125	1030	11
GRIMMER	2.6	22.6	17.4	62	13	150	1194	11
DAM	4.12	21.6	20.0	98	12	150	1705	4

Average minimum temperature., mean temperature, number of days >23˚C, and maximum temperature, were all positively correlated, in order of significance, to pool width and depth ($p<0.05$), but negatively to pool length ($p<.05$). This association between higher temperatures and pool depth/width, and lower temperatures with length is a reflection of higher temperatures in 1.9 rkm Lunch and 2.6 rkm Grimmer, which are wide and deep, than in 1.0 rkm Start Pool which is relatively long and shallow. These trends may or may not be consistent throughout Malibu Creek. Pool volume did not correlate to rainfall, which is likely due to the fact that natural creek flows are altered by water releases from Tapia Wastewater Treatment Plant.

Summer augmentation flows from the Tapia Water Reclamation Plant occurred whenever flow at the stream gauge located upstream of Rindge Dam fell below 2.5 cubic feet per second (cfs). Releases of approximately 82 million gallons occurred in 2013-2015 but were insufficient to reconnect surface flow within the creek, leaving many of the pools isolated and limiting movement of fish. Due to a gauge problem, augmentation flows were not initiated until September 2016, which caused extensive dry down throughout the reach below the dam. Water released from Tapia ranges from 20 – 25ºC.

Higher temperatures had a negative correlation to % canopy cover, wherein greater canopy cover was associated with lower temperatures. The trend was significant for maximum temperature, and number of days >23˚C ($p<0.05$). Canopy cover was typically greater in years with higher rainfall, but the trend was not significant.

Multiple regression analysis was carried out at to assess if drought climate and creek habitat variables correlated to *O. mykiss* distribution and abundance at the creek-wide scale for 2011-2018. Drought index was referenced from DroughtMonitor.unl.edu; flow was collected at stream gauge F-130; minimum water temperature (MIN T) was calculated from daily minimum temperature, averaged by year across study pools; 7DADM was selected as the maximum temperature variable to reduce correlation with MIN T. Fish counts were recorded during monthly snorkel surveys of the entire creek from 1.0 rkm to 4.1 rkm. Number of sites (# sites) with *O. mykiss* and number of *O. mykiss* by size class (Adult >25 cm, Intermediate > 10-24 cm, Juvenile <10 cm) are peak annual counts. To correct for non-independence of *O. mykiss* population metrics across years, the previous year's total *O. mykiss* count was included in regression modeling as a potential explanatory variable (POP (t-1)). None of the explanatory variables correlated strongly ($p>0.05$). Ordinary least-squares linear regression was performed stepwise, removing least significant explanatory variables one at a time. Explanatory variables were retained if exclusion decreased model standard error by >20% or resulted in residuals surpassing 10.

Multiple regression analysis resulted in explanatory models that associated water temperature and flow conditions with fish population trends, specific to different age classes (Table 3.20). Seven-day maximum water temperature (7DADM) correlated negatively and significantly to number of sites, number of adult and intermediate trout. Average daily minimum temperature (MIN T) correlated negatively and significantly to number of juvenile *O. mykiss*. Flow significantly and positively correlated to number of intermediate and juvenile trout with high coefficients. Drought index correlated negatively to number of sites where *O. mykiss* were observed and was included in two additional models as a negative but non-significant term. The population correction term (POP t-1) was significant in three models, although it had a relatively small coefficient of variance.

Table 3.20. OLS stepwise regression matrix modeling climate condition and O. mykiss population relationships in Malibu Creek 2011-2018 (p<0.001***, .01**, .05*). No asterix indicates term was included in final model but was not a significant term (p>0.05). Dashes indicate response variable not included in final model.

Explanatory Variables	# Sites	Total # Adult	Total # Int.	Total # Juveniles
	Response Variables			
7DADM	-21.2**	-4.3**	-21.9*	--
MIN T	--	--	--	-186.2**
FLOW	--	--	31.6*	146.1**
Drought Index	-9.4**	--	-9.0	-24.4
POP (t-1)	<1**	<1****	<1**	--
Final model:	R^2=.95, F(3,7)=48.0**	R^2=.97, F(2,7)=105.3 ****	R^2=.98, F(4,7)= 71.6 **	R^2=.95, F(3,7)=43.9**

3.2.6.7. Relationship of O. mykiss abundance, temperature and abiotic functions during drought

During the drought, average number of *O. mykiss* per month observed in the study pools (all size classes), and *O. mykiss* numbers throughout Malibu creek significantly and positively correlated to wet year rainfall (p<0.05), the strongest correlation was between rainfall and the juvenile size class, followed by intermediates. The average number of adults observed did not correlate to rainfall. Number of locations (pools) where *O. mykiss* were observed in monthly surveys positively correlated to wet year rainfall, but not significantly. Average number of *O. mykiss* observed per month in 1.0 rkm Start, 1.9 rkm Lunch, and 2.6 rkm Grimmer positively correlated to percent canopy cover (p<0.05).

Pool volume, however, negatively correlated to average numbers of intermediates and adult *O. mykiss*, and number of locations where *O. mykiss* were observed throughout the creek (p<0.05). This is likely due to the fact that steadily fewer numbers of fish were observed over the course of the drought, despite higher pool volumes 2014 – 2016. Higher pool volumes these years could have resulted from increased frequency and/or magnitude of augmentation flows. Number of fish in the study pools, and number of juvenile fish throughout Malibu Creek did not correlate significantly to changes in pool volume.

In summary, rainfall seemed to yield stronger influence on observed *O. mykiss* abundance than water temperature, and more *O. mykiss* are found during years and in locations with greater canopy cover and in years with more rainfall.

This suggests that although Malibu Creek experienced maximum temperatures identified as potentially close to the critical thermal maximum, *O. mykiss* of all size classes were minimally affected by high temperatures, instead, abundance responded to other variables, such as predation, precipitation and/or other abiotic factors.

3.2.6.8. Flow

Discharge and flow stage were recorded at the 0 rkm Cross Creek Road Bridge by USGS from 2007-2011 and also at the Los Angeles County stream gauge (F130, Figure 3.23) located downstream of the outlet of the Tapia Water Reclamation Plant. The flow varied from below 0.68 cfs to a high of 1,440 cfs in 2016. During the summers in 2013-2016, flows fell below the 2.5 cfs requirement for discharge to support steelhead so augmentation discharges of approximately 82 million gallons were released in order to comply with their NMFS permit. Unfortunately, these flows were not sufficient to maintain surface connectivity downstream of Rindge Dam for much of the summer and fall months. Annual mean flow positively correlated to wet year rainfall ($r \geq 0.64$, $F_{1,4,}$ $p < 0.05$). Daily mean flow had negative, though weak correlations to maximum and minimum air temperatures ($r \geq 0\ .03$, $F_{1,890,}$ $p < 0.05$). Peak flows in excess of 300 cfs occurred in January 2017, but it was not until January 2019 that flows again exceeded 1000 cfs. Summer flows were almost not measurable.

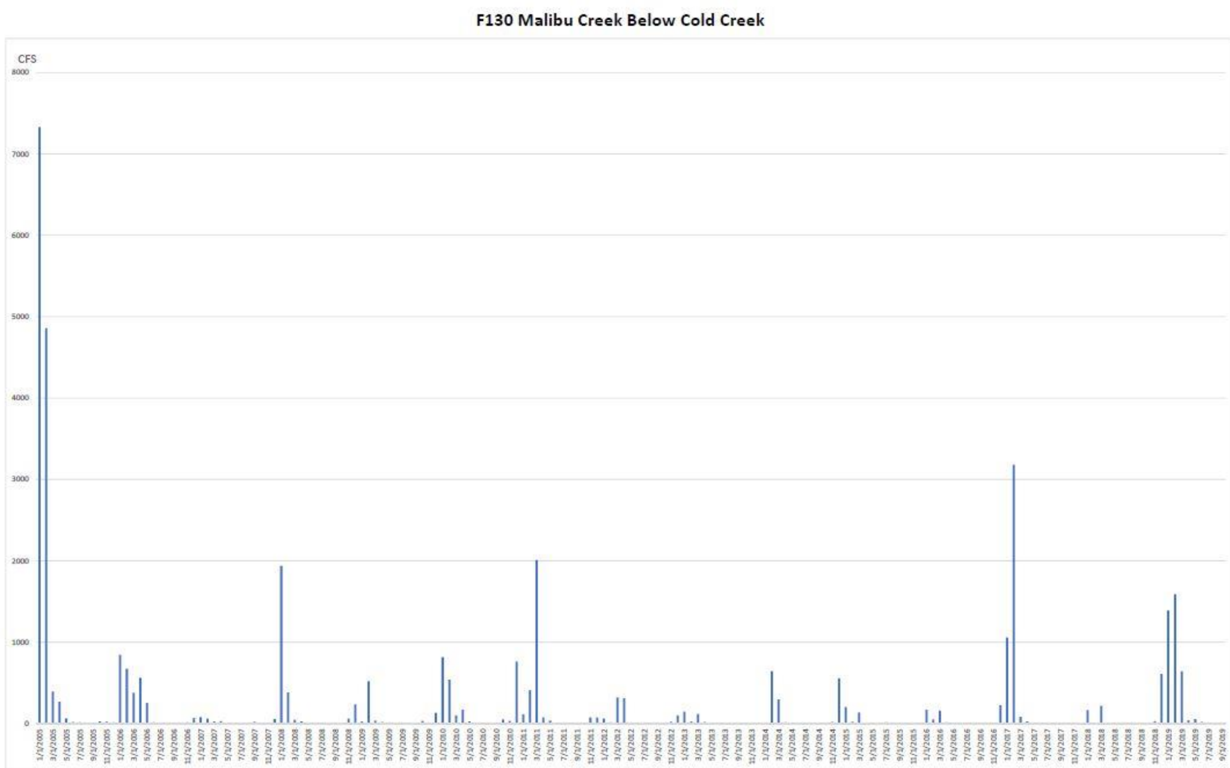


Figure 3.23. Mean Daily Flow at Malibu Creek gauge (F130) 2011-2019.

3.2.6.9. Malibu Creek Connectivity

Malibu Creek consistently remained connected from the ocean to Rindge Dam from November through April in all study years. During the summer months, we documented several times when pools dried up and the creek was interrupted by reaches of subsurface flow, and these reaches increased significantly in 2016 (Table 3.21). Not only did this provide a barrier to fish movement between pools, it decreased habitat availablity overall. Following the 2007 wildfire in the watershed, several pools were filled by sediments, altering the distribution and availability of suitable refugia pools, however the flash floods in January and February 2017 redistributed these materials and restored many smaller step pools. Monitoring conditions of pools downstream of Rindge Dam is particularly important in light of the proposed effort to remove the dam. Data collected during snorkel surveys was incorporated into the Malibu Creek Restoration Project Environmental Impact Report (USACOE 2014) and the EIR (USACOE 2017) in order to examine potential impacts associated with predicted sediment inputs and scour associated with dam removal in specific locations, and will continue to be updated as surveys continue. One of the main variables considered in the USACOE Habitat Evaluation was surface connectivity. Despite additional sedimentation from the Woolsey Fire (2018), rainfall was sufficient to maintain connectivity throughout much of the study reach with a small drydown in the Mullett Pool during August and September 2019.

Table 3.21. Summary of Interrupted Flow conditions 2011-2019.

Dates	Locations
September 2008	1.4 rkm Mullet Pool dry
October 2008	Reach from step pools below 1.4 rkm Mullet Pool to just below 1.6 rkm Lower Twin Pool
July –August 2009	1.4 rkm Mullet Pool dry
September 2009	1.4 rkm Mullet Pool to 1.7 rkm Upper Twin Pool dry
October 2010	1.0 rkm Start Pool to 1.6 rkm Lower Twin Pool dry
2011	Fully connected
July - November 2012	1.0 rkm Start Pool to 1.6 rkm Lower Twin Pool dry
June - November 2013	1.0 rkm Start Pool to 1.6 rkm Lower Twin Pool ol dry
June – November 2014	Cross Creek Bridge to 1.0 rkm Start Pool, 1.0 rkm Start Pool to 1.6 rkm Lower Twin Pool dry
June – December 2015	Cross Creek Bridge to 1.0 rkm Start Pool, above 1.0 rkm Start Pool to 1.7 rkm Upper Twin Pool dry
May – September 2016	Cross Creek Bridge to 1.0 rkm Start Pool, above 1.0 rkm Start Pool to 1.9 rkm Lunch Pool, above 1.9 rkm Lunch Pool to 2.6 rkm Grimmer Pool dry, above Grimmer to Big Wide Pool dry
August – September 2017	1.0 rkm Start Pool to 1.7 rkm Upper Twin Pool dry
November – December 2017	1.0 rkm Start Pool to 1.4 rkm Mullet Pool Dry, 1.78 rkm Turtle Run to 1.9 rkm Lunch Pool dry
June 2018	1.4 rkm Mullet Pool to 1.7 rkm Upper Twin Pool dry
July – September 2018	1.0 rkm Start Pool to 1.6 rkm Lower Twin Pool dry
August – September 2019	1.4 rkm Mullet Pool dry

3.2.6.10. Water Quality

Water quality parameters (dissolved oxygen, temperature, nitrates, nitrites, ammonia and orthophosphate) were recorded by the Heal the Bay Stream Team using monthly grab samples (Table 3.22 and 3.23). Samples are collected at MC1, located just upstream of the Cross Creek Rd. Bridge and at MC15 which is located at the stream gauge. Sampling ceased in 2016, but restarted following the Woolsey Fire (2018) however results are not yet available.

Table 3.22. MC1 Water Quality Summary 2011-2014. Courtesy of Heal The Bay (n=26 sampling events from January 2012 through September 2014).

Variable	Average Value	Highest value	Lowest value
Dissolved oxygen (mg/l)	9.36	12.50	5.25
Turbidity (NTU)	0.76	1.95	0.00
Conductivity (uS)	1679	2405	1027
Nitrates (ppt)	1.95	8.10	0.00
Phosphates (ppt)	2.18	3.59	0.37
Ammonia (ppt)	0.08	0.17	0.00

Table 3.23. MC1 and MC15 Water Quality Summary. Courtesy of Heal The Bay (n=7 sampling events from January 2015 through February 2016).

Variable	Average Value	Highest value	Lowest value
MC1			
Water Temperature ºC	15.18	19.25	12.30
Dissolved oxygen (mg/l)	9.36	12.50	5.25
Turbidity (NTU)	0.76	1.95	0.00
Conductivity (uS)	1679	2405	1027
Nitrates (ppt)	1.95	8.10	0.00
Phosphates (ppt)	2.18	3.59	0.37
MC15			
Water Temperature ºC	18.97	23.05	16.30
Dissolved oxygen (mg/l)	8.60	10.25	5.79
Turbidity (NTU)	1.60	4.05	0.00
Conductivity (uS)	1759	2730	1335
Nitrates (ppt)	3.29	9.6	0.00
Phosphates (ppt)	3.27	4.13	0.64

A continuously logging data sonde was deployed in 1.0 rkm Start Pool from November 2012 to September 2019. Yearly averages were calculated and summarized in Table 3.24. Despite several gaps in the data due to sensor malfunctions, trends for pH, temperature, dissolved oxygen (DO) and conductivity can be seen in the graphs in Appendix D. During the months when the data sonde was functioning properly in 1.0 rkm Start Pool, DO levels were highest during the winter months and lowest during the summer. During the drought, levels dropped as low as 1.4 mg/l. The pH levels generally ranged from 7 to 8.5 but did not display much seasonality. Conductivity levels ranged from 1000-1500 µS/cm during the winter months and 1800-2000 µS/cm during the summer months. Temperatures were lowest during the winter months, ranging from 10-20˚C, and higher during the summer months, ranging from 17-22˚C. While pH, temperatures and conductivity are all within range considered suitable for wildlife, dissolved oxygen levels are cause for concern, especially during the drier months.

Table 3.24. Parameters measured by continuously logging data sonde in Start Pool, Malibu.

	2013			2014			2015			2016			2017			2018			2019		
Parameter	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**
pH	8.19	7.44	7.75	8.59	7.28	7.84	8.02	7.07	7.40	8.42	7.11	7.67	8.33	6.22	7.54	8.17	7.51	7.81	8.79	6.86	7.82
Conductivity (µS/cm)	1837.00	1412.58	1605.80	1956.83	1502.33	1741.75	1936.92	1425.20	1737.82	1926.00	1076.53	1568.77	1998.00	1.20	900.00	1726.70	992.61	1555.29	1880.00	1.30	830.04
DO (mg/L) *(n=7mo)	10.75	2.78	6.21	7.84	1.59	4.82	8.15	1.95	4.64	8.09	1.49	4.72	52.50	0.00	7.37	8.22	0.22	2.59	13.32	0.00	4.15
Temperature	19.44	14.01	16.62	19.84	14.84	17.34	19.95	14.65	17.45	18.90	14.00	16.50	24.61	16.29	19.75	23.33	9.92	17.96	20.82	15.00	17.74

*Dissolved oxygen sensor malfunctioning, n=7 months of data
** sonde failed for

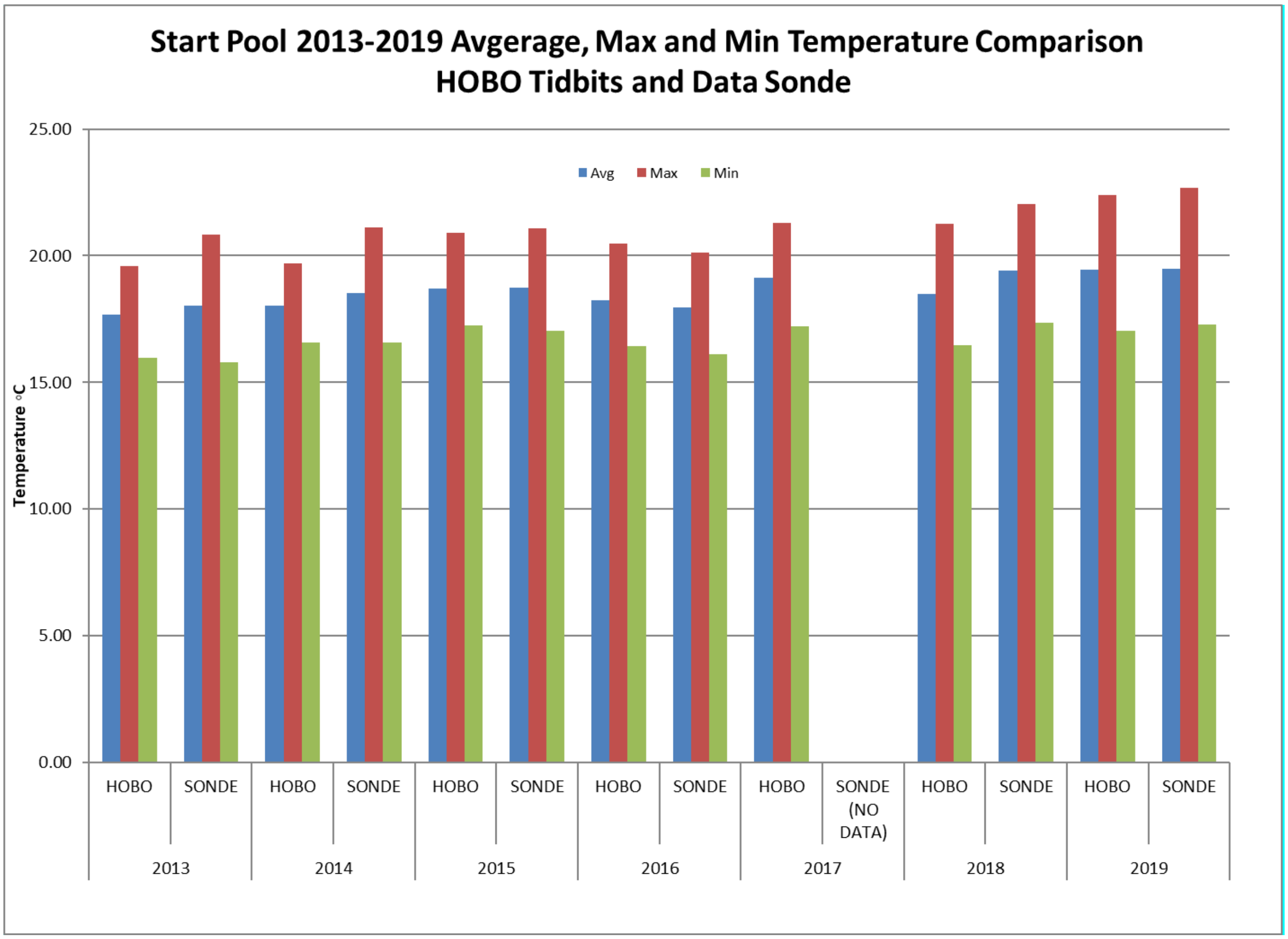


Figure 3.24. Comparison of data continuously collected in Start Pool by two data loggers (HOBO tidbit, and Data Sonde) shows that temperatures were similar, as expected.

3.2.7. Benthic Macroinvertebrates

Macroinvertebrate samples were collected from four locations in the Malibu Creek Watershed, one site in Malibu Creek (MC15) mainstem and two in the tributary Cold Creek (CC2, CC3), by the Heal the Bay Stream Team in July 2015-2016. Using the metrics developed by the Index of Biological Integrity for the Santa Monica Mountains (Ode et. al. 2005), sites in Malibu Creek were very poor (IBI scores between 7-17). Scores were slightly higher at Cold Creek upstream tributary sites but drought impacts still kept them in the very poor to good range (7-76). Samples taken near the stream gauge upstream of Rindge Dam (MC15) scored the lowest (7-17), categorized as 'very poor' for all five years with significant decline in 2014-2015, however all sites showed decreased IBI scores as the drought progressed from 2013-2016. No samples are available since 2016.

3.2.8. Invasive Species Monitoring

Introduced Freshwater species observed during snorkel surveys include:

Green sunfish	*Lepomis cyanellus*
Bluegill	*Lepomis macrochirus*
Largemouth bass	*Micropterus salmoides*
Mosquitofish	*Gambusia affinis*
Black bullhead	*Ictalurus melas*
Channel catfish	*Ictalurus punctatus*
Common carp	*Cyprinus carpio*
Fathead minnow	*Pimephales promelas*

Non-fish invasive species observed during snorkel surveys include:

Bullfrog	*Rana catesbeiana*
Crayfish	*Procambarus clarkii*
Asiatic clam	*Corbicula fluminea*
New Zealand mudsnail	*Potamopyrgus antipodarum*

We were not able to quantify the exact abundance of these invasive species, although notes were made if species were extremely abundant or few in number (and thus easier to count). The following bar graphs (Figures 3.25-3.31) summarize the individual abundance as well as the distribution of the most common invasive species within the study reach of Malibu Creek from January 2006 to November 2019. Data were gathered during monthly snorkel surveys in which the objective was to determine the number of *O. mykiss* present, hence numbers for individual invasive species reflect trends rather that accurate abundance.

Figure 3.25 represents the number of Red Swamp Crayfish (*Procambarus clarkii*) present throughout the study reach of Malibu Creek. This graph indicates a sharp increase in crayfish in May 2015, when there was a record 10,000 crayfish present in just one pool. Crayfish populations in Malibu Creek, when compared to Topanga Creek, appear less evenly distributed throughout the creek. Crayfish instread appear to be present in sporadic numbers over, at most, 18 pools in Malibu Creek whereas in Topanga their population is spread over 60 pools. Since

2010, crayfish abundance appears to fluctuate in a semi-regular pattern, with a population spike in June or July and steady decline as the summer fades into fall and winter.

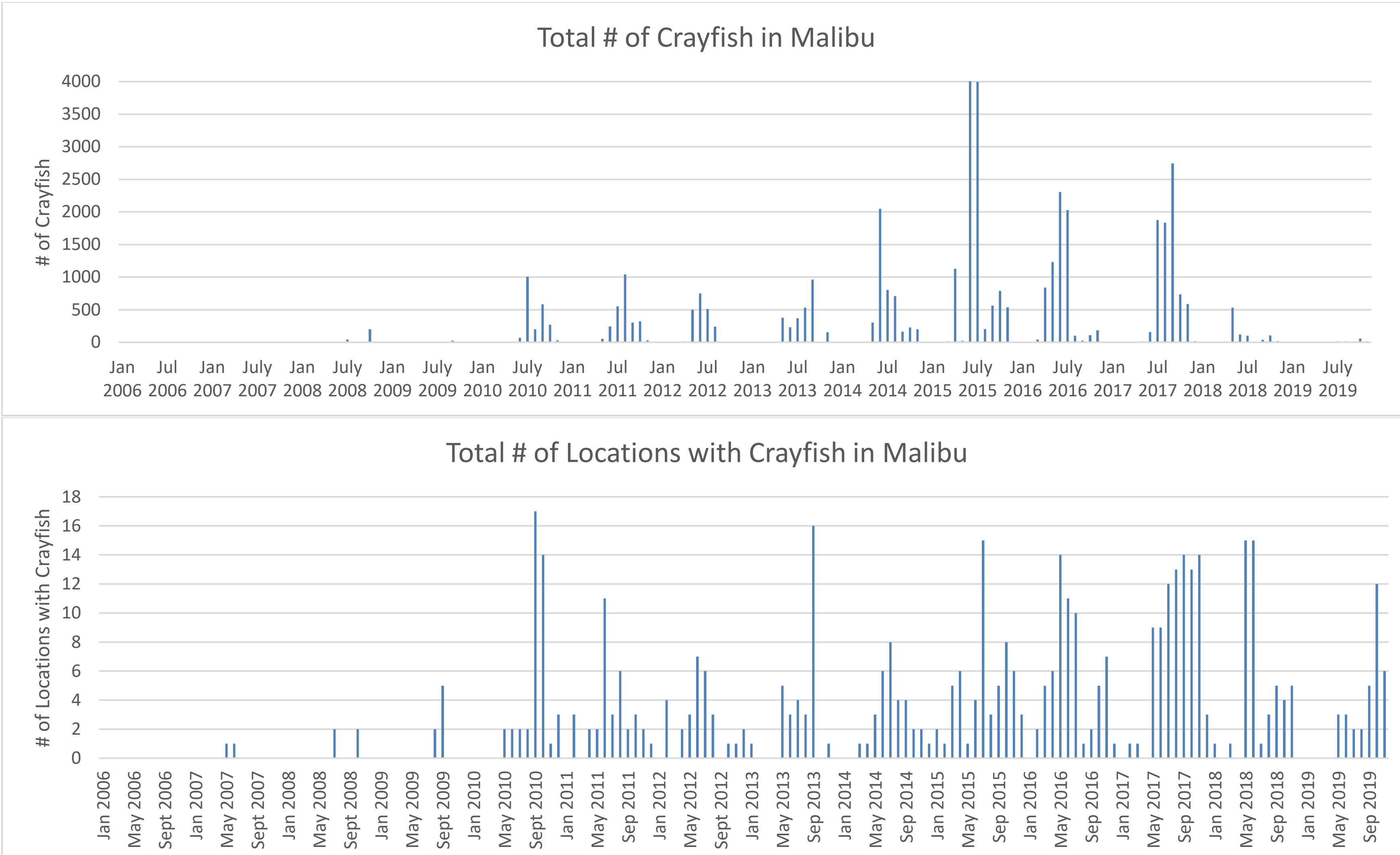


Figure 3.25. Abundance (top graph) and distribution (bottom graph) of crayfish in Malibu Creek.

Figure 3.26 represents the number of Red Swamp Crayfish (*Procambarus clarkii*) in comparison to the number of *O. mykiss* Young of the Year (YOY) present in Malibu Creek. According to the graph, YOY were present in low numbers from 2006 to 2019, with a small population spike in mid to late 2008. The *O. mykiss* numbers deplete to zero by late 2016, while the crayfish population appears to steadily rise post 2014, with a peak in 2015. Crayfish are a known predator of YOY, so this pattern could be significant when considering *O. mykiss* population declines in Malibu Creek, along with other invasive species population increases.

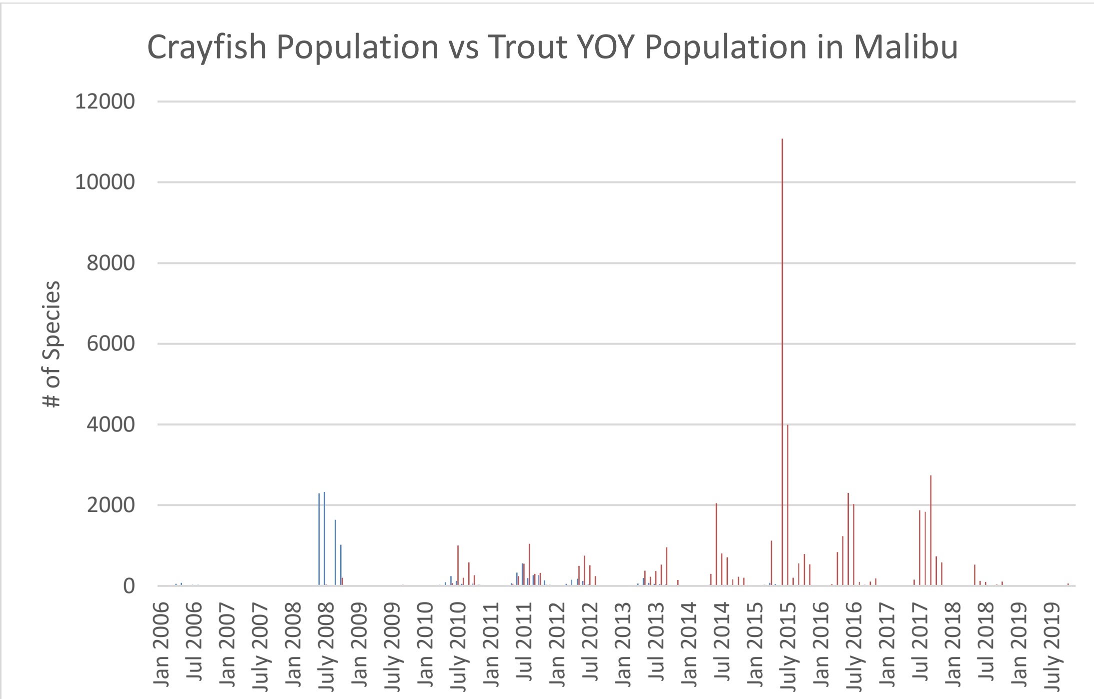
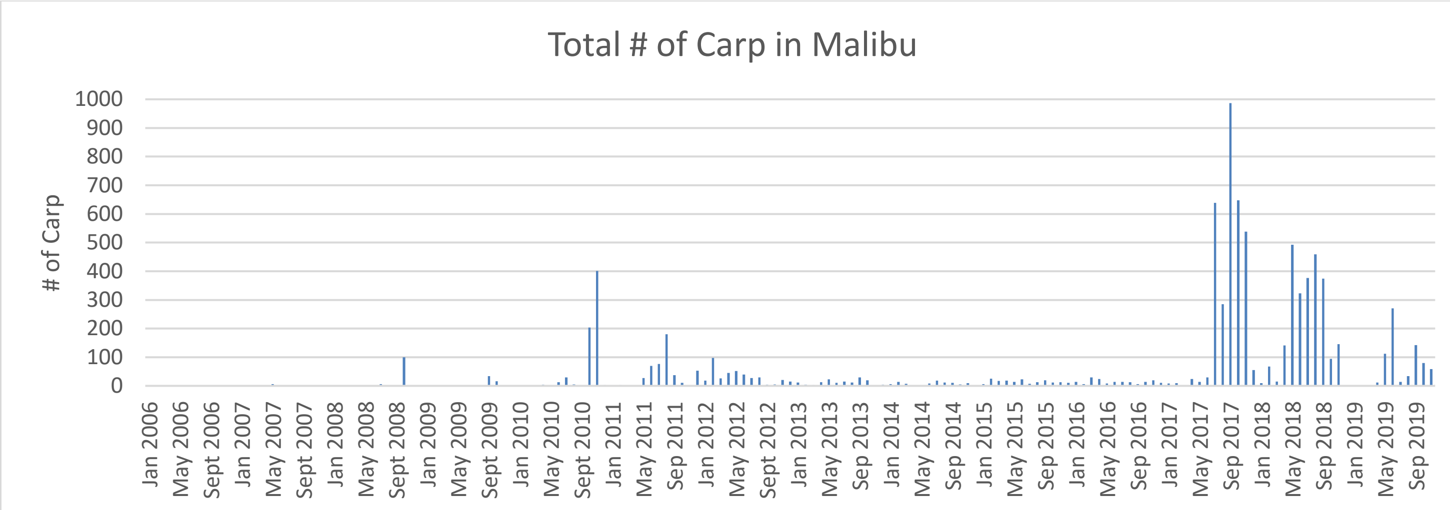


Figure 3.26. Abundance of crayfish (red) and Trout young of the year (YOY) (blue) in Malibu Creek.

Figure 3.27 represents Common Carp (*Cyprinus carpio*) population fluctuations over time in Malibu Creek. It appears carp population numbers remained low until 2017. It should be noted very low numbers of *O. mykiss* have been seen in Malibu since 2015. Carp may be competing with *O. mykiss* for limited resources available in Malibu Creek, so this correlation could be significant when considering salmonid population declines in Malibu Creek. Carp appear slightly more evenly distributed than crayfish, appearing in higher numbers in 20 or so pools compared to 15. Larger spikes in carp population, in the high hundreds, consisted of mostly juvenile carp.



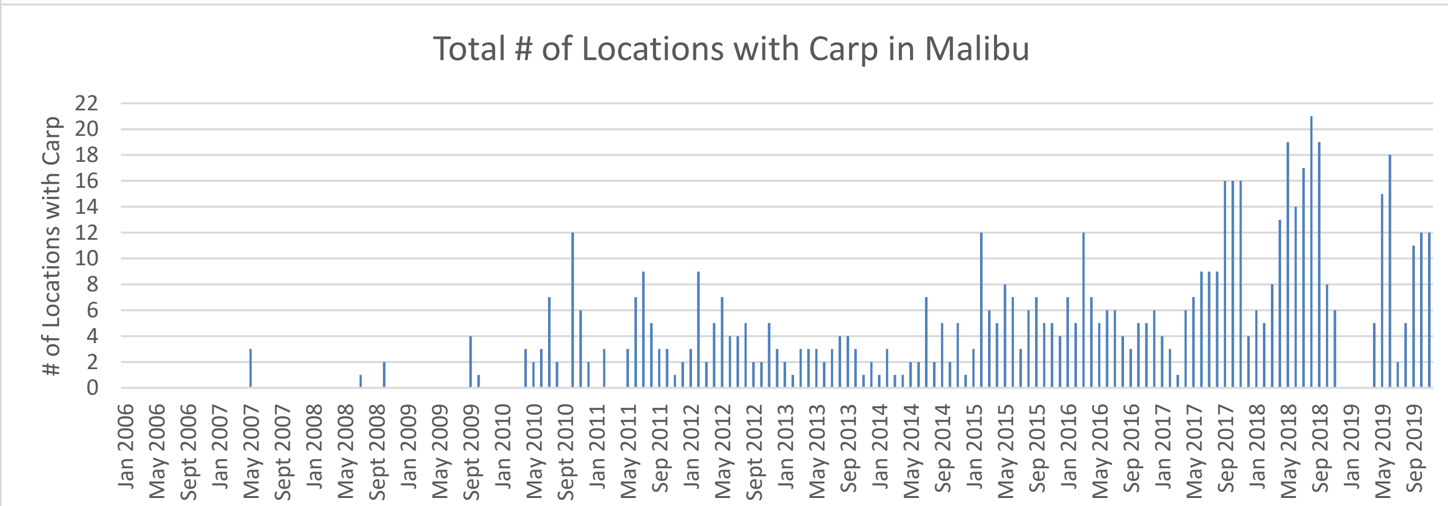


Figure 3.27. Abundance (top graph) and distribution (bottom graph) of Common Carp in Malibu Creek.

Figure 3.28 represents Largemouth Bass (*Micropterus salmoides*) population fluctuations over time in Malibu Creek. It appears, like carp, bass population numbers remained low until 2017. Again, it should be noted that bass may be competing with trout for limited resources available in Malibu Creek, and so the correlation between low trout population numbers and increasing bass population could be significant. Bass, also similar to carp, appear more evenly distributed than crayfish, appearing in higher numbers in 30 or so pools. Larger spikes in bass population numbers (in the thousands) consisted of mostly juvenile bass.

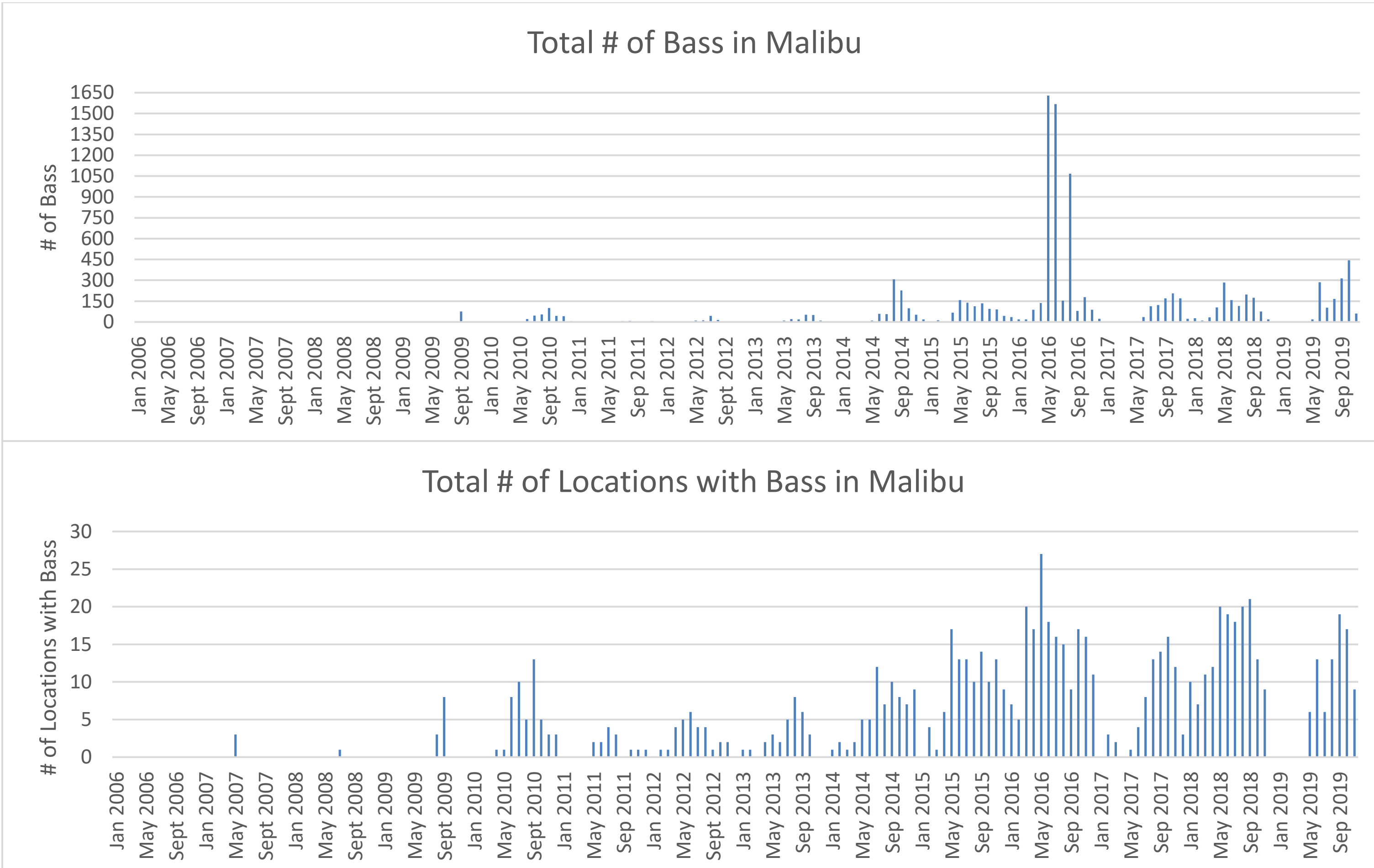


Figure 3.28. Abundance (top graph) and distribution (bottom graph) of Largemouth Bass in Malibu Creek.

Figure 3.29 represents population size of Bluegill (*Lepomis macrochirus*) and Green Sunfish (*Lepomis cyanellus*) in Malibu. Not many sunfish appear after 2017 and they are consistenly present in much smaller numbers when compared to crayfish, carp and bass.

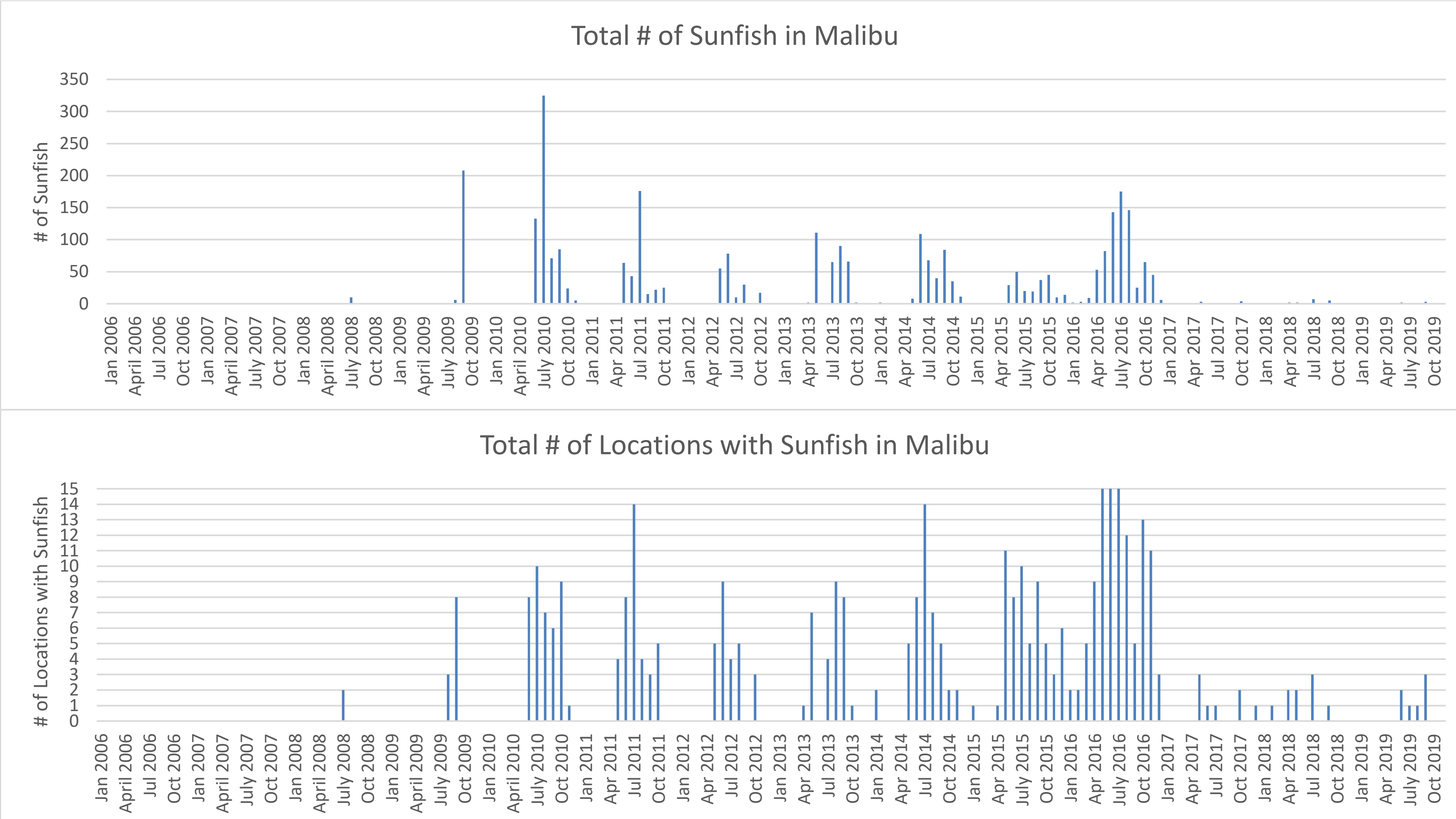


Figure 3.29. Abundance (top graph) and distribution (bottom graph) of Bluegill/Green Sunfish in Malibu Creek.

Figure 3.30 represents poplation size of Channel Catfish (*Ictalurus punctatus*) in Malibu Creek. Catfish populations spikes appear somewhat random, occurring in 2008, 2009 and 2013, with otherwise low numbers. They never appear in more than 3 pools and so do not seem evenly distrubuted. Large spikes in population consisted of mostly juvenile catfish.

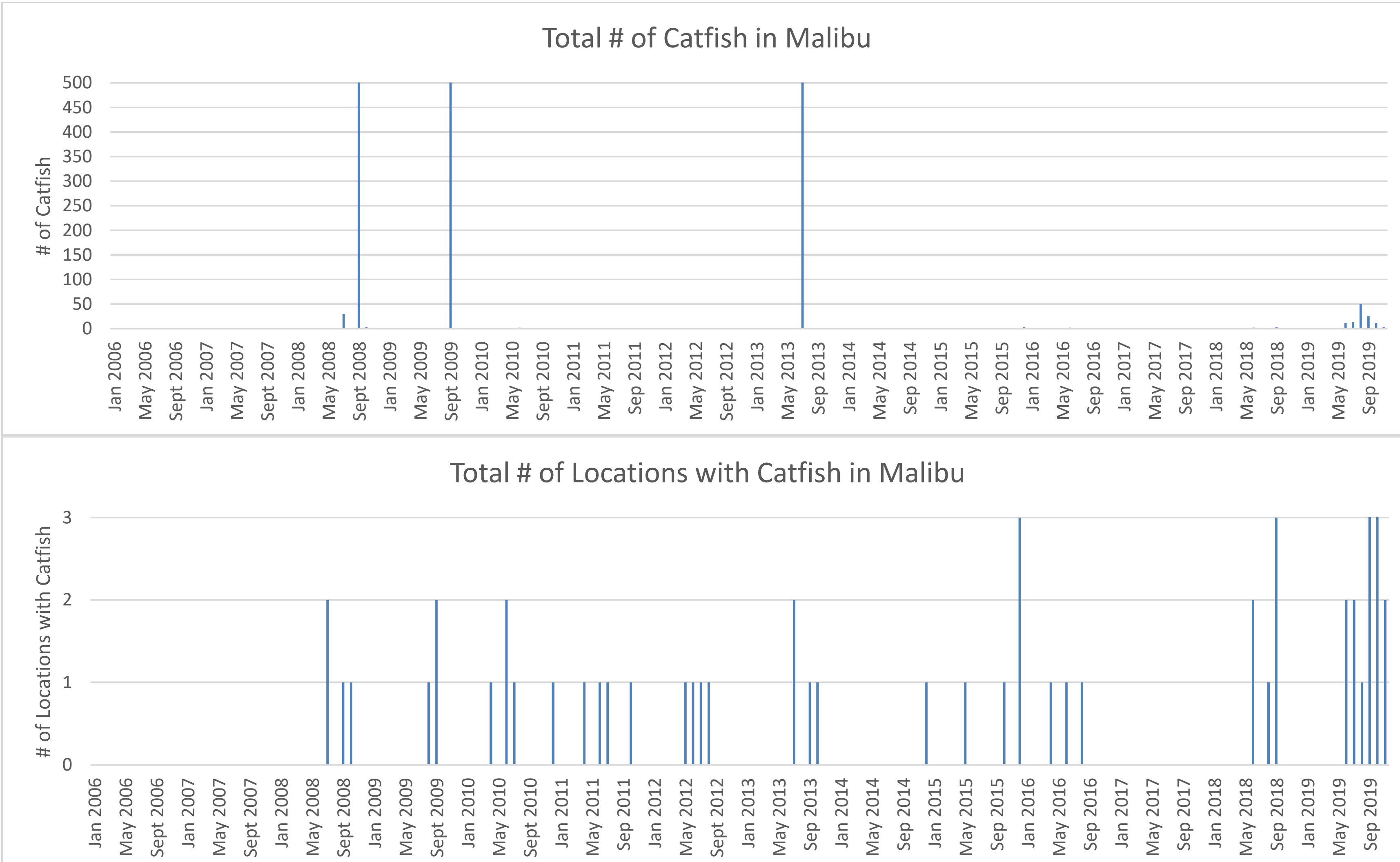
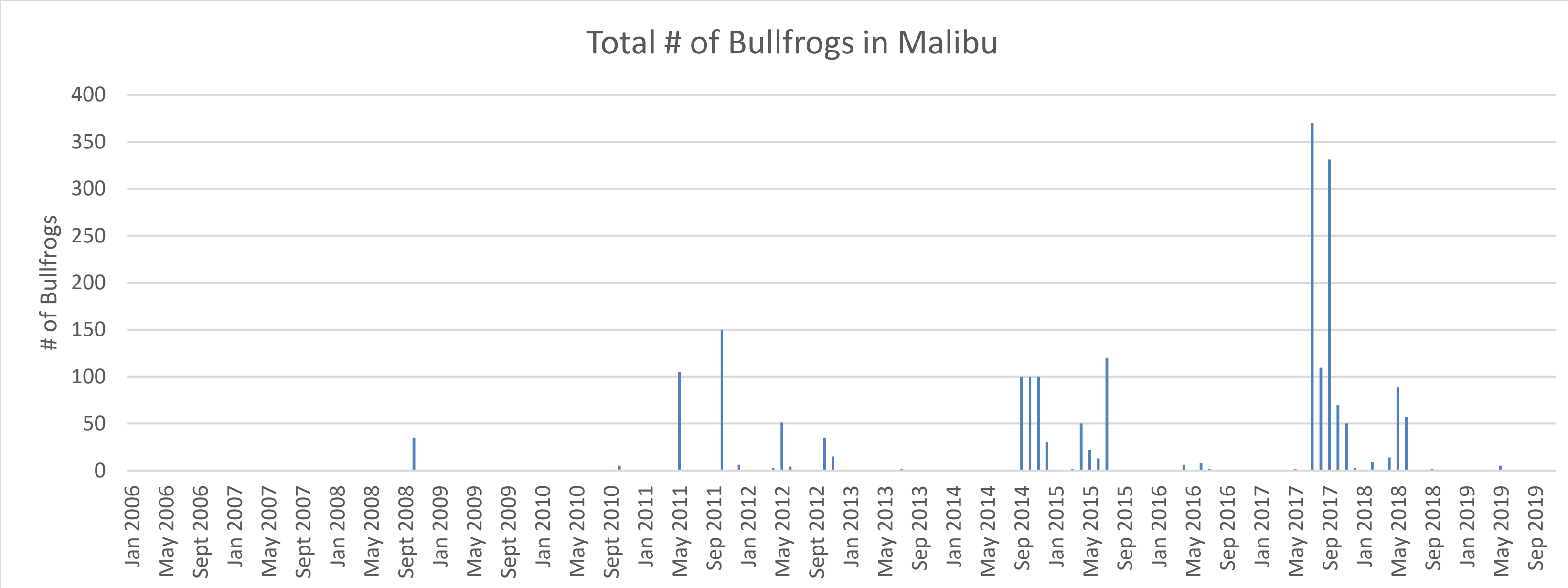


Figure 3.30. Abundance (top graph) and distribution (bottom graph) of Channel Catfish in Malibu Creek.

Figure 3.31 displays population fluctuations in the American Bullfrog. There appears to be a similar population spike to the spike of carp and bass, occuring in 2017. The bullfrogs are not as evenly distributed as other invasive species, appearing in at most five pools. Population sizes in the 100s are correlated with spawning times of bullfrog, when tadpoles accounted for higher numbers.

Most graphs show a steady increase of invasive species after 2012 with a steep drop in late 2018. This timeline may be correlated with the drought, which began in 2011, as well as the Woolsey Fire, which erupted in early November of 2018. The number of locations (pools) which contain invasive species also remains relatively low, in comparison to Topanga.



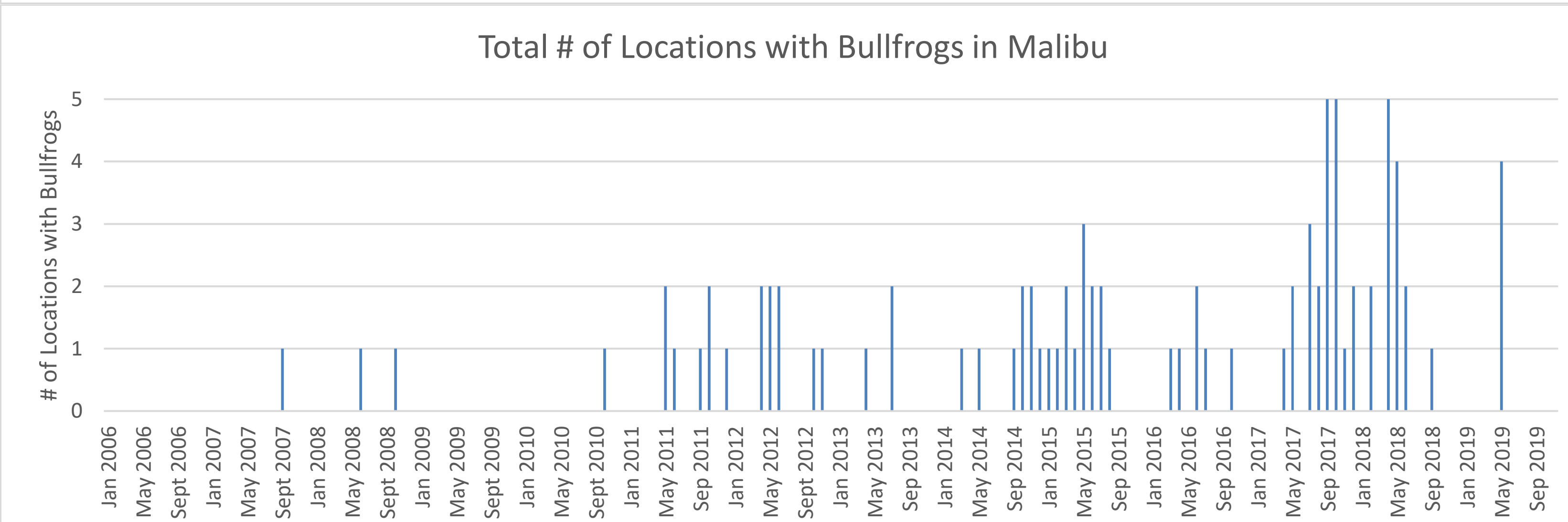


Figure 3.31. Abundance (top graph) and distribution (bottom graph) of American Bullfrog in Malibu Creek.

New Zealand Mud Snail Distribution

New Zealand Mud Snails (NZMS) (Figure 3.32) were first documented in the Malibu Creek Watershed at upper and lower Medea Creek in June 2005 (Aquatic Bioassay and Consulting Laboratories 2005). At those locations, they represented 85 and 15% of all organisms. By September 2005, the population at upper Medea (MED1) had increased to 80% and that at lower Medea (MED2) shot up to 91%. Further investigation found populations also established at lower Malibu (MAL) and several other locations in the upper watershed. These infestations were confirmed by the Heal the Bay data collected in December 2005 and during the NZMS survey in July 2006.

The concerns about the invasion of the NZMS are twofold: a) their overall density could overwhelm the habitat and outcompete native benthic infauna; and, b) snails are known vectors for parasitic trematodes, as well as other potential pathogens.

A targeted visual survey conducted in July 2006 by a team from Heal the Bay and the Santa Monica Bay Restoration Commission found evidence of NZMS distributed throughout the length of Malibu Creek and within the entire reach of lower Malibu Creek where *O. mykiss* reside. NZMS were typically found on all hard substrate, including rocks, emergent vegetation, woody debris, and trash. They were also observed on floating or attached mats of algae.

On 12 February 2007, a sample of over 100 NZMS was collected from the reach between the Start Pool and Upper Twin Pool in the lower reach of Malibu Creek. Fewer than ten native snails (*Physids sp*.) were included in the sample, as that was all that were found. Seven Asiatic clams were also collected when found in the sandy substrate at the tail of Lower Twin Pool. NZMS were widely distributed on most cobble and small boulders along the edge of the bank. On several boulders, the density of NZMS present completely covered the submerged portion of the rock.

Figure 3.32. NZMS on substrate in Malibu Creek February 2007.

Another sample of both native snail and NZMS was collected in the reach just upstream of the location of the former Texas crossing, located in Malibu Creek State Park. At this location, both types of native snails (*Hydrobiid sp*. and *Physid sp*.) were also collected. The NZMS were more widely dispersed across the creek channel, not concentrated along the banks. At least a few individuals were found on almost every cobble or boulder examined.

Both samples were labeled and kept in plastic containers with damp paper towels and transported the following day for examination at UCSB.

Observation of the crushed snails and examination of the gonads under a high power binocular microscope by Dr. Fredensborg at UCSB failed to find any evidence of trematode presence. No parasites of any kind were found on the specimens examined. (Fredensborg, pers. Communication).

Based on sampling done by LVMWD, it appears that the abundance of NZMS dropped during the drought but remain a persistent presence.

3.3. TOPANGA CREEK

3.3.1. *O. mykiss* Population Assessment

We have gathered 19 years of data on population abundance and distribution, habitat suitability during both extremely high and low flow conditions, results of 10 migration trapping events, and an archive of over 1000 fin clips. All snorkel survey counts are summarized in Figures 3.33-35. The overall abundance of *O. mykiss* initially increased from the start of the study in 2001, but even though there were seasonal increases due to young of the year in some years, overall abundance has been decreasing since 2012. This appears to be more related to drought conditions than outmigration, as connection to the ocean has been very limited. In 2017 and again in 2019, winter storms provided both connection and passable conditions with anadromous adults observed in 2017. Visibility constraints could affect the numbers of fish observed during the surveys, however the impacts of excessive algal growth are not as problematic in Topanga compared to Malibu. Instead, potentially conservative estimates of the smallest size classes could be the result of locations that are too shallow to effectively snorkel. The severe decline in abundance associated with the drought 2012-2018 is extremely concerning, even though there was limited recovery in 2019.

The seasonal shift in population structure, with a higher number of individuals, (mostly Young of the Year) in May –June, followed by a decrease in overall numbers of individuals as the year progresses held up until 2019, when low flows decreased numbers in all size classes. Numbers of *O. mykiss* observed have varied year to year and are related to rainfall as shown in Table 3.25.

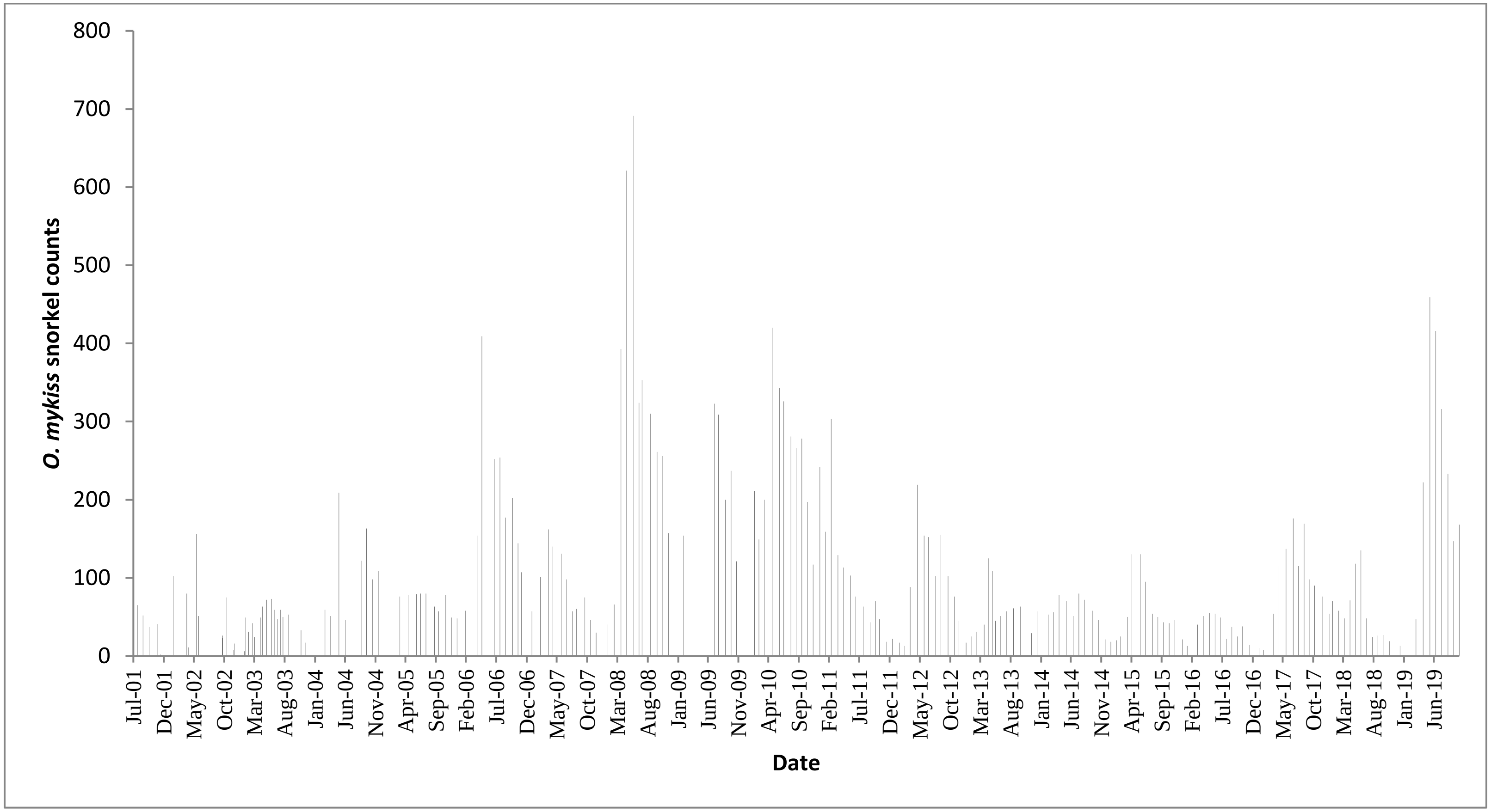


Figure 3.33. Total *O. mykiss* observed in Topanga Creek 2001-November 2019.

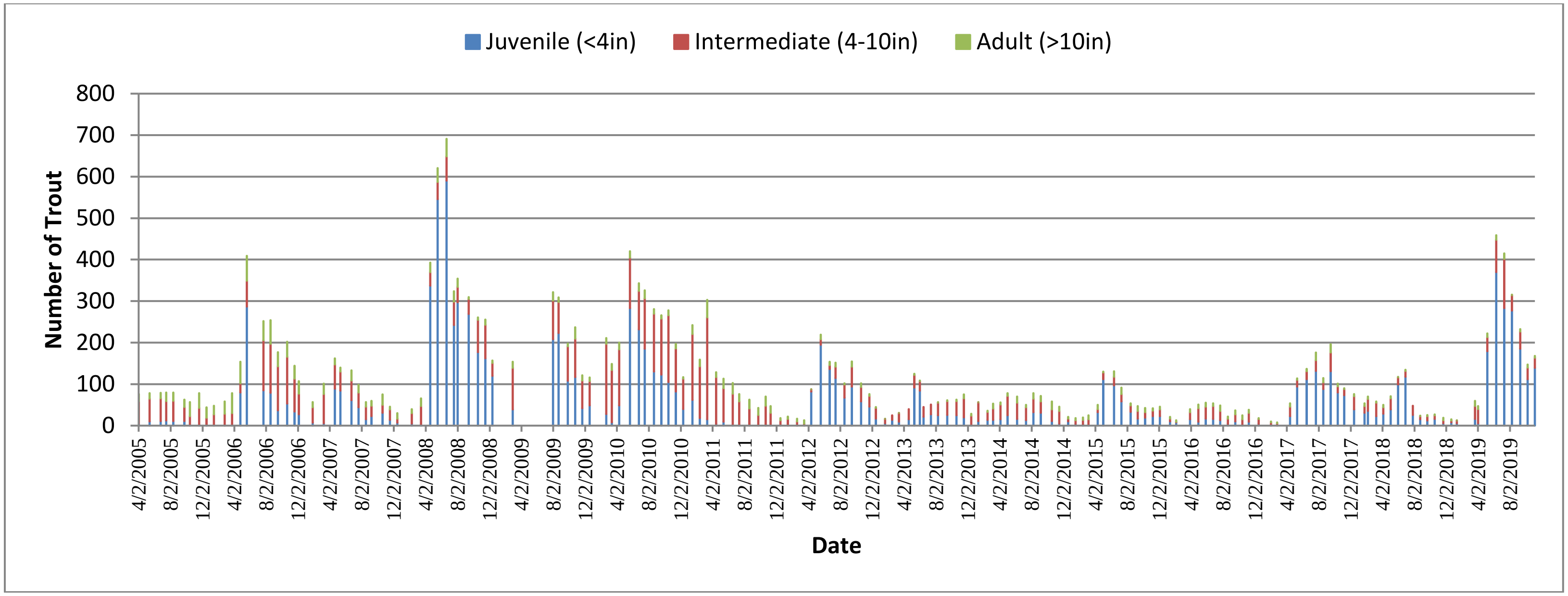


Figure 3.34. Number of O. mykiss by size class in Topanga Creek 2005- November 2019.

Table 3.25. Average number of *O. mykiss* observed per month in Topanga Creek 2001-2019 (n=# survey months/year).

Year	Average Total Juvenile <100mm	Average Total Intermediate 100-250mm	Average Total Adult >250mm	Average Total (n=# survey months/year)	Size Range mm	Smolts Observed	Anadromous Adults Observed	Rainfall* (inches)
2001	25	25	3	8 (n=7)	76-508	0	1	28.16
2002	34	56	6	10 (n=10)	50-508	0	2	9.9
2003	6	34	19	4 (n=16)	76–432	14	1	18.71
2004	46	50	12	14 (n=8)	50–457	0	0	13.16
2005	6	46	20	8 (n=9)	50–431	0	0	61.58
2006	62	68	40	15 (n=11)	38–508	9	1	21.98
2007	35	37	16	8 (n=11)	25–431	0	2	7.17
2008	250	48	18	29 (n=11)	25–508	1	1	23.08
2009	112	82	15	30 (n=7)	50–508	1	0	15.16
2010	115	128	13	34 (n=11)	25-508	1	1	24.34
2011	9	85	20	10 (n=12)	50-508	1	0	31.50
2012	68	21	7	8 (n=12)	25-457	0	1	16.22
2013	28	26	2	4 (n=13)	25-356	4	0	9.99
2014	16	31	9	5 (n=12)	13-483	0	0	6.85
2015	35	14	9	5 (n=12)	25-508	0	0	13.49
2016	9	18	7	3 (n=13)	51-508	0	0	10.54
2017	70	20	8	9 (n=11)	25-711	0	2	26.34
2018	35	16	4	4 (n=13)	25-457	1	0	9.91
2019	115	37	8	32 (n=12)	25-508	0	0	32.55

3.3.1.1. Distribution

The distribution of *O. mykiss* throughout the creek varied seasonally (Figure 3.35). When the numbers of fish observed increased, the number of locations where they were found also increased. As the drought continued, available habitat decreased and shifted distribution of fish into the higher gradient reach above 3.6 rkm where step pools and mid-channel pools remained more stable and reliable.

Analysis of habitat preferences and pool conditions is detailed in Dagit et al. (2016).

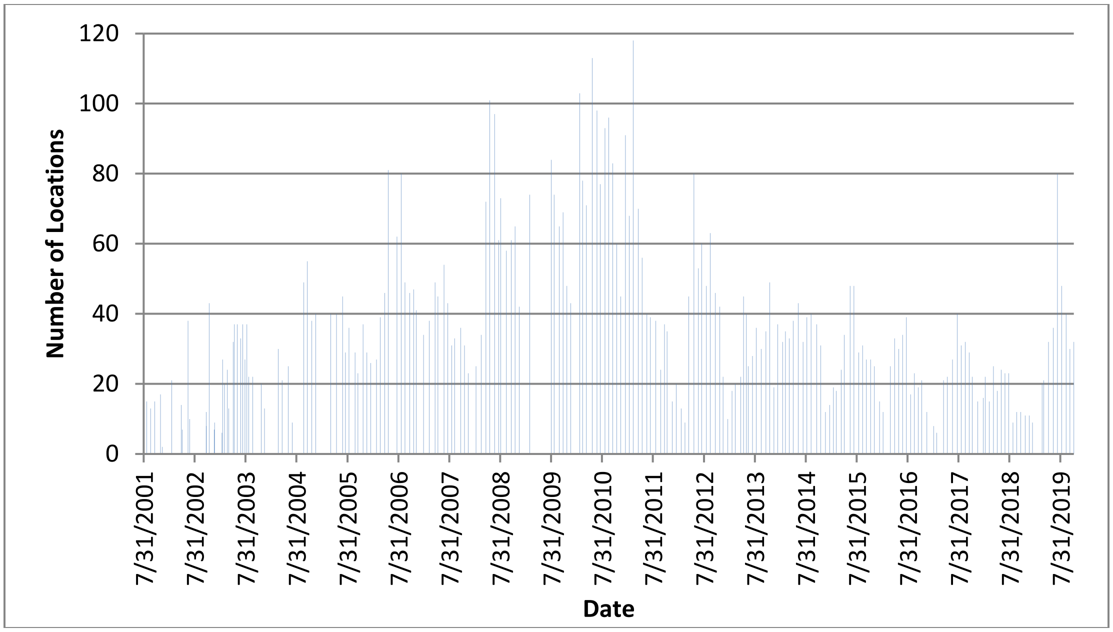


Figure 3.35. Number of locations used by *O. mykiss* in Topanga Creek, 2005- November 2019.

3.3.1.2. Relocation Disease and Mortality

During August 2016, we noted several pools where *O. mykiss* were located that were disconnected and began to dry down. Dissolved oxygen and water temperatures were collected during snorkel surveys to identify pools where fish were at risk of stranding. On 4 August 2016 in coordination with the CDFW electrofishing team, we relocated three fish into larger, deeper and more stable pools having better dissolved oxygen conditions. A single backpack electrofisher was used set on 130 volts, 30 Hz and 25% duty cycle. Every effort was made to minimize exposure and stress. The largest *O.mykiss* was a 274 mm FL individual first tagged in 2013 in 1.925 rkm pool. We captured it in the pool at 1.97 rkm and moved it to 2.0 rkm and the pit tag was recovered in late August suggesting that the fish had not survived. Another 186 mm FL individual with no tag was captured in 3.2 rkm and released at 3.32 rkm, which was a larger, more stable pool. Dissolved oxygen levels in the capture pools was 2-3 mg/l, and over 5 mg/l in the relocation pools. Water temperatures in the all pools were over 20^{o}C at the middle of the day.

Notes on presence of diseased or dead individuals were made during snorkel surveys and carcasses were retrieved if possible. Table 3.26 summarizes the observations on diseased individuals. None of the *O. mykiss* in Topanga Creek were oddly colored but many showed evidence of Ich. No diseased individuals were noted prior to 2006. Table 3.27 notes mortalities observed. Frequently, carcasses are too decayed to salvage although attempts to collect tissue samples and otoliths were always made.

Table 3.26. Observations of diseased *O. mykiss* in Topanga Creek 2001-2019.

Date	Number of Diseased Individuals	Notes
2001	0	None Observed
2002	0	None Observed
2003	0	None Observed
2004	0	None Observed
2005	0	None Observed
2006	0	None Observed
2007	0	None Observed
4/18/2008	1	10”, 4.2 RKM Ken2 Pool
2009	0	None Observed
2010	0	None Observed
2011	0	None Observed
2012	0	None Observed
10/2013	1	10", 3.525 RKM Shrine Pool
5/2014	1	4", 4.05 RKM Fern Grotto
6/2014	1	8", 2.0 RKM Ski Pole Pool
11/2014	1	7", 3.5 RKM Engine Pool
5/11/2017	2	10", 4.0 RKM Noel Pool
5/11/2017	1	10", 4.13 RKM Rip Rap Willow Trench
5/11/2017	1	12", 4.25 RKM No Parking Pool
6/15/2017	2	9", 6", 3.8 RKM Big Boulder Pool
6/16/2017	1	17", 5.275 Pool Below Grotto
7/21/2017	1	14", 4.16 RKM Alders Pool
9/15/2017	1	11", 3.8 RKM Big Boulder Pool
1/23/2018	1	12", 3.9 RKM Step Above Sycamore Pool
1/23/2018	1	16", 5.14 RKM Fig Tree Pool
8/23/2018	1	14", 4.02 RKM Pool Above Noel
9/20/2018	1	9", 4.3 RKM Car Pool
10/18/2018	1	14", 4.3 RKM Car Pool
2019	0	None Observed

Table 3.27. Observations of Dead *O. mykiss* in Topanga Creek 2001-2019.

Date	Number of Dead Individuals	Notes
10/22/2002	1	16”, 3.7 RKM culvert above the bridge
10/27/2002	1	12”, 3.9 RKM Sycamore tree
2/26/2003	1	19”, 1.69 RKM Pool below Brookside
2004	0	None Observed
2005	0	None Observed
8/18/2006	1	4”, 3.49 RKM Engine Pool
2007	0	None Observed
6/20/2008	1	3”, 4.1 RKM Cal Trans Formation
11/14/2008	1	11”, 4.11 RKM Top of Cal Trans Formation
2009	0	None Observed
2010	0	None Observed
2011	0	None Observed
2/17/2012	1	8", 2.24 RKM Headshot Culvert Pool
3/16/2012	1	11", 4.45 RKM above Duck Seep
2013	0	None Observed
10/17/2014	1	Too decomposed to get size, 4.92 RKM J2 Pool
2015	0	None Observed
2/4/2016	1	13", 4.45 RKM
1/31/2017	1	8", tagged(P262), dead at bottom of 3.5 RKM
8/18/2017	1	9", 5.025 RKM Red Rock Pool
1/23/2018	1	16", 5.025 RKM Red Rock
2/5/2018	1	12", 5.2 RKM, Pool Below Grotto, very decomposed
3/8/2018	1	8", 2.6 RKM Ken 2
4/5/2018	1	12", 4.735 RKM Bedrock Trench
2019	0	None Observed

3.3.1.3. Pre and Post Restoration 0-1.3 RKM

The removal of the Rodeo Grounds Berm and subsequent restoration of the reach between 0.5 – 1.3 rkm was completed in October 2008 (Table 3.28). More *O. mykiss* had been observed in that reach since the restoration, until drought took hold in 2013. A scour pool formed under a fallen sycamore tree that held water from December 2013 through May 2014, but no *O. mykiss* were observed. The entire reach dried out during most of 2015-2016. Despite average rainfall levels in 2017, the reach dried out during the summer months and remained disconnected through 2018 except during rain events. Continuous flow was restored in winter 2019 through June 2019, but no fish or redds were observed. A few *O. mykiss* were observed passing through by the instream antenna and DIDSON camera. That information is provided in Dagit et al. (2018b).

Table 3.28. Abundance and distribution of *O. mykiss* 2001-2019 in the 0-1.3 RKM reach.

YEAR	Total # of *O. mykiss*	# Locations *O. mykiss*	Duration of surface flow and connectivity	Rainfall inches
2001-2002	0	0	Berm pool only	28.16
2002-2003	2	2	March 2003	9.9
2003-2004	0	0	Berm pool only	18.71
2004-2005	5	3	Berm pool only	13.16
2005-2006	17	2	Berm pool only	61.58
2006-2007	1	1	Berm pool only	21.98
2007-2008	7	8	April – May 2008	7.17
2008-2009	1	1	Dec. 2008 –Feb. 2009	23.08
2009-2010	40	12	February – June 2010	15.16
2010-2011	2	1	May 2010	24.34
2011- 2012	10	1	May 2011-May 2012	16.22
2012-2013	0	0	December 2012-January 2013	9.99
2013-2014	0	0	Jan 2013, Dec, Mar-April 2014	6.85
2014-2015	0	0	Dec 2014 – Mar 2015	13.49
2015-2016	0	0	March	10.54
2016-2017	0	0	Dec 24, Jan 11 – March 2017	26.33
2017-2018	0	0	January 2018, March 2018	9.91
2018-2019	0	0	January 2019 – May 2019	32.55

3.3.2. Spawning and Redd Survey Data

Snorkel and redd surveys conducted between January and May observed few redds overall and most have been associated with resident *O. mykiss* ranging in size from 152-305 mm (Table 3.29). It is difficult to determine how many of the *O. mykiss* present in Topanga Creek are resident versus anadromous without genetic data, but given the limited passage opportunities, we are assuming that the majority of young of the year since 2011 are progeny of resident adults.

Table 3.29. Summary of Redd observations in Topanga Creek 2001-2019.

YEAR	Number of Redds Observed	Rainfall inches
2001	0	28.16
2002	0	9.9
2003	0	18.71
2004	0	13.16
2005	0	61.58
2006	3	21.98
2007	0	7.17
2008	0	23.08
2009	0	15.16
2010	4	24.34
2011	4	31.50
2012	2	16.22
2013	3	9.99
2014	3	6.85
2015	0	16.06
2016	0	10.54
2017	2	26.34
2018	4	9.91
2019	0	32.55

Overall, gravel sites increased between 2010 and 2012, and then decreased in 2013 and 2014. (Figure 3.36) In early 2015, the availability of gravel sites increased briefly as a result of a spring flushing rain event, but then decreased again as vegetation encroached into the channel during the drought. In winter 2017, availability of gravel sites recovered slightly following more flushing flows. Suitable gravel areas decreased again in 2018 and did not increase during the rains of 2019. In 2018 and 2019 embeddedness throughout the creek increased 40 to 50% based on spring mapping events.

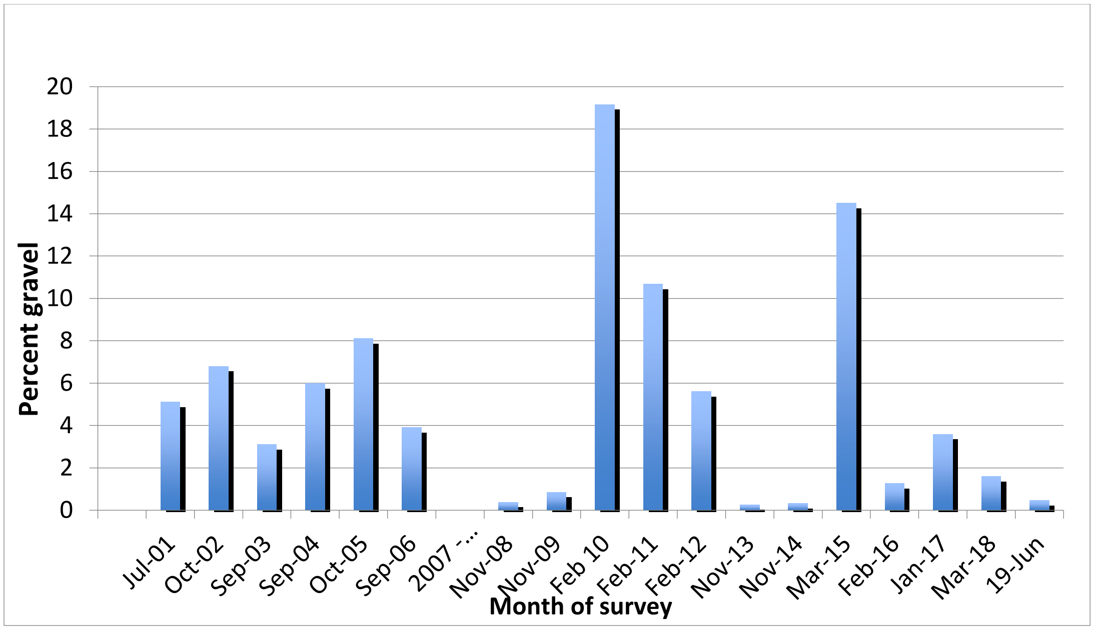


Figure 3.36. Percentage of Topanga Creek (RKM 0–6.0) with gravel suitable for O. mykiss spawning.

Water temperature does not appear to be a limiting factor for successful spawning, with temperatures continuing to range from 10-12ºC in February through April when measured during snorkel and redd surveys. Snorkel survey observations indicate that typically young of the year emerging in May and June moved into the 100 mm or greater size classes by early fall, although this pattern was disrupted from 2016 to 2018 due to drought. The numbers of young of the year *O. mykiss* observed varies yearly, with low numbers observed during both high flow and low flow conditions. It is not possible to determine if the recent low numbers are due to drought or increased predation pressure from crayfish.

Until 2013, there continued to be approximately 2 rkm of suitable rearing habitat providing adequate food, shelter, and suitable water quality to support young fish. However decreased flow and increased vegetation encroaching into the channel reduced potential rearing habitat during drought 2012-2018 and the numbers of YOY declined significantly. Restored base flow in 2019 resulted in more YOY observed (Table 3.30).

Table 3.30. Yearly peak of Young of the Year observed in Topanga Creek 2001-2019.

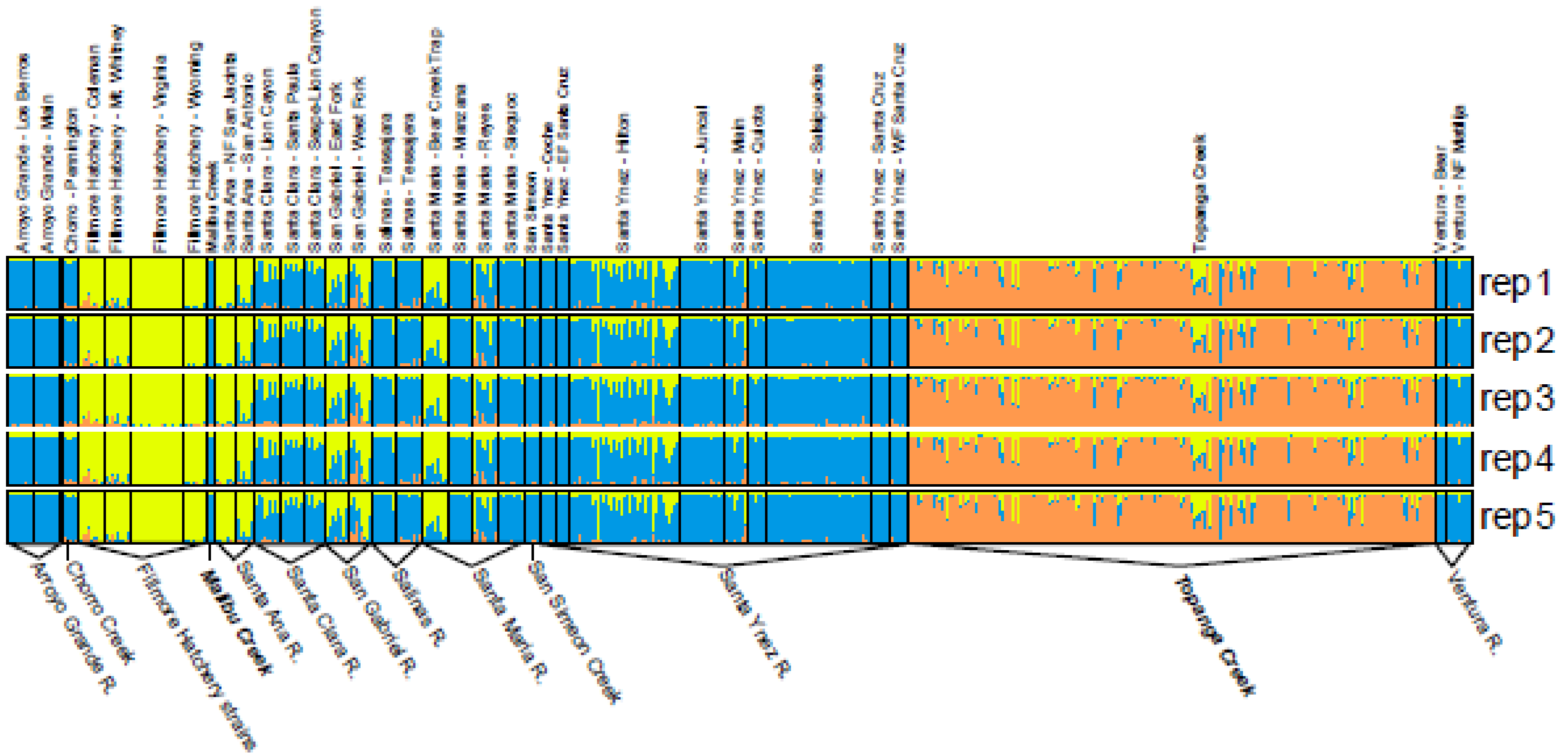
Month - Year	Peak count of *O. mykiss* <100mm observed	Water Year Rainfall Total (Inches)	Water Year Type
June 2001	118	28.16	AN
June 2002	133	9.9	D
June 2003	20	18.71	BN
May 2004	189	13.16	BN
June 2005	11	61.58	W
May 2006	287	21.98	N
May 2007	84	7.17	D
June 2008	590	23.08	BN
August 2009	223	15.16	BN
May 2010	283	24.34	AN
January 2011	62	31.50	AN
May 2012	195	16.22	BN
May 2013	92	9.99	D
August 2014	33	6.85	D
May 2015	112	13.49	D
May 2016	17	10.54	D
July 2017	132	26.34	D
June 2018	118	9.91	D
June 2019	370	32.55	AN

3.3.3. Genetic Information

Of the 1,086 tissue samples collected between 2002- 2017, it was possible to analyze 972.

Population Genetic Structure and Ancestry

In the first STRUCTURE analysis – to identify hatchery-introgressed individuals in the baseline – the clustering constraint that appeared to most cleanly describe population structuring amongst the focal populations, the southern California populations, and Fillmore Hatchery strains was k = 3. At k=3, the Topanga Creek population, the hatchery strains, and the southern California populations were grouped into separate clusters (Figure 3.37); however, there was evidence of admixture in several groups, including Topanga Creek. This admixture reflects the discovery of hatchery-introgression in several baseline populations, some so significantly to suggest total replacement by hatchery trout (i.e. Santa Ana River populations). After removing any individuals with >12.5% proportional assignment to the hatchery cluster, the Santa Ana River basin was completely excluded and 77 individuals were removed from the San Gabriel River basin populations (Figure 3.38). This aligns with previous findings of significant hatchery introgression in several populations within these larger river systems (Jacobsen et al. 2014). After removing these hatchery-introgressed individuals and the clustering constraint that appeared to most cleanly describe population structure was again, k = 3 (Figure 3.39). The level of hatchery-introgression in the remaining baseline populations is notably lower, while certain Fillmore Hatchery strains actually display an increased level of admixture. After the removal of these hatchery-introgressed individuals, however, Topanga Creek is consistently grouped into a separate, apparently distinct cluster.



Distruct Plots at K = 3.

Figure 3.37. Structure analysis including hatchery strains.

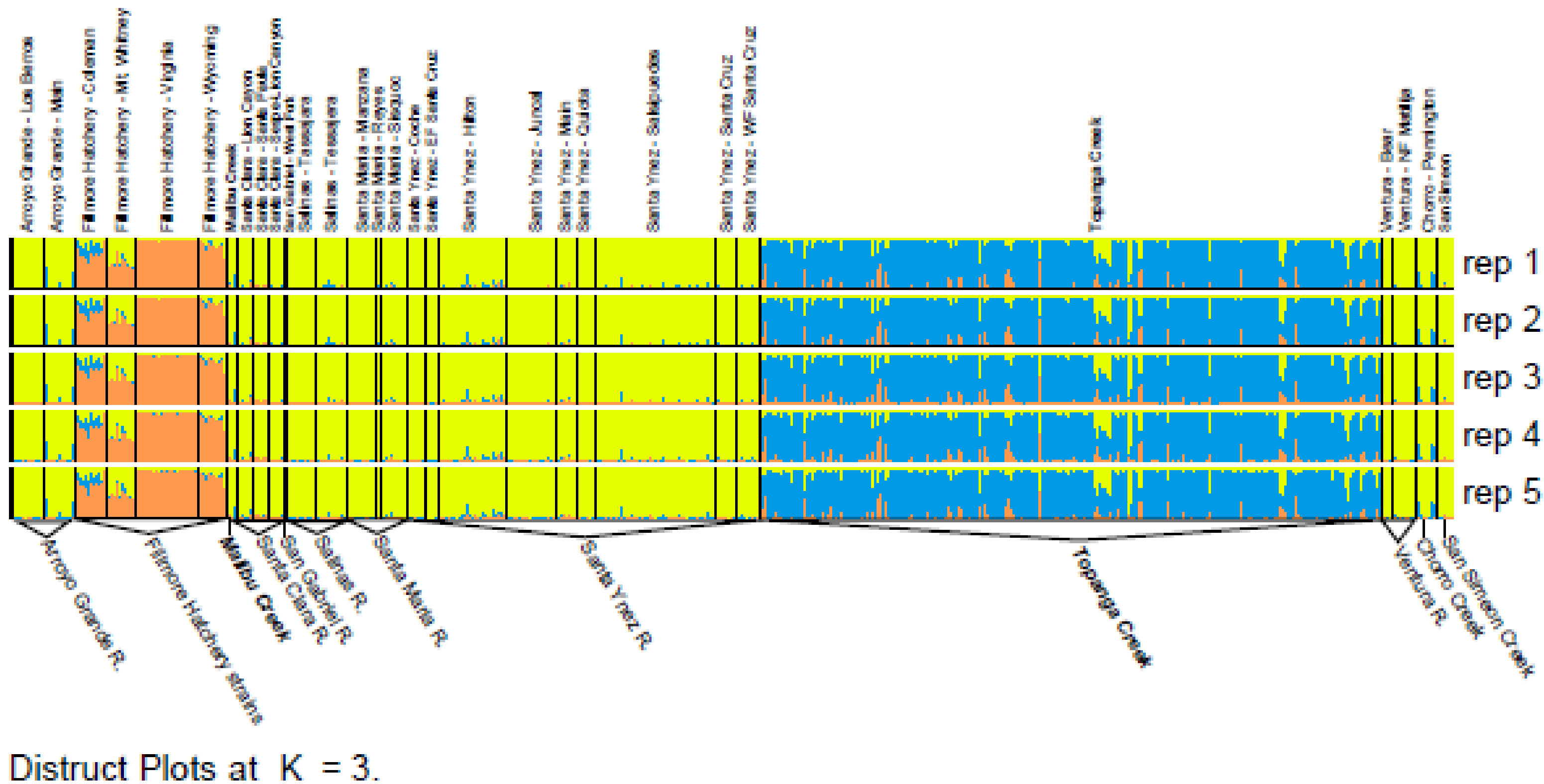


Figure 3.38. Structure analysis without hatchery strains.

The population-level phylogeographic relationships clarify and generally simplify these clustering patterns, presenting a clearer division between hatchery and native coastal steelhead lineages, marked by a solid bar on the central line dividing them (Figure 3.39). Both clustering-based methods and phylogeographic tree construction display strong evidence that Malibu Creek is of predominately coastal steelhead lineage. Similar to the clustering-based results implemented in STRUCTURE, Topanga Creek does not strongly group with either native or hatchery lineages. However, while bootstrap support values, or essentially confidence values, seemingly erode as one moves towards the putatively coastal populations, the clustering of the Fillmore Hatchery strains, and the placement of Topanga Creek as their closest relative display the highest confidence levels amongst divisions on the main branch.

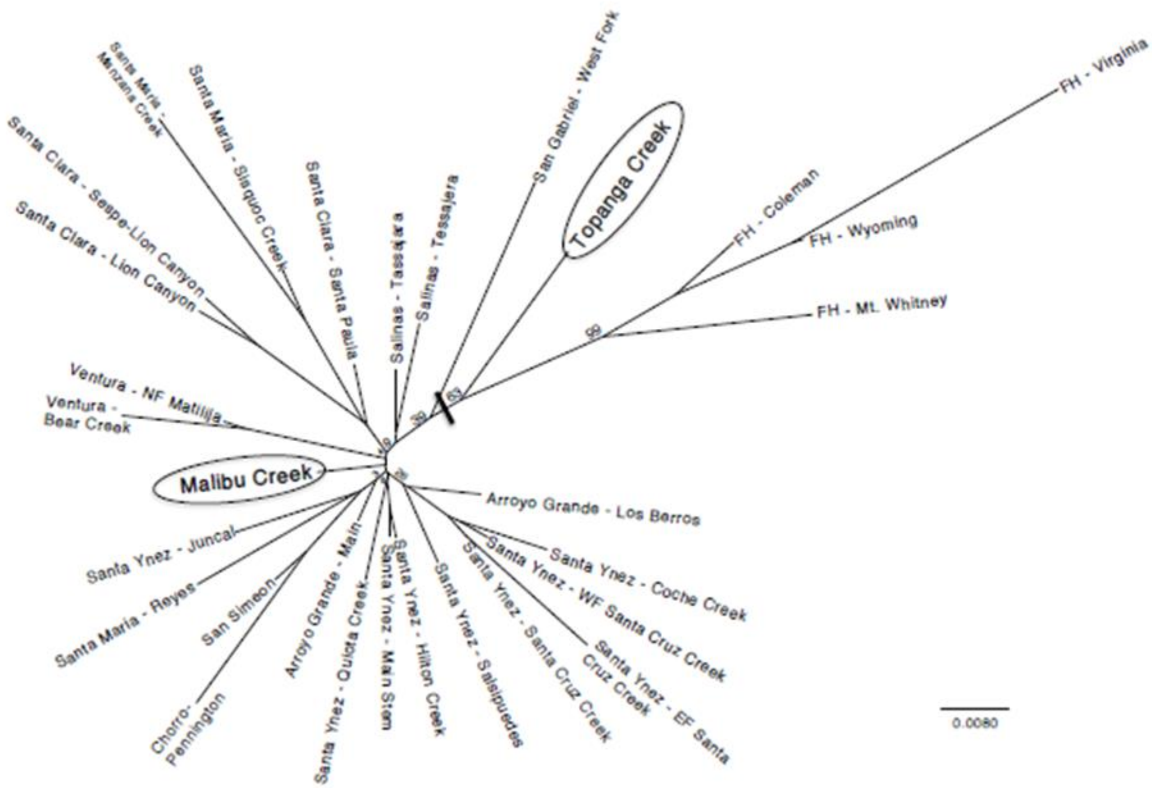


Figure 3.39. Population-level phylogeographic relationships of southern *O. mykiss.*

We summarized the individual genetic assignment results via mixture analysis by identifying the maximum-a-posteriori inferred population for each individual passing posterior probability filtration criteria (Posterior Prob. ≥ 0.95). When the Santa Monica Mountains populations were not included in the reference, the majority of individuals from Topanga and Malibu creeks assigned to populations within the Santa Ynez River basin: 60.5% of Topanga Creek individuals and 60% of Malibu Creek individuals. However, it should be noted only 10 individuals from Malibu Creek are included in this estimate.

After the Santa Ynez River, the next most common inferred population for Topanga Creek individuals was the Fillmore Hatchery – Coleman strain. When the individuals from Topanga, Malibu and Arroyo Sequit Creeks were included in the reference and then assigned to a population using the self-assignment approach, only 12 of 923 individuals passing filtration criteria (Posterior Prob. ≥ 0.95) did not assign back to the location at which they were sampled (Table 3). Six of these assignments included individuals sampled in Topanga Creek, but which assigned to Malibu Creek. Amongst the remaining six assignments, three individuals assigned to the Fillmore Hatchery strains, two to populations in the Arroyo Grande River, and one to a population in the Santa Maria River basin.

Parentage and Family Structure Analysis

After filtering all individuals for duplicate sampling and missing data the potential offspring and parent pools were constructed as described in Table 3.31. The earliest cohort for which we recovered trios that passed our established filtration criteria was 2009, and we recovered a total of 152 parent-offspring trios across all cohorts. Among these 152 trios, we identified 50 unique parent pairs, indicating several parent pairs produced multiple offspring. The maximum number of offspring attributed to a single parent pair was 27, all of which were born in 2010.

Table 3.31. Number of parent-offspring trios recovered by SNPPIT (FDR <= 0.05; Anderson 2010), by offspring cohort. Using known age-length relationships, every individual was assigned a birth year, or cohort. Each cohort was then separately analyzed to reconstruct parent-offspring relationships. The potential parent pool outlines the cohorts included as potential parents for the corresponding cohort being assigned as offspring.

Offspring cohort	n	Potential Parent Pool	No. individuals assigned parents
2017	94	2011 - 2016 (n= 340)	17
2016	19	2010 - 2015 (n= 473)	8
2015	21	2009 - 2014 (n= 610)	18
2014	27	2008 - 2013 (n= 729)	15
2013	38	2007 - 2012 (n= 735)	23
2012	136	2006 - 2011 (n= 611)	14
2011	99	2005 - 2010 (n= 520)	12
2010	152	2004 - 2009 (n= 374)	44
2009	158	2003 - 2008 (n= 219)	1
		Total	152

From these 152 parent-offspring trios we identified nine iteroparous spawners, of which two were male and seven were female (Table 3.32). The iteroparous individuals identified by this analysis generally spawned twice and in subsequent years; however, one female apparently spawned in 2014 and again in 2017, and one male spawned three times. Our size at capture does not match the size at spawning, which was only known for a single male (T11-196) that spawned in same year as capture.

Table 3.32. Occurrences of iteroparity inferred from pedigree reconstruction analysis implemented in SNPPIT (FDR <= 0.05; Anderson 2010). Results suggest iteroparous spawning is more common amongst females. It is important to note this is likely a subset of all individuals that may attempt iteroparous spawning in any given year. RCD ID provides year of capture.

Individual ID	Inferred Population 1	Proportional Assignment 1	RCD ID	Sex	No. times spawned	Years spawned	Ages at spawning	Length at Capture (mm)
M031359	SYnzHilt	0.595628	T08-4	M	2	2013, 2014	5, 6	120
M038246	ArGrMain	0.649343	T09-179	F	2	2012, 2013	4, 5	155
M065212	SYnzHilt	0.999615	T11-185	F	2	2013, 2014	3, 4	176
M065228	SYnzHilt	0.730195	T11-196	M	3	2011, 2012, 2014	2, 3, 5	201
M065204	SYnzHilt	0.993394	T11-212	F	2	2013, 2014	3, 4	218
M065313	SYnzHilt	0.601270	T12-209	F	2	2016, 2017	4, 5	111
M062953	SYnzHilt	0.936942	T13-137	F	2	2014, 2015	3, 4	156
M062971	SYnzHilt	0.997490	T13-171	F	2	2015, 2016	4, 5	154
M062915	FilHaCole	0.977531	T13-83	F	2	2014, 2017	3, 6	157

The age at which the recovered parents spawned ranged from age-1 to age-6 (Table 3.33). Males were most commonly observed spawning at age-2 or age-3, while females were most commonly observed spawning at age-3 or age-4. The recovered parent-offspring trios also suggest increased incidence of precocious spawning by males, with seven individuals spawning at age-1 versus only three females at age-1 and four females at age-2.

Table 3.33. Age at spawning inferred from pedigree reconstruction analysis implemented in SNPPIT (FDR <= 0.05; Anderson 2010).

Age at spawning	No. males	No. females
1	7	3
2	11	4
3	11	16
4	7	13
5	5	5
6	3	1
mean	*3.02*	*3.38*
median	*3*	*3*

Full-sibling (FullSib) family reconstruction was inferred for cohorts 2007 through 2017. After excluding FullSib families of size two and filtering by P(Inc.) ≥ 0.90, we recovered a total of 73 FullSib families across all cohorts (Table 3.34). The maximum family sizes ranged from size three (2014 cohort) to size 30 (2017 cohort); however the median FullSib family size was less than 10 in all years except 2017. No inferred FullSib families passed filter within the 2015 cohort.

Table 3.34. Results of full-sibling family inference implemented in COLONY2 (P(Inc.) >= 0.90; Jones and Wang 2009). Summary results presented here only include full-sibling families with more than two members.

cohort	No. FullSib families	Max Family Size	Median Family Size
2007	2	7	5
2008	14	21	6
2009	17	19	6
2010	11	22	9
2011	9	19	9
2012	10	26	9
2013	2	4	4
2014	1	3	NA
2015	0	NA	NA
2016	1	4	NA
2017	6	30	13.5

Genetic Diversity Statistics

After removing all but one representative individual for all duplicate clusters and FullSib family groups, 427 individuals from Topanga Creek were examined. The expected heterozygosity (0.3421) and observed heterozygosity for Topanga Creek was 0.3351. The mean observed heterozygosity amongst all southern California populations (after removing hatchery-introgressed individuals) and hatchery strains in the analytical baseline was 0.3323 and 0.3086, respectively amongst individuals from all Southern California populations and hatchery strains that were included in the baseline for genetic assignment. Of the 427 samples tested, 67.71% had a frequency of anadromous allele at OmyR04944 and 66.78% had a frequency of anadromous allele at SH114448-87, both of which are high as compared to the frequency of anadromous alleles observed in other southern California native populations, even though they are lower than Malibu (calculated in MS Toolkit (Park 1999).

Due to developments in genotyping and SNP marker design, genotype data at the OmyR04944 marker was lacking for the southern California baseline and hatchery populations. The frequency of the allele associate with anadromy at this locus is quite variable across the Southern California baseline populations and occurs at a mean frequency of ~41.3% across all Fillmore Hatchery strains.

Smolt Information derived from genetic analysis

It was possible to assess the size and sex of smolts captured in the downstream weir trap from 2003 to 2011 when flows allowed deployment of a fyke trap. It appears that the size of smolts was variable (Table 3.35) and that more individuals with native ancestry assignments outmigrated than those with hatchery assignments (Table 3.36) although the sample size (n=43) is not large enough for robust analysis.

Table 3.35. Size of smolts out-migrating from Topanga Creek.

Year	TOTAL	# Male	Length Range (mm)	# Female	Length Range (mm)	# NA	Length Range (mm)
2003	14	6	116-195	6	155-485	2	182-185
2006	7	6	180-260	1	175	0	0
2009	1	1	120	0	0	0	0
2010	9	2	110-115	7	115-145	0	0
2011	12	6	147-324	6	174-317	0	0

Table 3.36. Population ancestry assignment of smolts out-migrating from Topanga Creek. (NA indicates that assignment was not possible).

		Male			Female			# NA
Year	TOTAL	Native	Hatchery	NA	Native	Hatchery	NA	
2003	14	5	1	0	5	1	0	2
2006	7	2	2	2	1	0	0	0
2009	1	0	0	1	0	0	0	0
2010	9	1	1	0	6	1	0	0
2011	12	4	1	1	6	0	0	0
	TOTAL	12	5	4	18	2	0	2

Table 3.37 provides the details on age and sex over time. The vast majority of smolts were age 0 (n=7) or 1 (n=25), with only 8 age 2 individuals, 2 age 3 individuals and one age 4 (female individual). The age 4 female assigned to Santa Ynez Hilton basin ancestry and was the largest individual captured in the downstream migrant trap (X mm FL). She had rainbow coloration consistent with a resident lifehistory, which suggests that perhaps she had been residing in the creek for some time.

Table 3.37. Summary information on all individuals captured in the traps 2003-2011 in Topanga Creek.

Inferred Population 1	Proportional Assign	NMFS_ID	RCDSMM ID	COLLECTION DATE	Est age	Est cohort	LENGTH (mm)	Genetic sex
SYnzHilt	0.844442	M011641	NA	2/15/2003	2	2001	230	Female
FilHaCole	0.998907	M012442	NA	2/25/2003	1	2002	155	Female
SYnzHilt	0.949711	M012439	NA	2/25/2003	1	2002	225	Female
SYnzHilt	0.993887	M012438	NA	2/25/2003	2	2001	255	Female
SYnzHilt	0.940534	M012444	NA	2/25/2003	4	1999	485	Female
SaMaRey	0.848098	M012435	NA	3/17/2003	1	2002	172	Female
SYnzHilt	0.996672	M027337	T06-2	1/3/2006	1	2005	175	Female
SYnzHilt	0.99902	M103779	T10-8	1/23/2010	0	2010	115	Female
FilHaCole	0.687349	M041530	T10-5	1/23/2010	1	2008	115	Female
SaMaRey	0.841382	M103780	T10-9	1/23/2010	0	2010	130	Female
SYnzHilt	0.822276	M041528	T10-3	1/23/2010	1	2008	135	Female
SYnzHilt	0.499348	M041529	T10-4	1/23/2010	1	2008	140	Female
SYnzHilt	0.886537	M041527	T10-2	1/23/2010	1	2008	145	Female
SYnzHilt	0.835343	M103782	T10-11	1/24/2010	0	2010	118	Female
SYnzMain	0.777213	M065160	T11-03	2/27/2011	0	2010	174	Female
SYnzHilt	0.98591	M065151	T11-89	3/27/2011	1	2009	186	Female
SYnzHilt	0.535865	M065156	T11-94	3/28/2011	1	2009	178	Female
SaGaWFork	0.832348	M065154	T11-92	3/28/2011	1	2009	180	Female
SYnzHilt	0.994483	M065153	T11-91	3/28/2011	1	2009	200	Female
SYnzHilt	0.786107	M065155	T11-93	3/28/2011	3	2007	317	Female
FilHaCole	0.850226	M011640	NA	2/15/2003	0	2003	116	Male
ArGrMain	0.994304	M011642	NA	2/16/2003	1	2002	164	Male
FilHaCole	0.862483	M012441	NA	2/25/2003	1	2002	170	Male
ArGrMain	0.996916	M012440	NA	2/25/2003	1	2002	188	Male
ArGrMain	0.977204	M012443	NA	2/25/2003	1	2002	195	Male
FilHaCole	0.990823	M012434	NA	3/17/2003	1	2002	192	Male
NA	NA	M027336	T06-3	1/3/2006	2	2004	250	Male
SaMaRey	0.591048	M027335	T06-4	1/4/2006	1	2005	180	Male
NA	NA	M027334	T06-5	1/4/2006	2	2004	250	Male
ArGrMain	0.797558	M027333	T06-6	4/5/2006	2	2004	255	Male
FilHaCole	0.998367	M027332	T06-7	4/5/2006	2	2004	260	Male
FilHaCole	0.99143	M027339	T06-8	4/6/2006	1	2005	215	Male
NA	NA	M038265	SAMPLE 1	2/18/2009	0	2008	120	Male
SaMaRey	0.576202	M041531	T10-6	1/23/2010	1	2008	110	Male
FilHaCole	0.972357	M103778	T10-7	1/23/2010	0	2010	115	Male
NA	NA	M065158	T11-1	2/20/2011	2	2008	240	Male
SaMaRey	0.909918	M065159	T11-02	2/21/2011	1	2009	180	Male
SYnzHilt	0.48405	M065161	T11-04	2/27/2011	1	2009	169	Male
FilHaCole	0.930183	M065150	T11-88	3/27/2011	3	2007	324	Male
ArGrMain	0.54542	M065152	T11-90	3/28/2011	2	2008	301	Male
SYnzHilt	0.99959	M065157	T11-95	3/29/2011	1	2009	147	Male
NA	NA	M012436	NA	3/17/2003	1	2002	182	NA
NA	NA	M012437	NA	3/17/2003	1	2002	185	NA

3.3.4. Instream Habitat Mapping

Surveys were conducted in September 2006, in 2017 on 10/24/17, 11/28-30/17, and in 2019 on 5/13-14/2019, 5/20-23/2019. During this time the length of the stream starting at the lagoon (34.03928, -118.58312) to the limit of anadromy at Grotto Pool (5.3 rkm) (34.07672, -118.59141) were mapped.

The fall mapping event of 2006 was consistent with the lower flow conditions, although not as extreme as previous fall surveys due to the continued input of groundwater following the extreme precipitation of 2005 (Dagit et al. 2007). The fall mapping event of 2017 followed a six year drought that occurred between 2012 and 2017. This resulted in an increase in dry sections in the lower reach. The spring mapping event in 2019 followed an above normal rain year. That, in conjunction with the mapping occurring in the spring, resulted in an increased number of habitat units as well as the absence of any dry sections as of June 2019. The overall distribution of habitat types indicates that mid-channel and step pools remain the dominant features, with depth limitations affecting the presence and extent of riffles and runs.

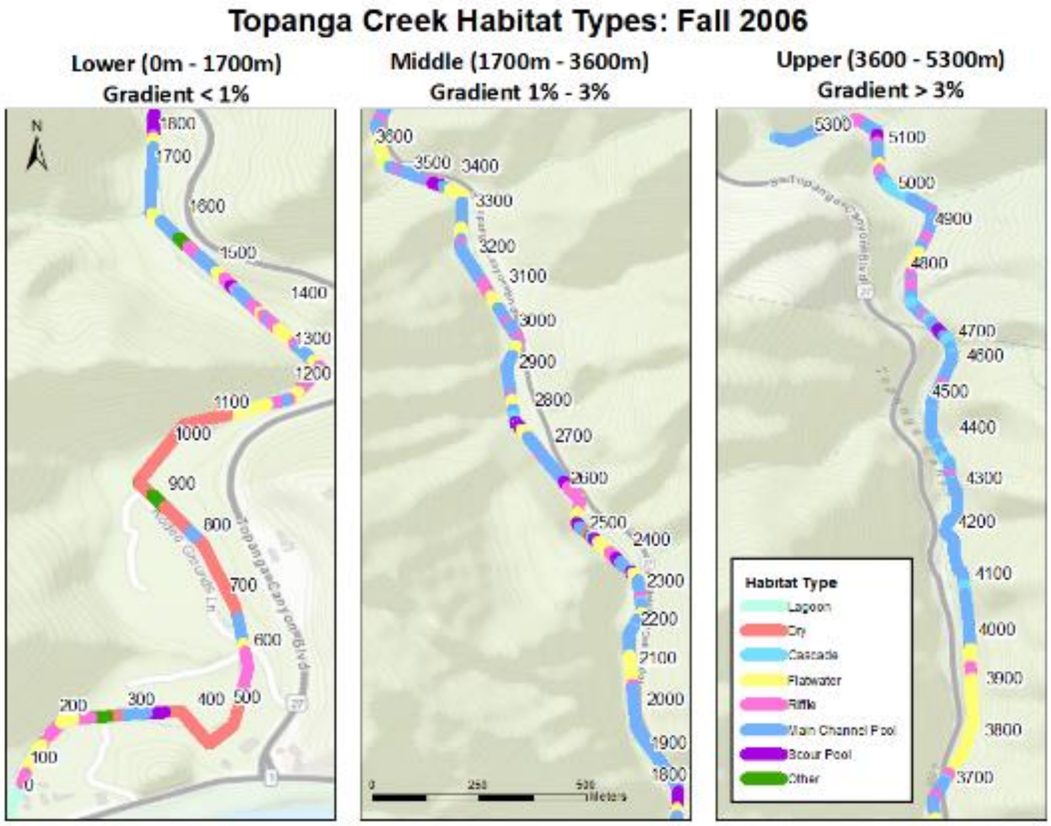
Figure 3.40 below summarizes the analysis of habitat type by length. The comparison of 2006 to 2017 shows a decrease in shallower habitats such as riffles, runs, and cascades. This pattern is reversed in 2019. Analysis of width dimensions comparing 2006 and 2017 show that the average width decreased for all habitat types between 2006 (4.6 m) and 2017 (4.1 m). In 2019, the average width increased (5.1 m). Because of the constrained canyon, width cannot vary too much, as there are few places where there is much available space for the creek to spread out.

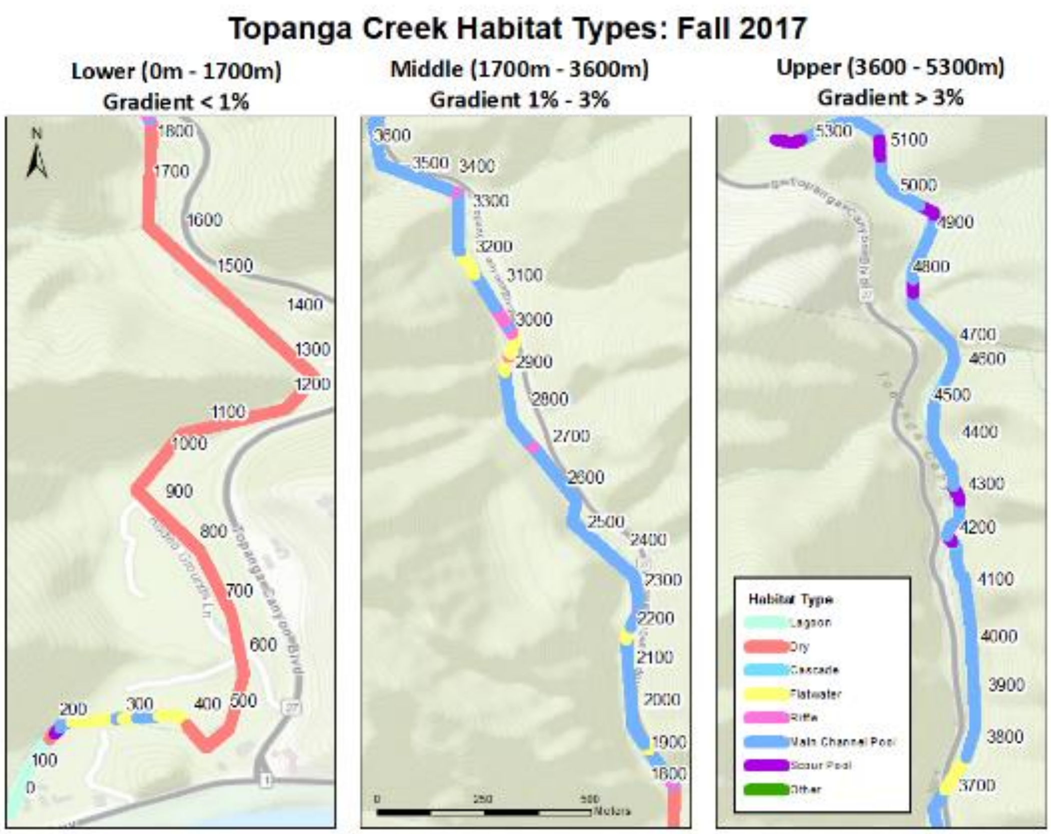
In 2006, the average canopy cover for Topanga Creek was 45.6%. Canopy decreased slightly in 2017 (44.25%) and then increased again slightly in 2019 (48.9%). Mean shelter value decreased between 2006 (1.14) and 2017 (.82), and then increased in 2019 (1.1).

Additionally, following the above normal rain events of 2019, the average cover by both large and small woody debris (2.7% SWD and .01% LWD) decreased as compared to 2017 (6.8% SWD and .6% LWD). This is consistent with both types of woody debris being washed out.

Summaries and further analysis of the data can be found in Appendix E.

Between 2006 and 2017, pool volume remained mostly constant. The exception was with some scour pools, which increased in volume despite drought conditions. (Figure 3.41). A similar pattern was observed between 2017 and 2019 (Figure 3.42).


Topanga Creek Habitat Types: Fall 2006
Lower (0m - 1700m)
Gradient < 1%
Middle (1700m - 3600m)
Gradient 1% - 3%
Upper (3600 - 5300m)
Gradient > 3%
Habitat Type
Lagoon
Dry
Cascade
Flatwater
Riffle
Main Channel Pool
Scour Pool
Other
Meters


Topanga Creek Habitat Types: Fall 2017
Lower (0m - 1700m)
Gradient < 1%
Middle (1700m - 3600m)
Gradient 1% - 3%
Upper (3600 - 5300m)
Gradient > 3%
Habitat Type
Lagoon
Dry
Cascade
Flatwater
Riffle
Main Channel Pool
Scour Pool
Other
Meters

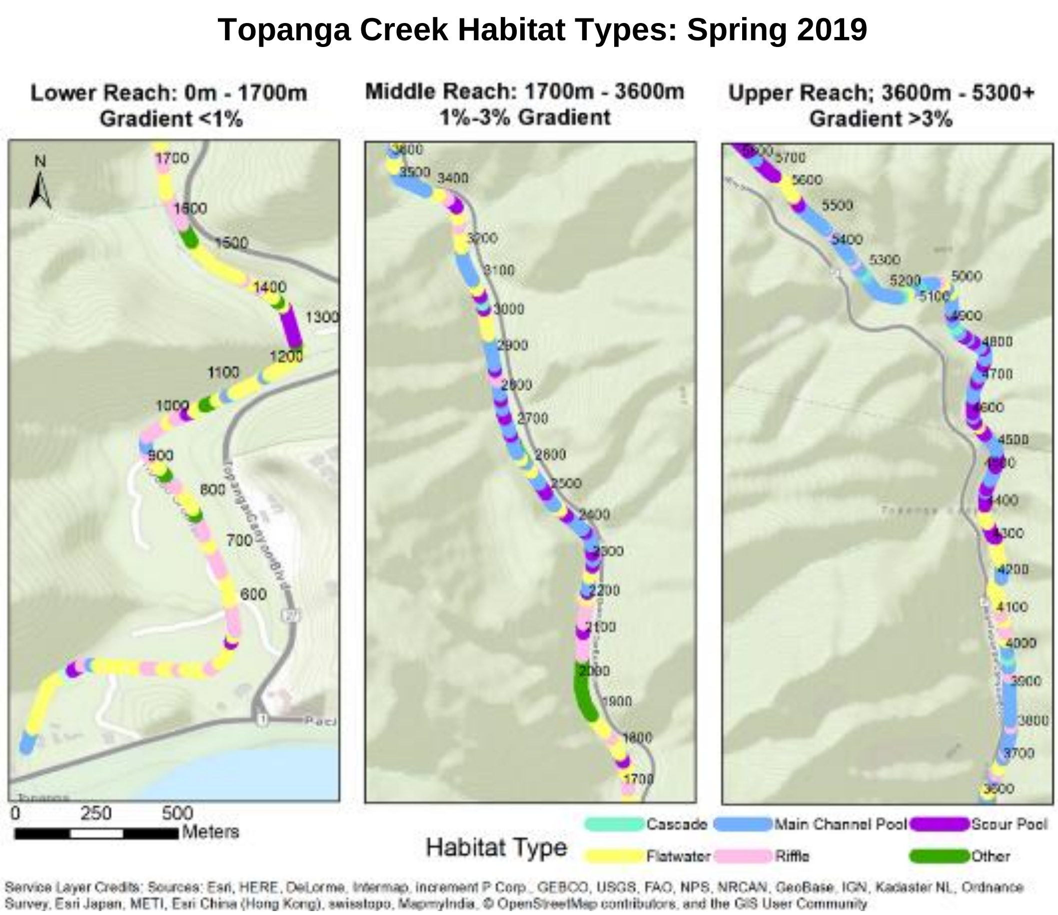


Figure 3.40. Summary map showing changes in habitat type distribution over time.

Pool Characteristics Comparison

For each of the mapping events, data was taken on the physical characteristics of pools and other habitat types. Pool volume in m^3 was calculated for thirty pools that in the past contained suitable habitat for trout (Table 3.38).

Table 3.38. Pool Dimensions in the Lower Reach of Topanga Creek September 2006, October/November 2017, and April/May 2019.

Pool Name	Year	Length (cm)	Avg Width (cm)	Avg Depth (cm)	Pool Volume (m3)
Elbow Pool 0.3 rkm	2006	1600	200	10	3.2
	2017	1300	150	20	3.9
	2019	1600	400	50	32
Cattail Pool 1.8 rkm	2006	3700	800	75	222
	2017	600	250	20	3
	2019	1600	800	50	64
Transient Pool 1.9 rkm	2006	1800	1500	45	121.5
	2017	2100	1200	80	201.6
	2019	2100	1000	80	168
Ski Pole Pool 2.0 rkm	2006	1300	1200	90	140.4
	2017	1300	2000	40	104
	2019	1200	1000	55	66
School Pool 2.1 rkm	2006	2600	700	85	154.7
	2017	2900	1200	70	243.6
	2019	3100	800	65	161.2
Headshot Culvert 2.24 rkm	2006	2000	300	30	18
	2017	1300	200	40	10.4
	2019	1500	200	40	12
Conor Pool 2.3 rkm	2006	1300	1000	70	91
	2017	1300	800	40	41.6
	2019	1200	700	60	50.4
Greenhouse Pool 2.43 rkm	2006	1000	400	20	8
	2017	1800	200	10	3.6
	2019	1600	500	50	40
Ken^2 Pool 2.6 rkm	2006	2300	500	60	69
	2017	2900	500	50	72.5
	2019	2600	300	50	39
Long Pool 2.65 rkm	2006	3200	1000	60	192
	2017	3100	2300	50	356.5
	2019	4300	600	25	64.5
Shale Falls 2.7 rkm	2006	1000	400	50	20
	2017	5700	500	40	114
	2019	1500	500	60	45
Tamarisk Pool 3.32 rkm	2006	5500	1000	60	330
	2017	5600	700	55	215.6
	2019	5600	400	40	89.6
Engine Pool 3.5 rkm	2006	3200	800	30	76.8
	2017	3800	500	35	66.5
	2019	2500	400	35	35
Shrine Pool 3.525 rkm	2006	2800	1000	50	140

Table 3.39. Pool Dimensions in the Upper Reach of Topanga Creek September 2006, October/November 2017, and April/May 2019.

Pool Name	Year	Length (cm)	Avg Width (cm)	Avg Depth (cm)	Pool Volume (m3)
Big Boulder Pool 3.8 rkm	2006	3400	600	60	122.4
	2017	2900	800	60	139.2
	2019	4400	900	55	217.8
Sycamore Tree Pool 3.94 rkm	2006	2900	600	30	52.2
	2017	2900	900	50	130.5
	2019	4600	400	40	73.6
Noel Pool 4.0 rkm	2006	3900	600	60	140.4
	2017	3500	1000	75	262.5
	2019	3600	800	115	331.2
Fern Grotto 4.05 rkm	2006	8600	400	50	172
	2017	3600	400	20	28.8
	2019	3800	600	50	114
Caltrans Frm. 4.1 rkm	2006	1700	300	25	12.75
	2017	3900	800	30	93.6
	2019	4100	800	45	147.6
Lodgepole Pool 4.2 rkm	2006	1500	800	60	72
	2017	1100	1000	70	77
	2019	1900	600	80	91.2
No Parking Pool 4.25 rkm	2006	4000	600	40	96
	2017	3500	700	65	159.25
	2019	4200	700	70	205.8
Willow Trench Pool 4.27 rkm	2006	2400	200	60	28.8
	2017	5300	300	45	71.55
	2019	3800	500	65	123.5
Car 4.3 Pool rkm	2006	2200	1500	30	99
	2017	3300	1200	55	217.8
	2019	1800	900	70	113.4
Josh Pool 4.36 rkm	2006	1600	1000	30	48
	2017	2000	1500	100	300
	2019	1600	700	100	112
Barrier Falls 4.4 rkm	2006	2000	400	20	16
	2017	1300	200	30	7.8
	2019	900	700	200	126
Kevin Pool 4.55 rkm	2006	3200	1000	70	224
	2017	1800	1200	45	97.2
	2019	3100	1200	80	297.6
Stevie Pool 4.875 rkm	2006	2000	1500	60	180
	2017	3600	1000	65	234
	2019	2500	700	100	175
Redrock Pool 5.025 rkm	2006	2500	1400	100	350
	2017	3200	1000	75	240
	2019	2800	600	60	100.8
Pool Below Grotto 5.275 rkm	2006	2200	1000	100	220
	2017	2700	900	200	486
	2019	2000	1800	160	576
Grotto Pool 5.3 rkm	2006	1000	1500	100	150
	2017	1500	1000	80	120
	2019	2200	1600	150	528

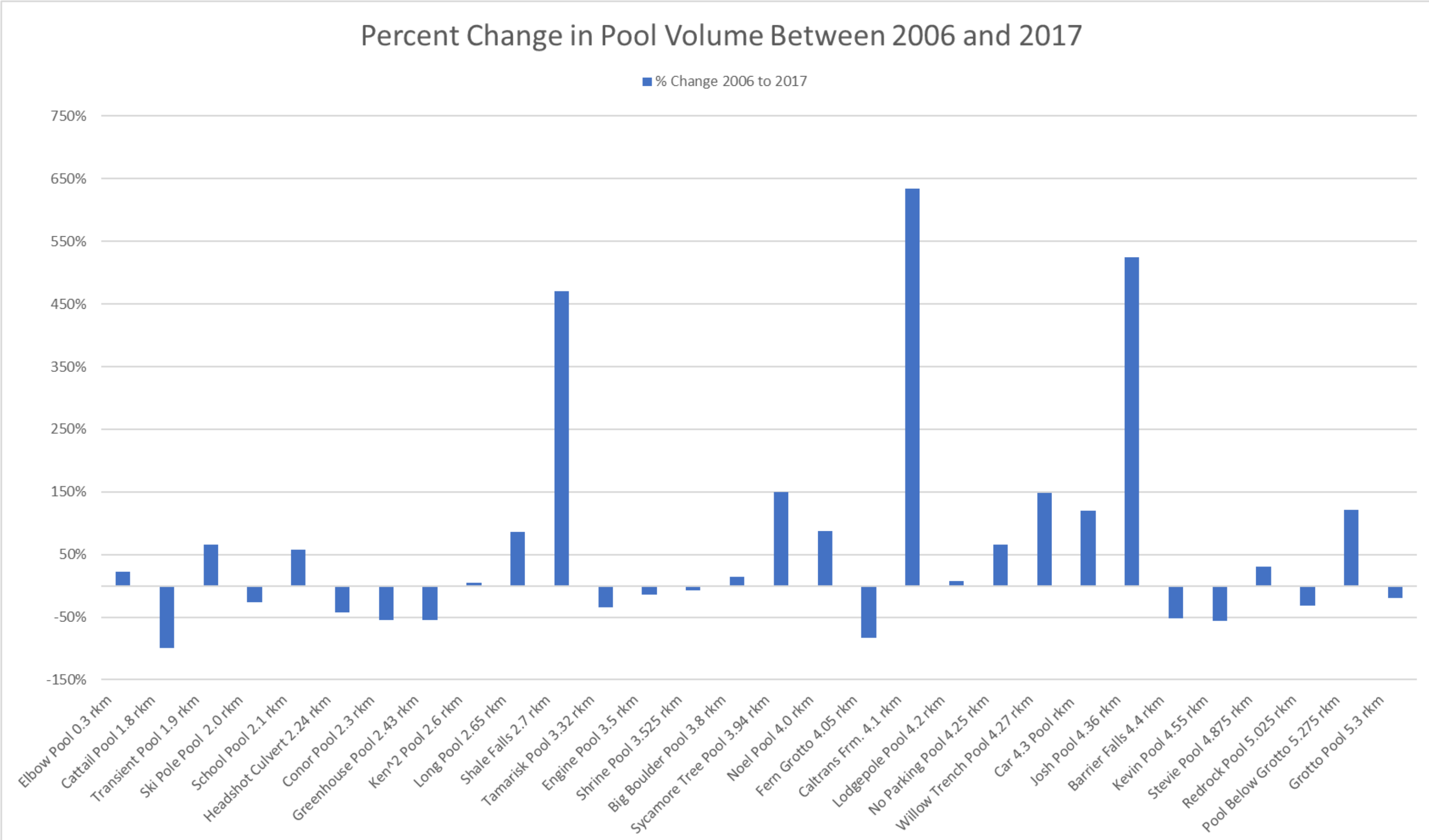


Figure 3.41. Percent change in pool volume between 2006 and 2017.

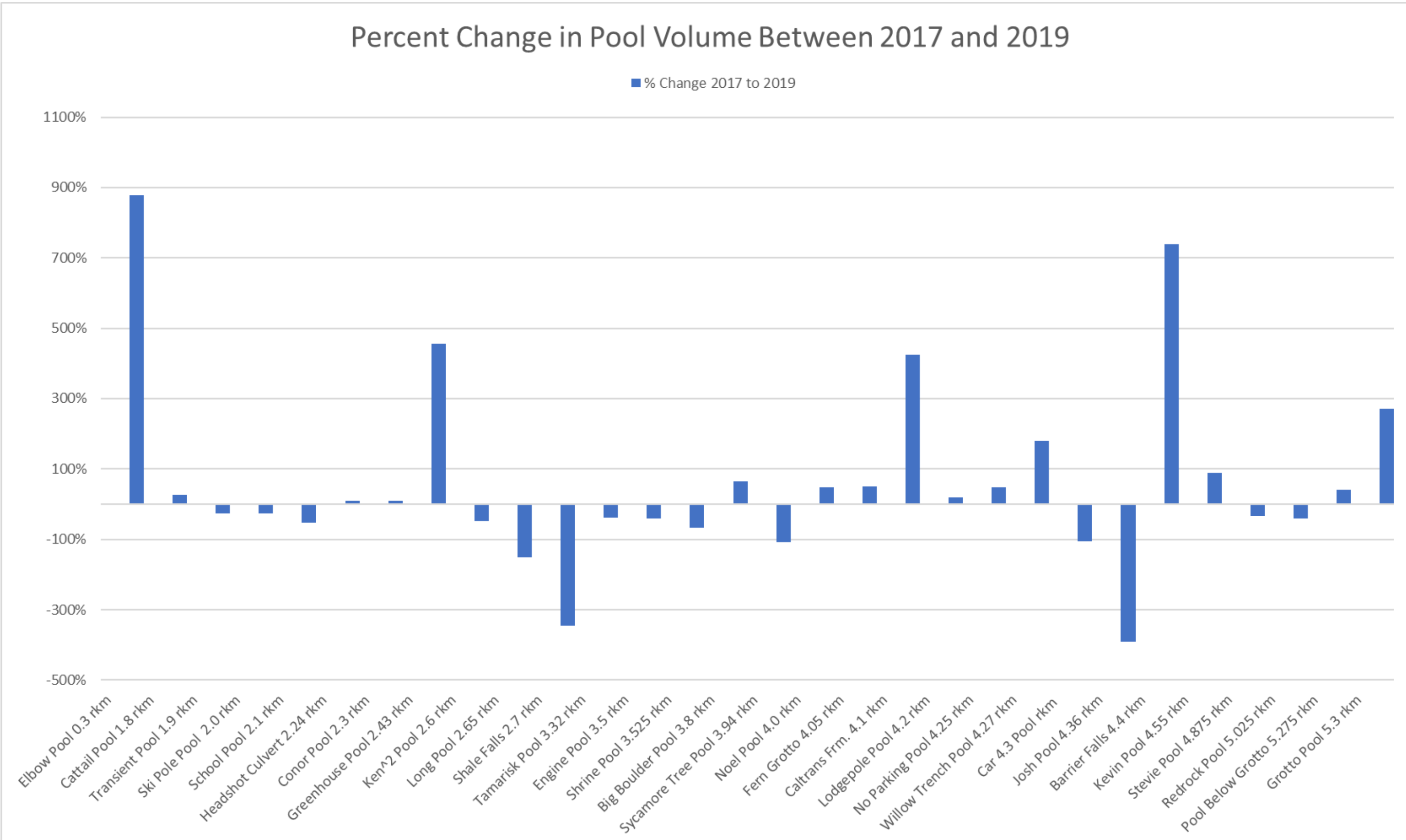


Figure 3.42. Percent change in pool volume between 2017 and 2019.

3.3.5. Lagoon/Ocean Interface Monitoring

Two variables must be aligned for *O. mykiss* to migrate into or out of the system. First, the lagoon entrance needs to be open and passable. Second, the base flow level throughout the lower reach of the creek needs to rise high enough to restore connectivity in areas with minimal depth, and to provide enough depth to move beyond low flow natural barriers.

Between May 2017 – January 2019, the lagoon/ocean entrance remained closed, opening only for a few days at a time when the rainfall was enough to breach the berm. These brief openings created a limited time window for *O. mykiss* to pass into or out of the system. Slugs of sediment settled in the lagoon following most rain events, and restricted passage further following the 55 acre Topanga Fire in June 2017 by reducing depth to just a few centimeters where it cut through the sand berm during both high and low tides for much of the duration of the opening. A narrow thalweg formed for brief periods of time, but again was quite shallow (less than 0.25 m) and quickly filled with sediments. This changed with the series of storm events January – June 2019, which maintained the ocean connection consistently, although passage opportunities were limited to high tides from the end of April 2019 into June 2019 (Table 3.40).

Movement into and out of the lagoon itself was limited by water depth to mostly high tide conditions, even during and immediately following storm events when creek flow was more constant. Weekly observations at Topanga Lagoon, as well as storm related event monitoring took place through April and continued monthly until November 2019.

Salinity in Topanga Lagoon remained relatively low at freshwater levels. In its present condition, Topanga Lagoon provides little cover, stagnation, extremely variable and unreliable depths, as well as primarily closed conditions more characteristic of a freshwater pond. Brackish conditions were noted rarely.

The storm events during each water year were scattered throughout the rainy season between December and June. Summaries of wet spells are found in Appendix F.

Table 3.40. Summary of Rainfall and Fish Passage Opportunities in Topanga Creek.

Water Year	Rainfall Total (inches)	Dates Entrance Open	Estimated Number of Connected /Passable Days
2000-2001	28.16	Nov 01	1-2
2001-2002	9.9	Nov 01-March 02	10
2002-2003	18.71	Nov 02-March 03	~20
2003-2004	13.16	Dec 03 – March 04	20-30
2004-2005	61.58	Dec 04 – Dec 05	>200
2005-2006	21.98	Jan 06- Mar 06	45
2006-2007	7.17	Jan 07	<5
2007-2008	23.08	Dec 07 – April 08	>150
2008-2009	15.16	Dec 08- April 09	15
2009-2010	24.34	December 09 – May 10	>100
2010-2011	31.50	Dec 10-May 11	<150
2011-2012	16.22	Nov 11-April 12	<20
2012-2013	9.99	Nov- Dec 12, Jan - Feb 13	<5
2013-2014	6.85	February 28-1 March 14	<5
2014-2015	13.49	~March	<10
2015-2016	10.54	March 7th,	1
2016-2017	26.34	December 24, 2016; January 11 – May 23 2017	~80
2017-2018	9.91	January 10, 2018; March 3, 2018-March 22, 2018	<5
2018-2019	32.55	February 8th, 2019 – July 3^{trd}, 2019	~95

3.3.6. Migration Trapping and Monitoring

The rainfall pattern between 2011 and November 2019 provided no opportunities for trapping. The flashy nature of the winter storms in 2017 and 2019 provided limited flows on the falling limb of the hydrograph, so effort was directed towards DIDSON camera deployment instead. Observations of true “smolts” have been erratic in Topanga Creek. These fish are generally observed either for a short time (1-2 days) in the lagoon waiting for a high tide to provide passage, or captured during November or March electrofishing events. Smolts have rarely been observed upstream as far as 3.7 rkm. No smolts were observed between January 2015-

November 2019. Previous results of trapping and DIDSON monitoring efforts are found in Dagit et al. (2015, 2018a, 2018b).

3.3.7. Water Temperature, Flow and Water Quality Monitoring

3.3.7.1. Overall Topanga Creek Temperature Patterns

Table 3.40 summarized the deployment history of Stowaway TIDBIT continuously recording thermometers in Topanga Creek from 2005-2019. Between six-eight pools were randomly selected annually to represent typical refugia locations where *O. mykiss* were consistently observed. The yearly temperature range in the reaches inhabited by *O. mykiss* varied seasonally and within the reach according to canopy cover, proximity to seeps and springs, and depth. Recording thermometers were installed from April to October 2011-2016 in six pools, adding to data collected since 2005 (Figure 3.43). Data was collected at 30-minute intervals. Data from 2011 to 2019 was most complete and is presented in the text below. Both the distance upstream along the instream mapping transect (0 rkm= PCH bridge) and the reference names of the location are provided. Summaries of all graphs for each location are found in Appendix D.

Topanga Creek does not receive imported water, and the hydrologic regime remains natural, unlike in Malibu Creek. In dry years, groundwater inputs dominate the system and as the drought continued, it appears that those inputs became less able to maintain cooler temperatures. The data suggest that although maximum temperatures have not changed significantly, minimum temperature in Topanga Creek in the month of August increased significantly with drought in three of four assessed habitats ($p < 0.05$), as indicated by Mann-Kendall trend analysis. Between 2011 – 2018 minimum water temperature increases from 14.2°C in 2010 to 17.3°C in 2016 (p=0001). Sen's Test estimated rate of change in mean August minimum water temperature at these sites ranged from an increase of 0.6 to 1.0 °C /year.

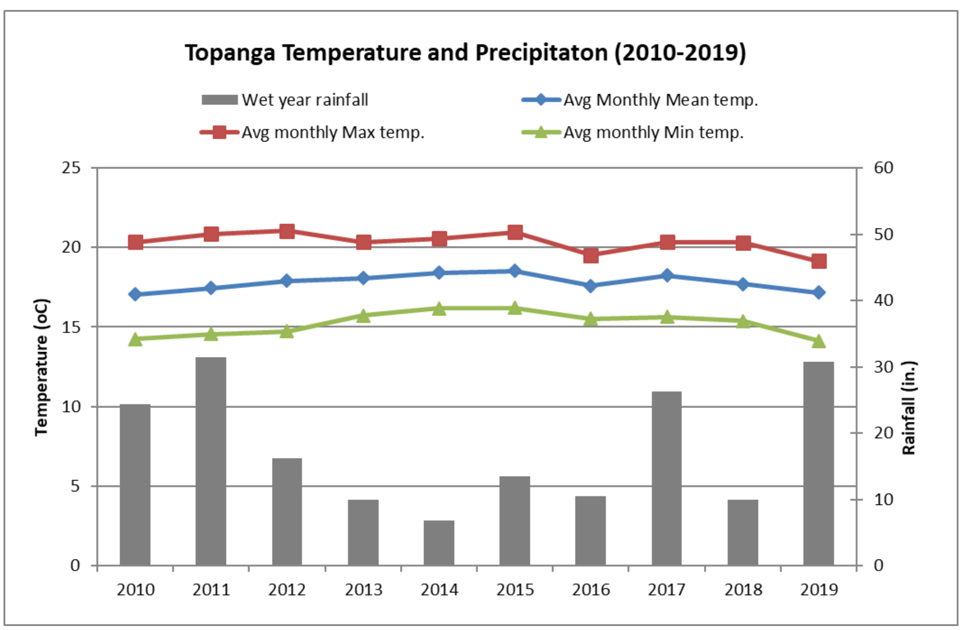


Figure 3.43. Topanga average max (red), mean (blue), and min (green) temperatures and precipitation (2010-2019).

Table 3.41. Summary of temperature monitored locations and dates in Topanga Creek, 2005-2019.

Pool	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Top Lagoon (0 RKM)	ND	ND	ND	ND	ND	ND	ND	ND	12 Jul – 31 Dec	01 Jan-14 Nov	10 Apr-06 Nov	06 April-10 Nov	15 Apr – 6 Nov	9 Mar – 18 Oct	4 Apr -
Ski Pole (water) (2.0 RKM)	17 Jun – 19 Oct	21 Jul – 27 Feb 07	11 May – 18 Dec	LM*	31 Jul – 23 Oct	12 Mar – 21 Nov	15 Apr – 8 Nov	15 Mar – 20 Nov	19 Apr – 15 Nov	04 Apr-14 Nov	10 Apr-continuous	continuous	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Ski Pole (air) (2.0 RKM)	ND	ND	ND	ND	ND	ND	ND	17 Feb-31 Dec	01 Jan – 15 Nov	04 Apr-14 Nov	10 Apr-continuous	continuous	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Ken^2 (2.6 RKM)	17 Jun – 19 Oct	30 May – 20 Sept	11 May – 18 Dec	17 Jul – 12 Sept	31 Jul – 23 Oct	22 May – 21 Nov	15 Apr – 8 Nov	15 Mar – 20 Nov	19 Apr – 15 Nov	04 Apr-14 Nov	10 Apr-06 Nov	28 Mar-07 Nov	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Ken^2 (air) (2.6 RKM)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	28 Mar-07 Nov	ND	ND	1 Apr -
Engine (3.5 RKM)	ND*	19 May – 18 Aug	11 May – 18 Dec	20 Jun – 25 Jul	31 Jul – 23 Oct	22 May – 21 Nov	15 Apr – 8 Nov	ND	2 May – 13 Sept	04 Apr-14 Nov	*10 Apr-06 Nov	28 Mar-07 Nov	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Sycamore Tree (3.94 RKM)	ND	21 Jul – 15 Sept	7 Sept – 19 Oct	20 Jun – 25 Jul	31 Jul – 23 Oct	22 May – 15 Nov	15 Apr – 8 Nov	16 Mar – 20 Nov	19 Apr – 13 Sept	04 Apr-14 Nov	10 Apr-06 Nov	28 Mar-07 Nov	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Noel (4.0 RKM)	ND	19 May – 18 Oct	11 May – 22 Jun	LM	31 Jul – 23 Oct	22 May – 21 Nov	15 Apr – 9 Nov	16 Mar – 20 Nov	19 Apr – 14 Sept	04 Apr-14 Nov	10 Apr-06 Nov	28 Mar-07 Nov	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Josh (4.36 RKM)	ND	19 May – 18 Oct	11 May – 19 Oct	20 Jun – 18 Jul	31 Jul – 23 Oct	ND	15 Apr – 9 Nov	15 Mar – 20 Nov	19 Apr – 15 Nov	04 Apr-14 Nov	10 Apr-06 Nov	28 Mar-07 Nov	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Red Rock (5.025 RKM)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10 Apr-06 Nov	28 Mar-07 Nov	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Grotto (5.275 RKM)	ND	ND	ND	ND	31 Jul – 23 Oct	ND	ND	ND	ND	ND	ND	28 Mar-07 Nov	15 Apr – 6 Nov	9 Mar – 18 Oct	1 Apr -
Lower Twin (5.3 RKM)	ND	ND	ND	ND	ND	ND	15Apr– 9 Nov	15Mar – 20 Nov	ND	ND	ND	28 Mar-07 Nov	ND	ND	ND

* ND = logger was not deployed in this location for this year, LM = logger malfunctioned.
*tidbit placed in Shrine Pool (3.52RKM) due to deer carcass in Engine Pool.

3.4.1.1. Average Maximum Temperature

Overall, average maximum temperatures in Topanga Creek remained within preferred thermal ranges for *O. mykiss* (Richter and Kolmes 2005). Average monthly maximum temperatures were less than 24°C in Topanga Creek, but varied by pool and year (Figure 3.44). Sycamore Tree (3.9 rkm) had the warmest maximum temperatures and can be characterized as a small, shallow step boulder complex pool with a groundwater seep emerging from the canyon wall on the easy bank of the pool.

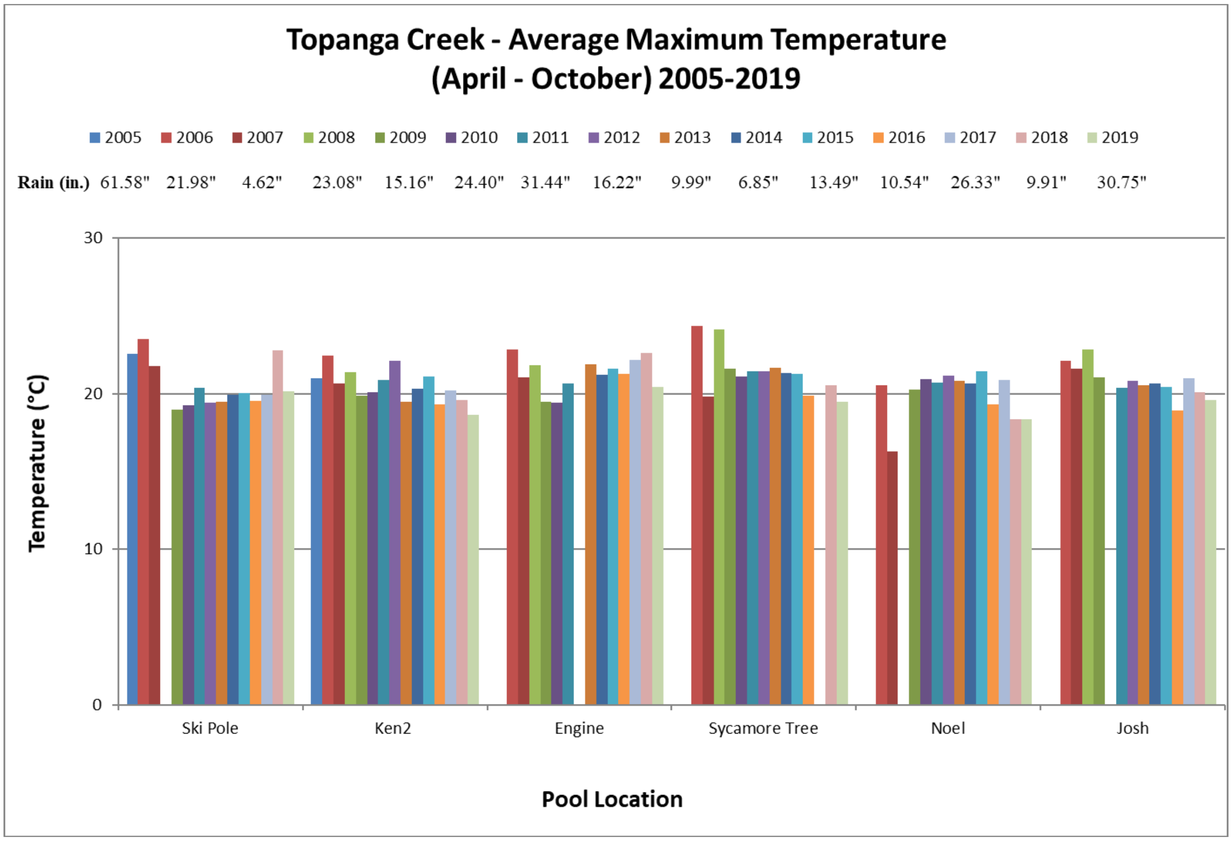


Figure 3.44. Average Maximum Summer Temperatures by Location 2005-2019.

Despite the intensifying drought between 2012-2018, average maximum temperature did not increase over the study period in any month between June-October. Warmest monthly maximum occurred in 2005, 2006, 2012 and 2015. This may be a result of shading from the canyon walls and canopy cover, or because of higher input of groundwater from the seep.

Between 2010 - 2014 only two pools (2.6 rkm Ken[2], 3.94 rkm Sycamore Tree) experienced any time periods when temperatures reached or exceeded the critical thermal limit of 23-25 °C (Hicks 2000). In 2015 and 2016, two additional pools (3.5 rkm Engine and 4.0 rkm Noel) also had temperatures in exceedance of 23 °C. In 2017, Sycamore Tree Pool contained eight days where the critical thermal limit was exceeded. However, in most years, and in most pools (Table 3.42), temperatures were suitable to support foraging and growth of *O. mykiss* (Spina 2007, Sloat and Osterback 2013), and since 2017 no pools in Topanga have exceeded the critical thermal limit for *O. mykiss*.

Table 3.42. Total number of days with temperatures greater than 23˚C at six pools in Topanga Creek, from April through October (n=number of logging days).

TOPANGA	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Precipitation (in)	24.4	31.44	16.22	9.99	6.85	13.49	10.54	26.33	9.91	30.75
Ski pole (2.o rkm) >23 ºC (n)	0 (254)	0 (207)	0 (250)	0 (209)	0 (223)	0 (205)	0 (215)	0 (xx)	0 (xx)	0 (xx)
Ken^2 (2.6 rkm) >23 ºC (n)	0 (183)	1 (207)	22 (250)	0 (209)	0 (223)	1 (205)	0 (202)	0 (xx)	0 (xx)	0 (xx)
Engine (3.5 rkm) >23 ºC (n)	0 (183)	0 (207)	0 (250)	0 (208)	0 (134)	2 (205)	1 (215)	34 (xx)	48 (xx)	0 (xx)
Sycamore (3.94 rkm) >23 ºC (n)	0 (183)	10 (207)	6 (250)	0 (208)	0 (147)	2 (205)	0 (215)	8 (xx)	0 (xx)	0 (xx)
Noel (4.0 rkm) >23 ºC (n)	0 (183)	0 (208)	0 (251)	0 (208)	0 (148)	2 (205)	0 (215)	1 (xx)	?? (xx)	0 (xx)
Josh (4.36 rkm) >23 ºC (n)	ND	0 (208)	0 (251)	0 (208)	0 (223)	0 (205)	0 (215)	1 (xx)	0 (xx)	0 (xx)

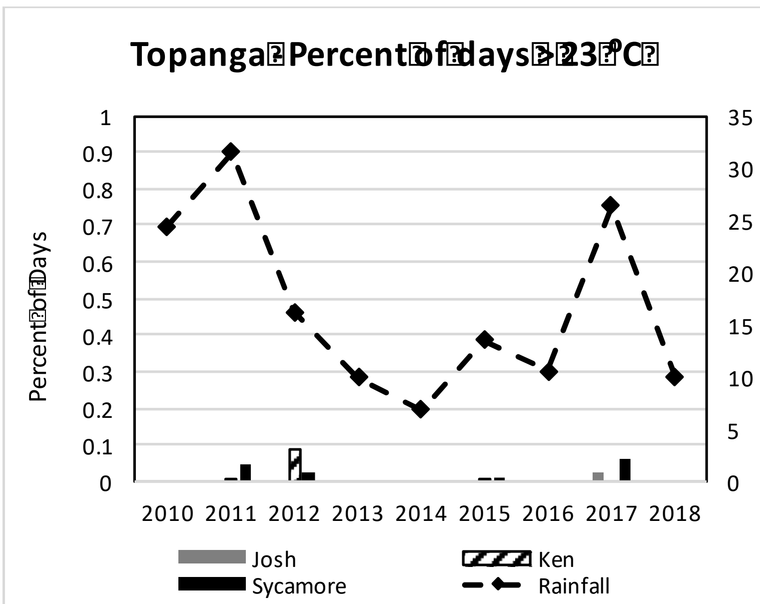


Figure 3.45. Proportion of days experiencing temperature >23 degrees Celsius in three Topanga Creek Pools 2010-2018.

7-DADM for Ski Pole Pool (2.0 rkm) ranged from a high of 25.5ºC (7/24-7/30, 2006) to 18.8ºC (7/31-8/6 2009), with no significant trend in magnitude overtime. 7-DADM for Ken^2 Pool (2.6 rkm) ranged from a high of 23.6ºC (7/20-7/26, 2005) to a low of 19.8ºC (9/2-9/8, 2009), with no significant trend in magnitude overtime. In Josh Pool (4.3 rkm), 7-DADM ranged from a high of 24.7ºC (7/24-7/31 2006) to a low of 22.0ºC (7/5-7/11 2011). 7-DADM was highest overall in Sycamore Tree Pool (3.94 rkm), ranging from 25.5ºC (7/22-7/28, 2006) decreasing to 21.2ºC (8/4-8/10, 2016). Significant downward trends were identified between 2005-2018 7-DADM in Josh Pool (4.3 rkm) ($z = -1.43$, $p < 0.05$) and Sycamore Tree Pool (3.94 rkm) ($z = -1.40$, $p < 0.05$) by Mann-Kendall test statistic. In contrast to Malibu Creek, 7-DADM temperatures in the drought period between 2011-2018 remained stable and did not increase or decrease significantly. There was no trend in timing of 7-DADM occurring later or earlier in the season from 2005 to 2019 (Figure 3.46).

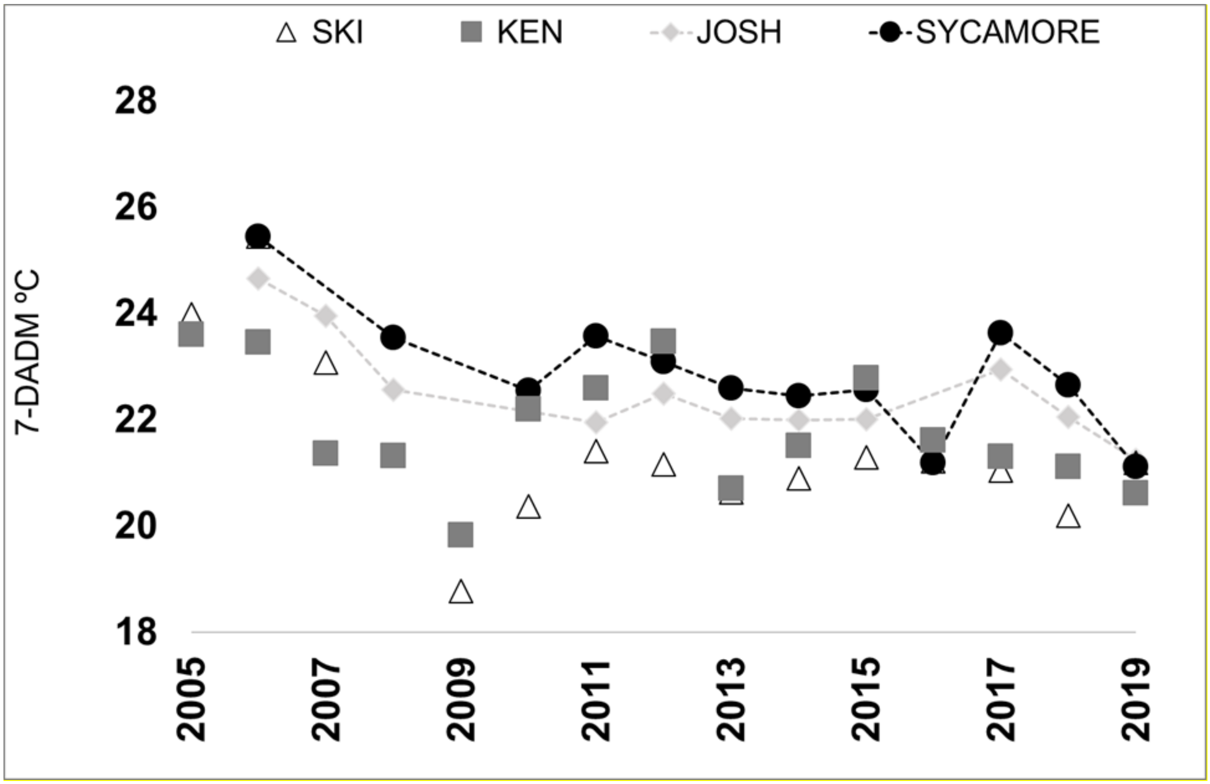


Figure 3.46. 7 Day Average Daily Maximum for Topanga Creek 2011 – 2018 (Ski Pole, Ken[2], Sycamore and Josh Pools).

3.4.1.2. Average Mean Temperature

Average mean temperatures were typically less than 20°C but varied by pool and rainfall (Figure 3.47). Sycamore Tree (3.9 rkm) had the warmest average mean temperatures and can be characterized as a small, shallow step boulder complex pool with a groundwater seep emerging from the canyon wall on the easy bank of the pool. Despite the drought, average mean temperatures did not increase consistently over time, in all pools. Average mean temperatures decreased in all pools for 2019 except for Noel Pool.

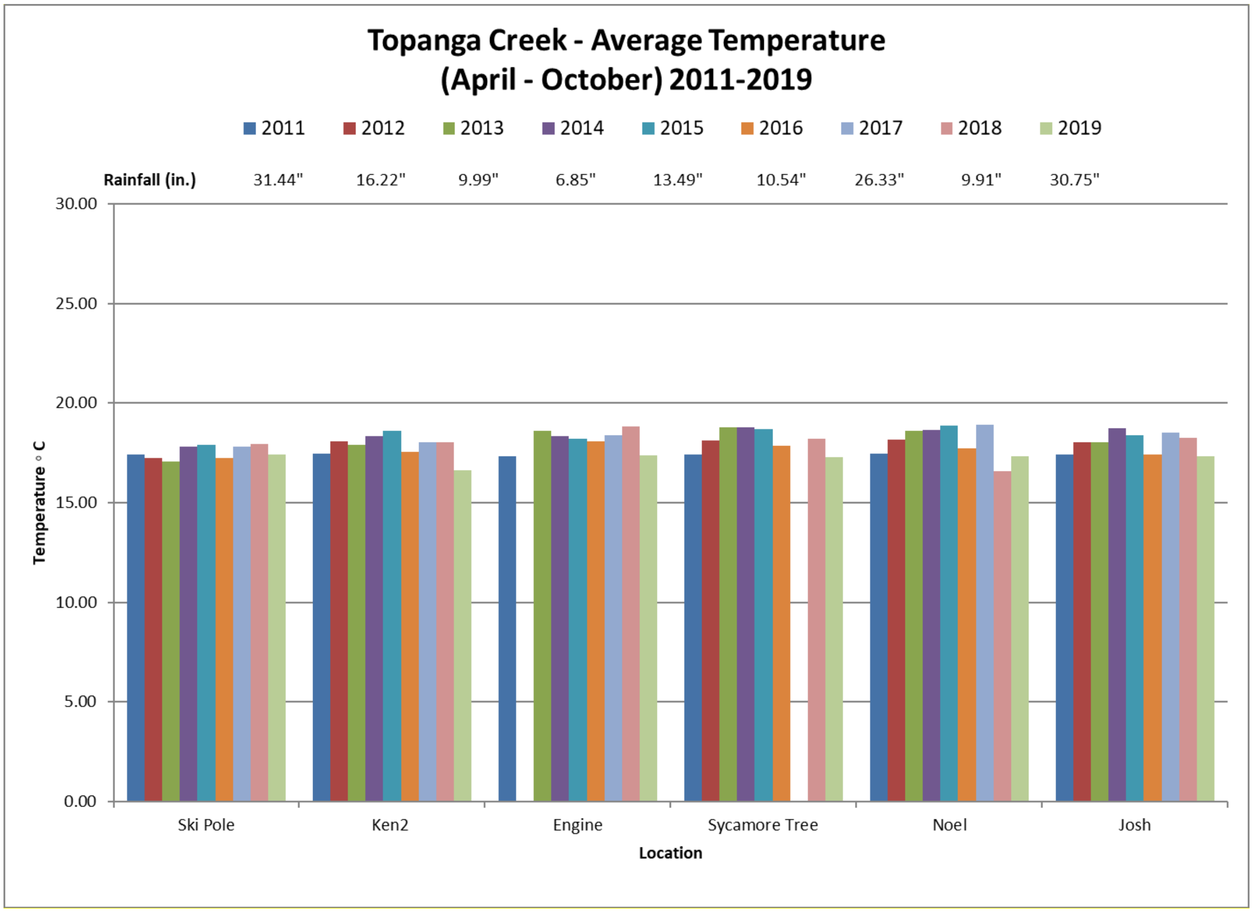


Figure 3.47. Average Mean Summer Temperatures by Location 2011-2019.

3.4.1.3. Average Minimum Temperature

Average monthly minimum temperatures were less than 21°C in Topanga Creek, but varied by pool and year (Figure 3.48). Josh Pool (4.3 rkm) had the warmest minimum temperatures, and can be characterized as a deeper, circular basin with lower canopy cover. In the extended drought period between 2011-2018, monthly minimum temperature was observed to increase in the month of August at study sites Ken^2 (2.6 rkm) ($z = 2.254$); Sycamore Tree (3.94 rkm) ($z = 2.703$); and Josh (4.3 rkm) ($z = 2.10$). Sen's Test estimated rate of change at these sites ranged from an increase of 0.6 to 1.0°C/year MnT. Warmest monthly mean minimum occurred in years 2006, 2015, and 2018. Average minimum temperatures decreased in all pools in Topanga Creek from 2018 to 2019.

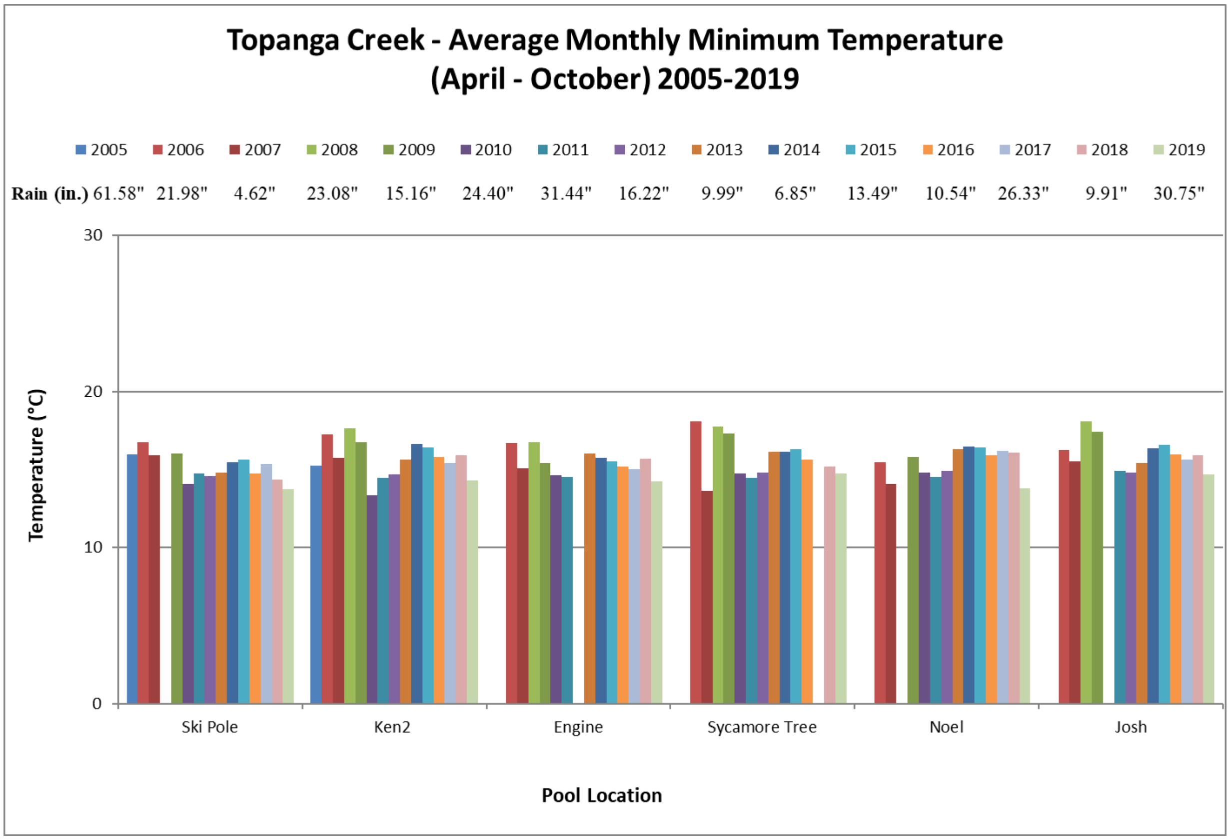


Figure 3.48. Minimum Summer Temperatures by Location 2005-2019.

3.4.1.4. Relationship of O mykiss abundance, temperatures and abiotic functions during drought

Analysis of temperature and physical variables indicates that there was a negative correlation between summer flow and average mean (-0.66) and minimum (-0.54) temperatures, which supports the concept that groundwater inputs play an important role in maintaining overall stream temperature. Pools in Topanga Creek are small, so the positive correlation between temperature and pool volume also makes sense. However, there was no significant difference between pools that had seeps versus those that did not, which is consistent with the overall homogeneity of temperatures throughout the creek (Table 3.43).

Rainfall significantly and negatively correlated to average minimum temperature in Topanga Creek (p<.05), but no correlation to maximum temperature was observed. Rainfall was also correlated to, in order of significance, the number of *O. mykiss* in the adult and intermediate size classes observed throughout Topanga Creek, the number of locations where *O. mykiss* were observed, and the average number of *O. mykiss* observed in the study pools (p<.05). Rainfall was not, however, correlated to the numbers observed of the juvenile size class.

During the drought average minimum temperature was also correlated to observed *O. mykiss* abundance in Topanga Creek. In order of significance, minimum temperature negatively correlated to the number of locations where *O. mykiss* were observed, the number of *O. mykiss* in the intermediate and juvenile size classes observed throughout Topanga Creek, and the average number of *O. mykiss* observed in the study pools (p<.05). As such, this suggests that more fish were observed in association with lower minimum temperatures.

Table 3.43. OLS stepwise regression matrix modeling climate condition and O. mykiss population relationships in Topanga Creek 2011-2018 (p<.001***, .01**, .05*). No asterix indicates term was included in final model but was not a significant term (p>0.05). Dashes indicate response variable not included in final model. N.S. indicates explanatory variables not found to correlate with response variables.

Explanatory	*Response Variables* # Sites	Total # Adult	Total # Int.	Total # Juveniles
7DADM	--	--	--	44.2**
MIN T	--	--	--	55.7**
FLOW	--	--	--	--
POP (t-1)	--	--	--	3.7**
Final model:	N.S.	N.S.	N.S.	R^2=.94, F(3,7)=37.1**

3.4.1.5. Flow

A stream gauge (F54C-R) located at the Topanga Canyon Blvd. Bridge (MM2.02) is maintained by Los Angeles County Department of Public Works (Table 3.44). Unfortunately, for much of the study period the inlet for the gauge was outside of the active channel low flow thalweg, which suggests that the gauge readings are not capturing the lower flow conditions accurately (Figure 3.49).

Table 3.44. Topanga Creek Stream Gauge Discharge Summary 2008-2019.

Water Year	Peak Daily Mean Flow Date	Peak Daily Mean Flow (cfs)	Rainfall inches
2008 – 2009	02/16/2009	101.00	16.16
2009 – 2010	02/06/2010	344.00	24.34
2010 – 2011	03/20/2011	512.00	31.44
2011 – 2012	03/25/2012	36.90	16.22
2012 – 2013	03/08/2013	5.31	9.99
2013 – 2014	02/28/2014	87.20	6.85
2014 – 2015	12/12/2014	37.40	13.49
2015 – 2016	03/06/2016	50.60	10.54
2016 - 2017	12/24/2016	58.9	26.34
2017-2018	02/02/2018	0.27	9.91
2018-2019*	01/172019	210	32.55

*Data as of June 6th, 2019

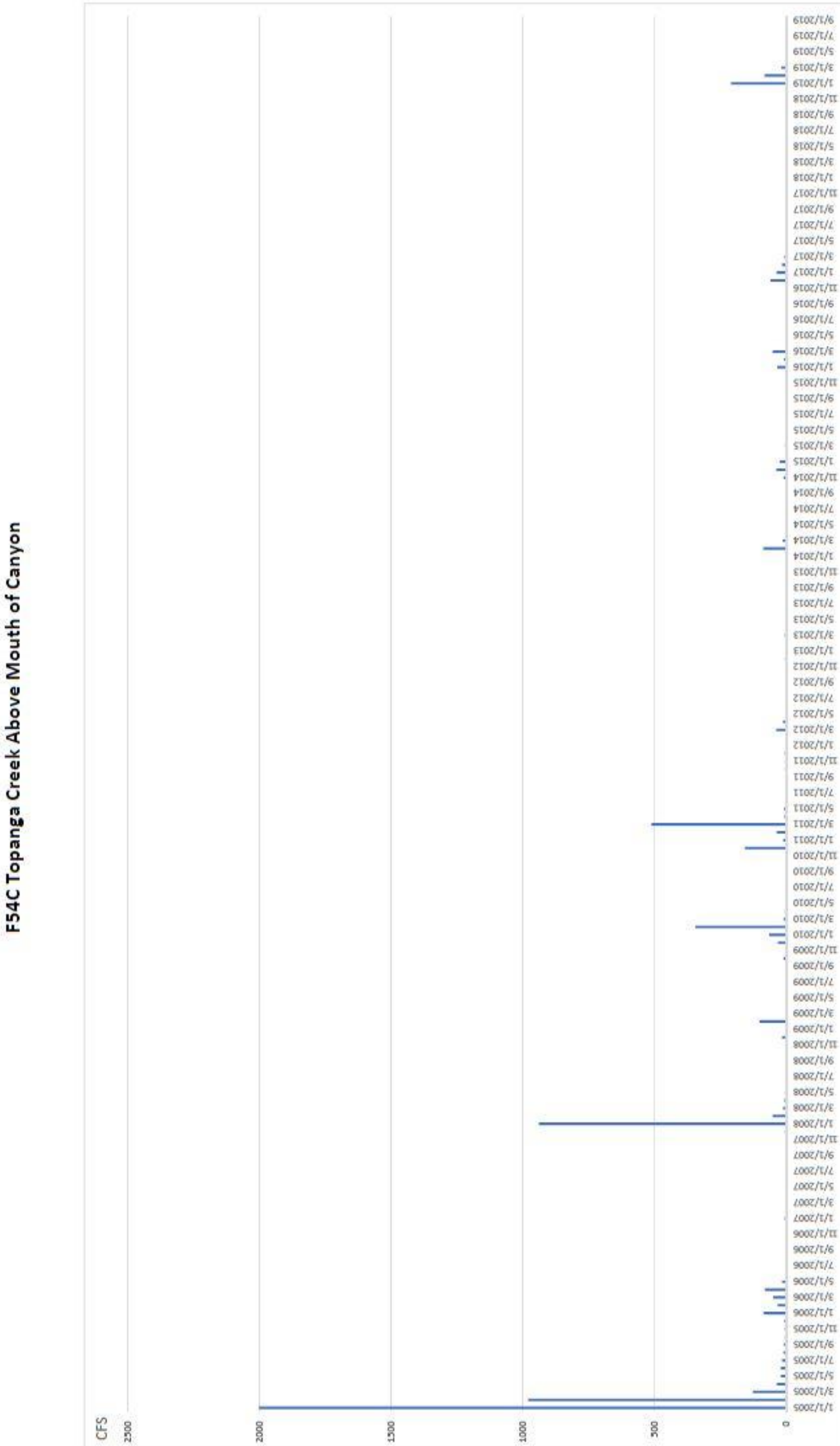


Figure 3.49. Flow in Topanga Creek from 2005-2019.

3.4.1.6. Water Quality

Water quality parameters (dissolved oxygen, pH, temperature, conductivity) were recorded at the start of spring stream surveys only in 2017-2019 (Table 3.45). Previous water quality data is summarized in Dagit et al. (2017a).

Nutrient and algae levels were, in general, low throughout the study period, with only occasional exceedances. Orthophosphates were in exceedance throughout much of the study area. In-situ parameters except dissolved oxygen were, in general, within the standard ranges for wildlife. Dissolved oxygen levels were consistently low at Snake Pit (0.3 rkm) but fine in other locations. Rainfall was below normal from 2012-2016, and significant rain events were few. Therefore, flow was consistently low throughout the study period until the winter storms of January 2017.

No additional water quality data was collected in 2018 and 2019 except during the snapshot of spring stream survey, which were consistent with previously recorded ranges.

Table 3.45. Average Water Quality March – July 2016 Topanga Creek. Exceedances in bold.

Parameter	**Topanga Lagoon (0 rkm)**	**Snake Pit (0.3 rkm)**	**Brookside (1.7 rkm)**	**Topanga Bridge (3.6 rkm)**	**Scratchy Trail (4.8 rkm)**
Elevation (m)	0	0	30	60	170
Depth (cm)	33	15	20	15	23
Salinity	1.75	0.75	0.5	0	0.25
Dissolved oxygen (mg/l)	8.09	3.13	7.14	7.47	8.78
Water Temp ºC	16.1	16.3	14.2	13.6	14.2
Turbidity (NTU)	0.96	0.86	0.31	1.12	0.65
Conductivity (uS)	4800	1727	1620	1470	1525
Nitrates (ppt)	0.02	0.04	0.04	0.01	0.05
Nitrites (ppt)	0.06	0.09	0.05	0.05	0.05
Phosphates (ppt)	**0.23**	**0.31**	0.09	**0.18**	**0.2**
Ammonia (ppt)	0.11	0.95	0.14	0.19	0.18

3.4.2. Benthic Macroinvertebrates

Overall, the abundance of all BMI was low especially during the drought. From 2016-2018, aquatic invertebrates were significantly more abundant than terrestrial invertebrates, comprising 83.5% of the mean drift net sample and 97% of the kick net sample abundance (Dagit et al. 2017b). The most abundant aquatic taxa were *Argia sp*., followed by chironimids, simulidae, Ceratopogonidae (midges), copopods, and baetids (mayflies). The most abundant terrestrial invertebrate was Thysanoptera (thrips).

While the sampling site selected was characteristic of habitat throughout Topanga Creek, the overall patchiness of invertebrate distribution and abundance is worth consideration. Low flow barriers present throughout the creek restricted invertebrates from moving throughout the creek freely.

The Southern California Coastal Index of Biotic Integrity (SCC-IBI, Ode et al. 2005) provides a tool for quantitatively comparing ecological conditions across a regional area. Scores are based on identification of 500 individuals per sample and then grouped into seven metrics (EPT taxa, Coleoptera, predator taxa richness, percent non-insect, tolerant taxa, percent intolerant individuals, collector-gatherer and collector-feeder individuals). Very poor samples had a combined metric score of less than 13, with 14-26 being poor, and 27-40 being considered fair. Mean IBI scores did not significantly change annually, so there was no obvious effect of the drought, however returning rains in 2017 were not enough to change the quality and diversity of the invertebrate assemblage.

These results are consistent with the patterns observed in Topanga Creek between 2002-2014 by Montgomery et al. (2015). Over that time, the extended drought resulted in increased abundance of chironomids, with decreased abundance of baetids. SCC-IBI scores for these reaches ranged between a low of 9 (upper reach 2013) to a high of 40 (lower reach 2007). Overall, the scores averaged 37 in the lower reach and 35 for the upper reach, putting them in the fair category. This suggests that the long-term drought affected overall species composition and abundance which resulted in continued decline during the study period.

3.4.3. Invasive Species Monitoring

Notes were made during each snorkel survey on any invasive aquatic species observed. Until 2009, red swamp crayfish were the only invasive species reproducing in Topanga Creek. Red swamp crayfish (*Procambarus clarkii*) were initially observed in the main stem of upper Topanga Creek above the limit of anadromy in 2001 but their population remained constrained due to flushing storm events until summer 2011. Between 2011 and December 2016, their population exploded. A targeted removal effort was initiated in 2013 with student volunteers, but the low flow conditions created favorable conditions for reproduction and growth. The flushing flows of winter 2017 appeared to have significantly reduced the population but based on 2018 observations, the population has rebounded with more individuals observed in more locations (Figure 3.50 and 3.51). Each of the refugia pools in Figure 3.55 are places where *O. mykiss* and crayfish have been consistently found. These pools range in average depth from 45 -200 cm.

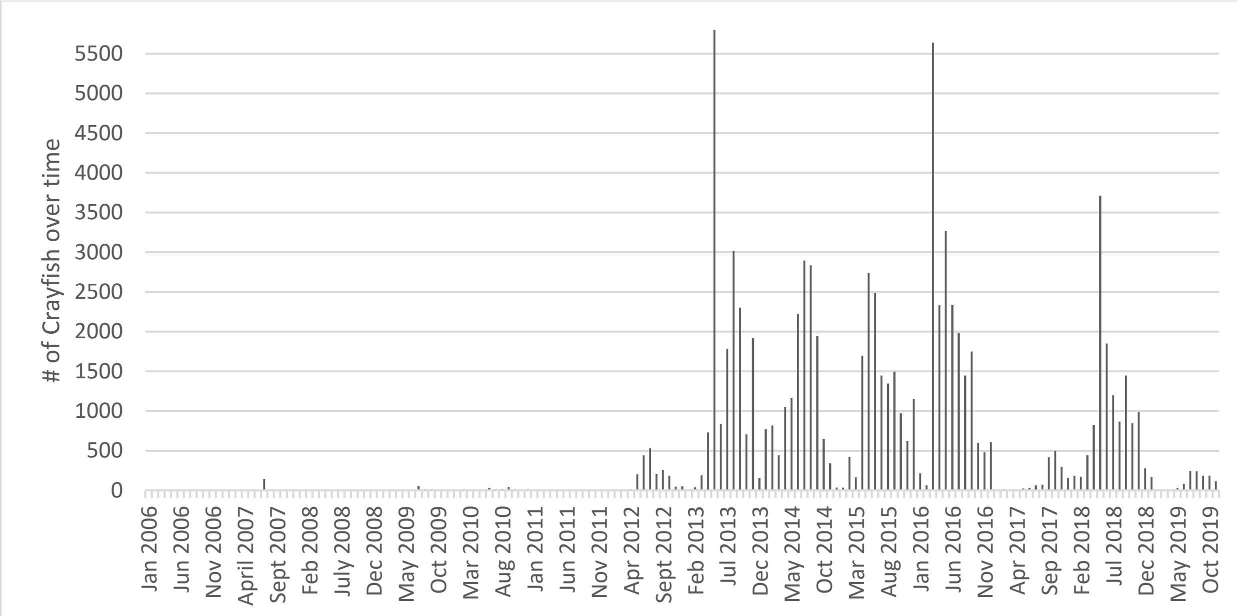


Figure 3.50. Total Crayfish in Topanga.

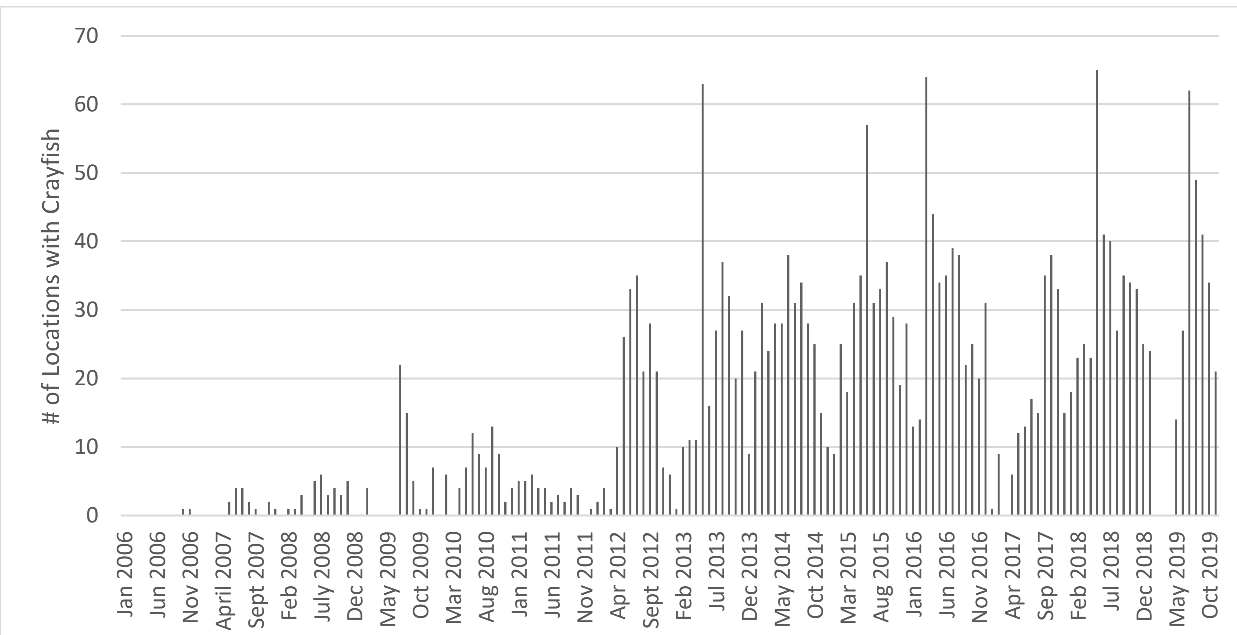


Figure 3.51. Number of locations with Crayfish in Topanga.

The increased crayfish population is a concern. Cox and Davis (2019 in review) used this data to develop a mathematical model looking at the impacts of crayfish to the *O. mykiss* population and estimate that in 10+ years at current levels they could cause local extirpation.

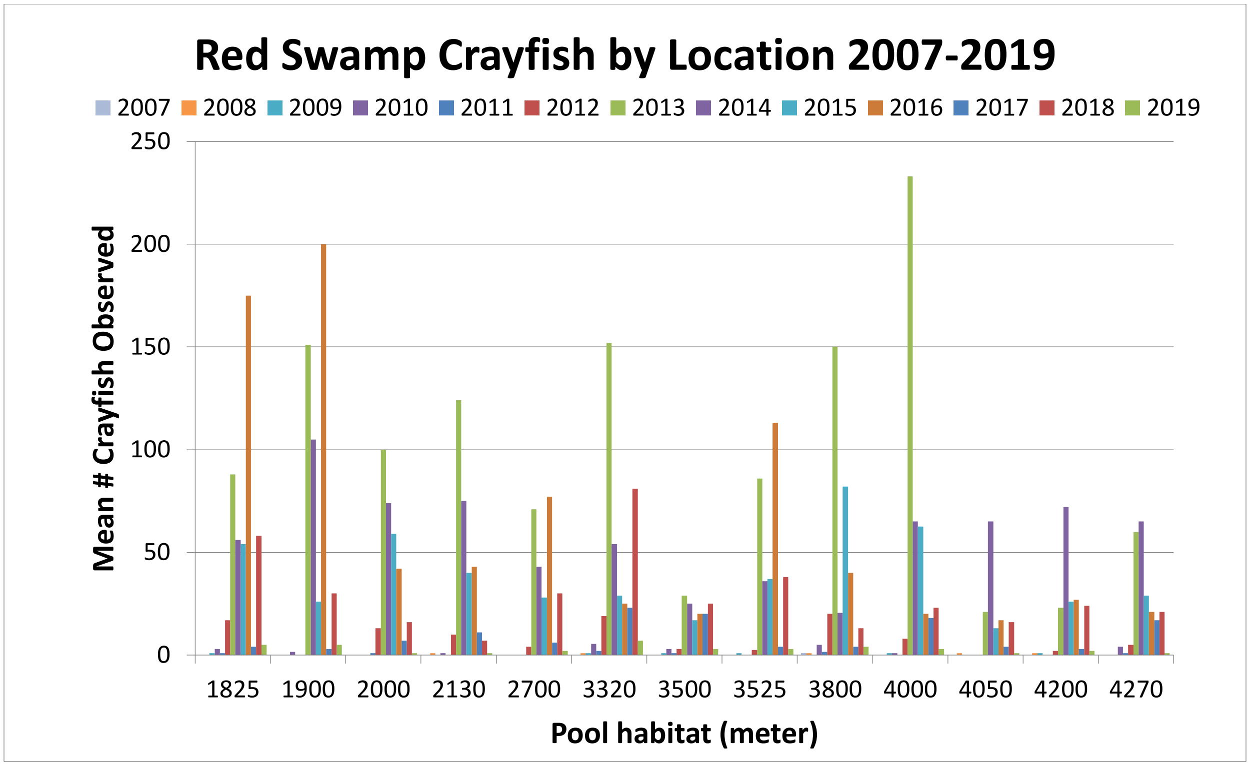


Figure 3.52. Average Abundance and Locations of crayfish observed in Topanga Creek.

Between 2001 and 2012 we occasionally observed random individual goldfish (*Carassius auratus*) that appeared to be pets released into the wild. Typically, they did not survive for long or we were able to capture and remove them. In 2012 a new and different "gold" fish (unidentified species) was observed. Voucher specimens were collected and are being examined by Drs. Rick Feeney and Camm Swift at the Los Angeles Natural History Museum. Based on fin morphology, they are not the more common pet store goldfish, nor are they rosy red minnows, which is a mutant form of the fathead minnow.

Initially they were only noted in a few pools in the upper reach. This changed in spring 2014 when they successfully began reproducing and spreading throughout more of the upper reach (Figures 3.53 and 3.54).

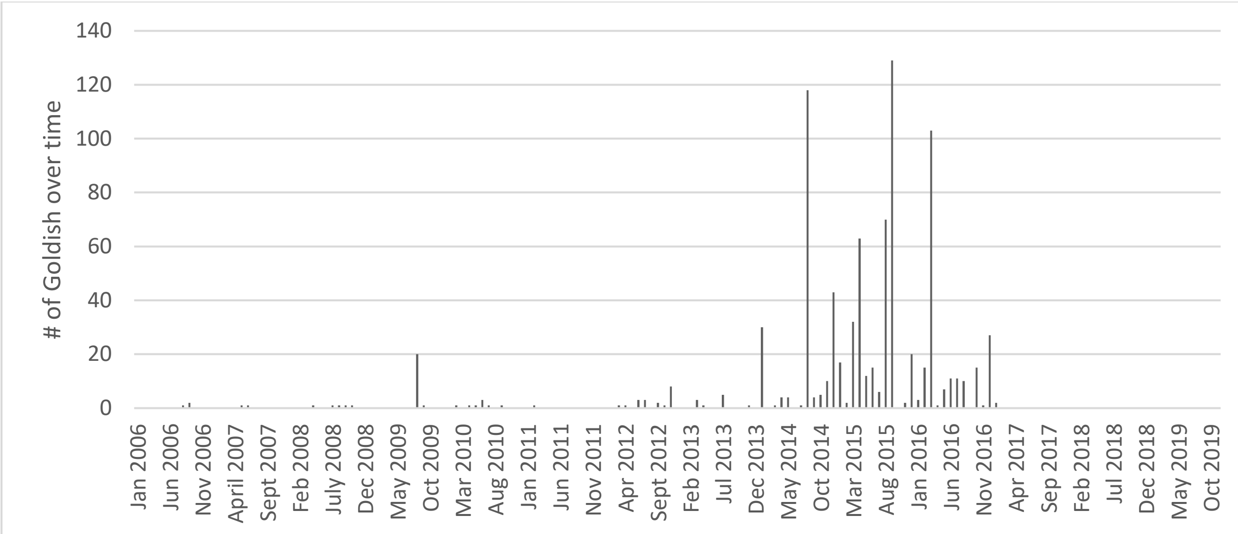


Figure 3.53. Estimated number of “Gold” fish in Topanga.

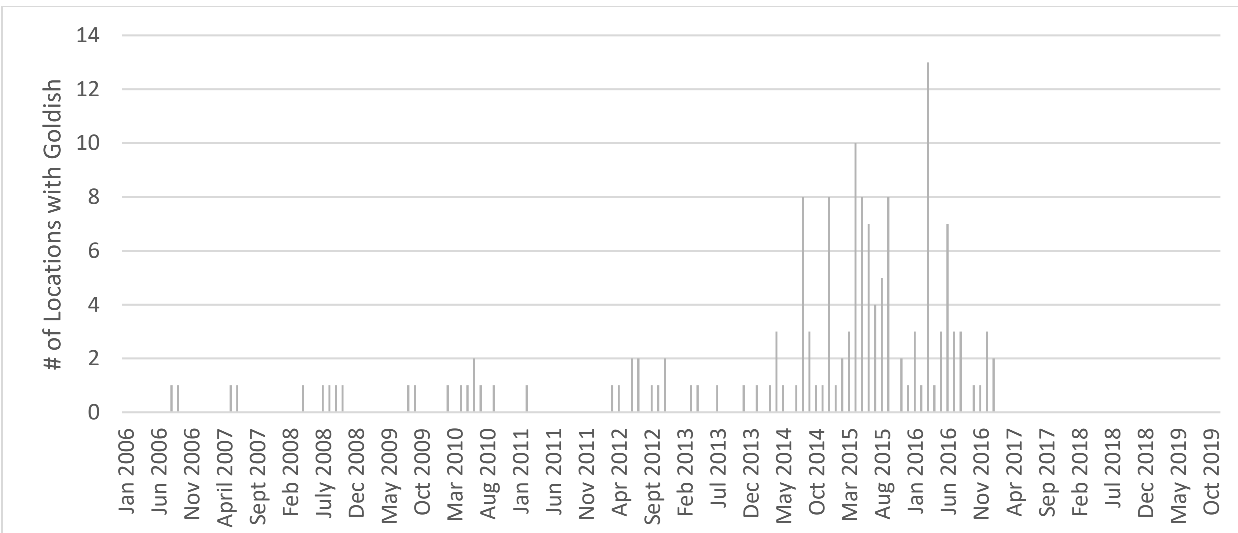


Figure 3.54. Number of locations with “Gold” fish in Topanga.

In July 2014, fathead minnows (*Pimephales promelas*) were also documented (Figures 3.55 and 3.56), and subsequently became reproductively successful. Low flow conditions limited their dispersal during the drought, but eradication efforts have been complicated by patchy dispersion and similar appearance to native Arroyo chub outside of mating season. They were not observed between 2018 and 2019 due to the flushing flows in January 2017.

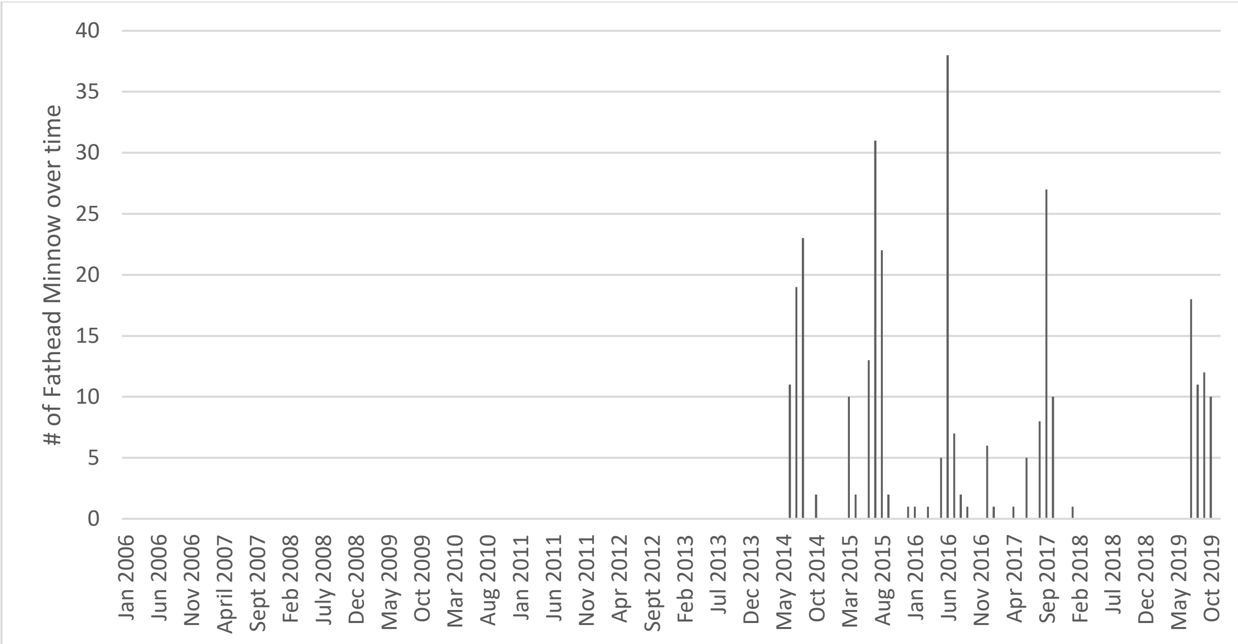


Figure 3.55. Estimated number of Fathead Minnow in Topanga.

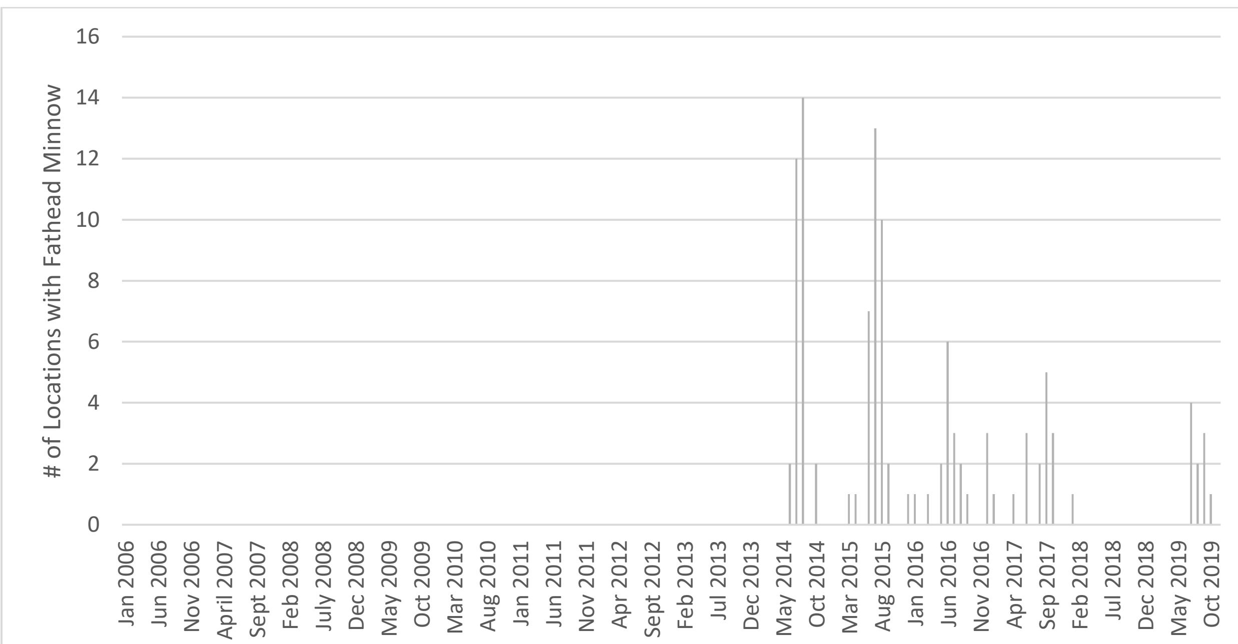


Figure 3.56. Number of locations with Fathead Minnow in Topanga.

4. DISCUSSION

4.1. Abundance Trends

Overall, abundance of *O. mykiss* has declined in both Malibu and Topanga Creeks since the onset of drought in 2012 (Figure 4.1). The decline is a matter of serious concern, with both local and regional implications. One important value of long-term data sets is that they provide context to natural variability. The abundance patterns can tell a very different story if you look at just subsets of the data, rather than trends over a longer time.

For instance, between 2008-2011, there were high numbers of young of the year (YOY), and the recruitment into larger size classes followed a predictable seasonal pattern with fewer YOY growing into more intermediate size fish through fall, and then counts declining as fish moved out of the creeks during winter storms when conditions were suitable (Figure 4.4). More anadromous adults were observed throughout the southern California Distinct Population Group region in 2008 (Dagit et al. 2020) than in any other year (Table 4.1), so the high numbers of YOY makes sense. High precipitation levels three years previously (2005) appeared to have been important in allowing smolts to get into the ocean, grow, and subsequently return to spawn. We documented smolt outmigration in spring 2011 in Topanga Creek, and so eagerly awaited the return of anadromous adults in 2014, however the drought precluded any creek access. Indeed, that year there were five anadromous adults observed in Malibu Creek, where ocean access was possible, but none in Topanga, and few in other regional streams (Dagit et al. 2020). This pattern supports the hypothesis that the viability of the regional metapopulation is dependent upon the life history strategy decisions of resident *O. mykiss*, which are influenced by a suite of environmental conditions including potential outmigration of smolts and in-migration and reproduction by anadromous adults.

During the seven year drought 2012-2018, abundance of all size classes declined in both Malibu and Topanga Creeks (Figure 4.1). Despite the fact that Malibu usually receives summer augmentation flows, and is a larger system overall, the challenges associated with high numbers of warm water invasive species competing for food and space, as well as higher water temperatures, appear to exert significant pressure on the abundance of all size classes, even with the appearance of five anadromous adults in 2014.

The pattern in Topanga is even more dramatic where overall numbers of all size classes has steadily declined from 2011 prior to the start of the drought to 2018. In Topanga, even with the restored connectivity for a few months in winter 2017, the overall low flow condition restricted movement and confined fish to small refugia pools where competition from red swamp crayfish is a potential threat. The rainy season of 2019 restored base flow in Topanga Creek from January through June, and an increased number of YOY were observed. Unfortunately, there has been no recovery observed in Malibu Creek, where the last *O. mykiss* was observed in 2018.

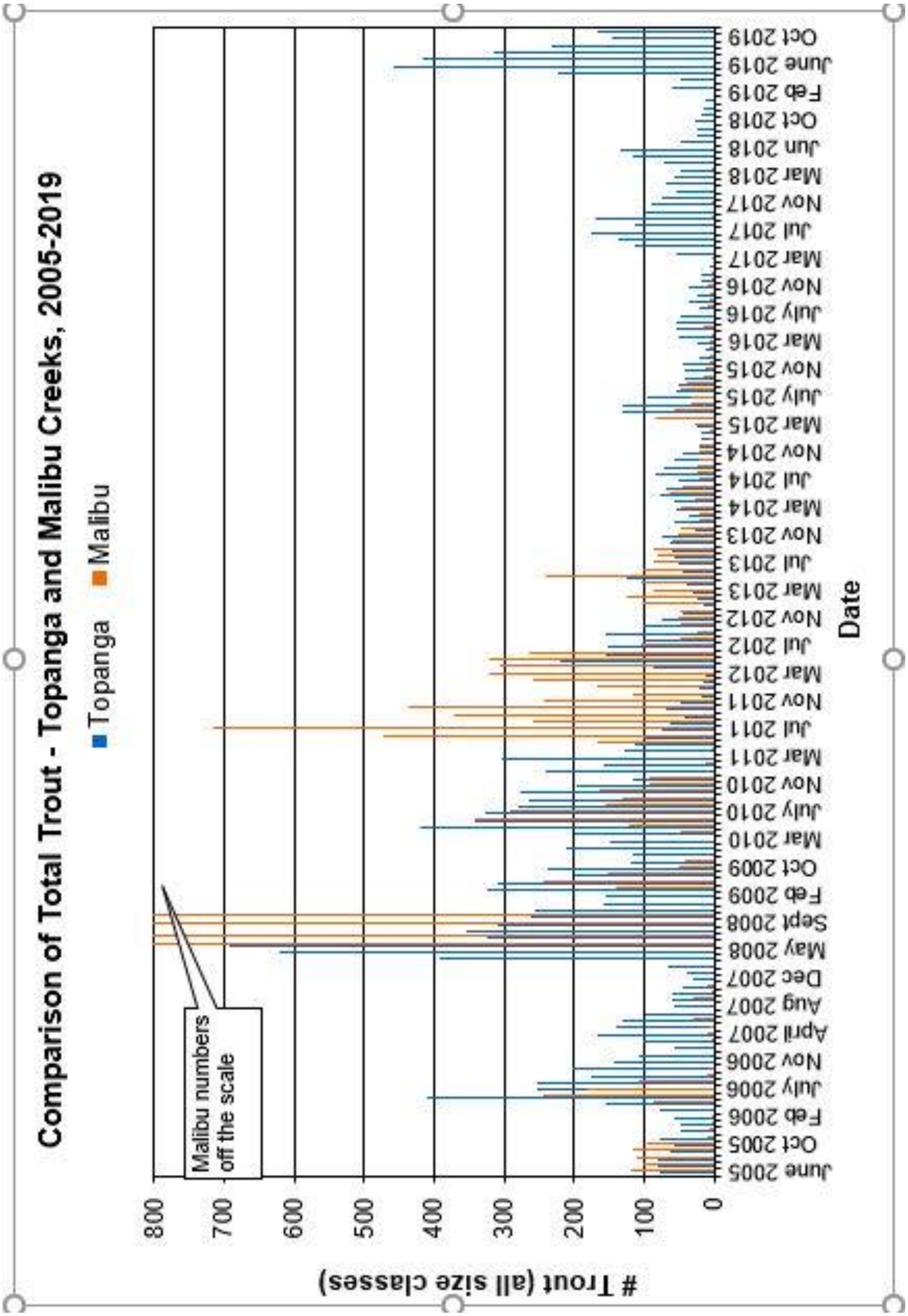


Figure 4.1. Abundance of *O. mykiss* in Malibu and Topanga Creeks 2005-2019.

Table 4.1. Summary of Anadromous Adults in the southern CA metapopulation region (blank rows indicate no surveys).

YEAR	Malibu	Topanga	TOTAL DPS
1994			2
1995			2
1996			2
1997			2
1998			1
1999			4
2000			5
2001		2	10
2002		0	2
2003		0	2
2004		0	1
2005	0	0	8
2006	1	1	8
2007	2	2	18
2008	4	2	49
2009	1	1	9
2010	2	1	7
2011	2	0	11
2012	3	1	9
2013	3	0	6
2014	5	0	5
2015	1	0	2
2016	0	0	1
2017	1	2	10
2018	0	0	1
2019	0	0	2
TOTAL	**25**	**12**	**179**

Another factor to consider is the potential role of the shift in the BMI community and abundance in Topanga Creek. Our data suggests that Baetids, which are a preferred food for *O. mykiss* were replaced by Chironomids (Montgomery et al. 2015, Dagit et al. 2018b). While both species are well documented food for *O. mykiss (*Rowley 2015*),* the community species shift may be resulting in less food for trout overall, or the competition for this food from the increasing numbers of red swamp crayfish may also be an issue.

While it was outside the scope of this study, the changing ocean conditions with increased warming, decreased upwelling in coastal zones throughout the southern California Bight may also be contributing to the low numbers of anadromous adults returning to spawn in coastal creeks. Black et al. (2015) describe a pattern of seasonal coastal upwelling extending back over 600 years based on analysis of tree rings in the Central Valley. They found that upwelling patterns have become more unpredictable and extreme in the past 50 years, creating shifts in nutrient availability that have ripple effects throughout the coastal marine system. Declining marine survival trends have been suggested as playing an important role in the declining abundance of *O. mykiss* in several Pacific Northwest populations (Kendall et al. 2017). Although there is limited information on how and where *O. mykiss* from the southern California DPS spend their ocean time, the synergistic effects of disturbed ocean productivity coupled with the freshwater associated impacts of drought and wildfire could be another factor in the decline of this species.

4.2. Distribution Trends

CalTrout (2006) documented over 8.05 kilometers of stream habitat in Arroyo Sequit to be potentially good to excellent for *O. mykiss*. Since that time, drought compromised the main refugia culvert pool located under Mulholland Highway. The undercut portion of the culvert, which created a highly sheltered pool, was then filled in with concrete filled sandbags by Los Angeles County. In spring 2014, the entire culvert pool dried up for the first time since records have been kept for that pool, and it remained either a small puddle or completely dry until January 2017 (Kats, *pers. communication*). In fall 2014, California Department of Parks and Recreation (CDPR) personnel observed a single adult *O. mykiss* in a small spring fed pool upstream from the group campground. Unfortunately, high visibility and easy public access was a real threat and the fish was gone by February 2014. Removal of the final instream barriers was completed in December 2016, and following the first large storm event in January 2017, two anadromous adults were able to move upstream almost to the culvert. Sadly, one fish died in September 2017, and the other was isolated in the culvert pool which continued to dry down during the fall. By November 2017, RCDSMM and CDPR efforts to add water to the pool were deemed insufficient and CDFW biologists captured and moved the fish to a more stable refugia pool in Topanga Creek.

For much of the drought (2012-2018), only a small refugia pool located at 1.62 rkm remained suitable for fish. During the Woolsey Fire (2018), the entire watershed was severely burned, and sedimentation aggraded the creek channel, limiting surface flow significantly (Figure 4.2). Following the rains in 2019, most of the creek remains sediment choked. There was limited connection to the ocean and the sediment deposition in the reach downstream of the previous refugia pools prevented any movement within the stream.

Figure 4.2. Pool at 1.62 RKM before (November 2017) and after (February 2019) the Woolsey Fire.

Distribution of *O. mykiss* in Malibu Creek varied according to the precipitation patterns, with the majority of fish holding in large mid-channel and step pools closer to Rindge Dam where the creek remains more connected. The reach downstream of 1.9 rkm Lunch Pool dried down all the way to 1.0 rkm Start Pool for much of the summer months, despite augmentation flow releases in 2013-2018. The reach between 1.0 rkm Start Pool and Malibu Lagoon also dried down. Habitat became severely limited in summer 2016, when due to a faulty stream gauge, augmentation flows did not commence until September, causing most of the reach downstream of the dam to dry up.

Connectivity was restored throughout the reach below Rindge Dam during the rains of winter 2017, but few fish have been observed since, and they were individually found in two different locations in the reach between 1.9 rkm Lunch Pool and the 4.12 rkm Dam. No *O. mykiss* were observed between November 2017 and April 2018, when a single 30 cm individual was observed in 1.7 rkm Upper Twin Pool. No *O. mykiss* have been observed since that time. Although the study reach below Rindge Dam did not burn in the Woolsey Fire (2018), much of the upper watershed was impacted, resulting in heavy turbidity and sediment movement during the rainy season of 2019. It was not possible to snorkel until April 2019, but visibility remained challenging until June. The connection to the ocean and surface flow remained connected through early July so it is possible that anadromous individuals came and went without detection.

The low flows associated with drought restricted movement of *O. mykiss* in Topanga Creek. From 2012- winter 2017, fish were confined to the reach from 1.7-5.3 rkm due to subsurface flows disconnecting the creek in the downstream reach below 1.7 rkm, and the natural boulder barrier 4.0 rkm precluding movement upstream. As flows continued to subside until December 2016, fish movement became more restricted and concentrated in the higher gradient reach upstream of 3.6 rkm. Flows were connected for a few months in 2017 before disconnecting again until the rains of January 2019 reconnected base flow.

Although the Woolsey Fire did not burn anywhere in the Topanga Creek Watershed, a small car fire ignited 55 acres of brush on the east bank in the reach between 2.1-2.5 rkm in June 2017. The mud slides and sedimentation associated with this fire had significant impact on the 1 rkm reach downstream of the burn area. Caltrans repaired the bank in summer 2018, and during that time the RCDSMM identified over 25 YOY that were trapped in extremely shallow areas that were drying down. With permission from NMFS, these fish were relocated to a more stable pool upstream in July 2018. There was some sediment movement following the 2019 rains, but overall pool habitat in that reach remains compromised compared to the pre-fire condition.

Most interesting is the comparison of numbers of locations used by *O. mykiss* between Malibu and Topanga Creek (Figure 4.3). Despite the fact that Malibu Creek has approximately three times as much available habitat even with drought conditions, *O. mykiss* were found in an average of 11 locations within the 3.3 rkm survey reach, as compared to approximately 28 locations on average in Topanga Creek (5.3 rkm) during the drought of 2012-2018. The implication is that factors other than habitat availability are impacting the abundance and distribution of *O. mykiss* in Malibu in ways they are not in Topanga Creek.

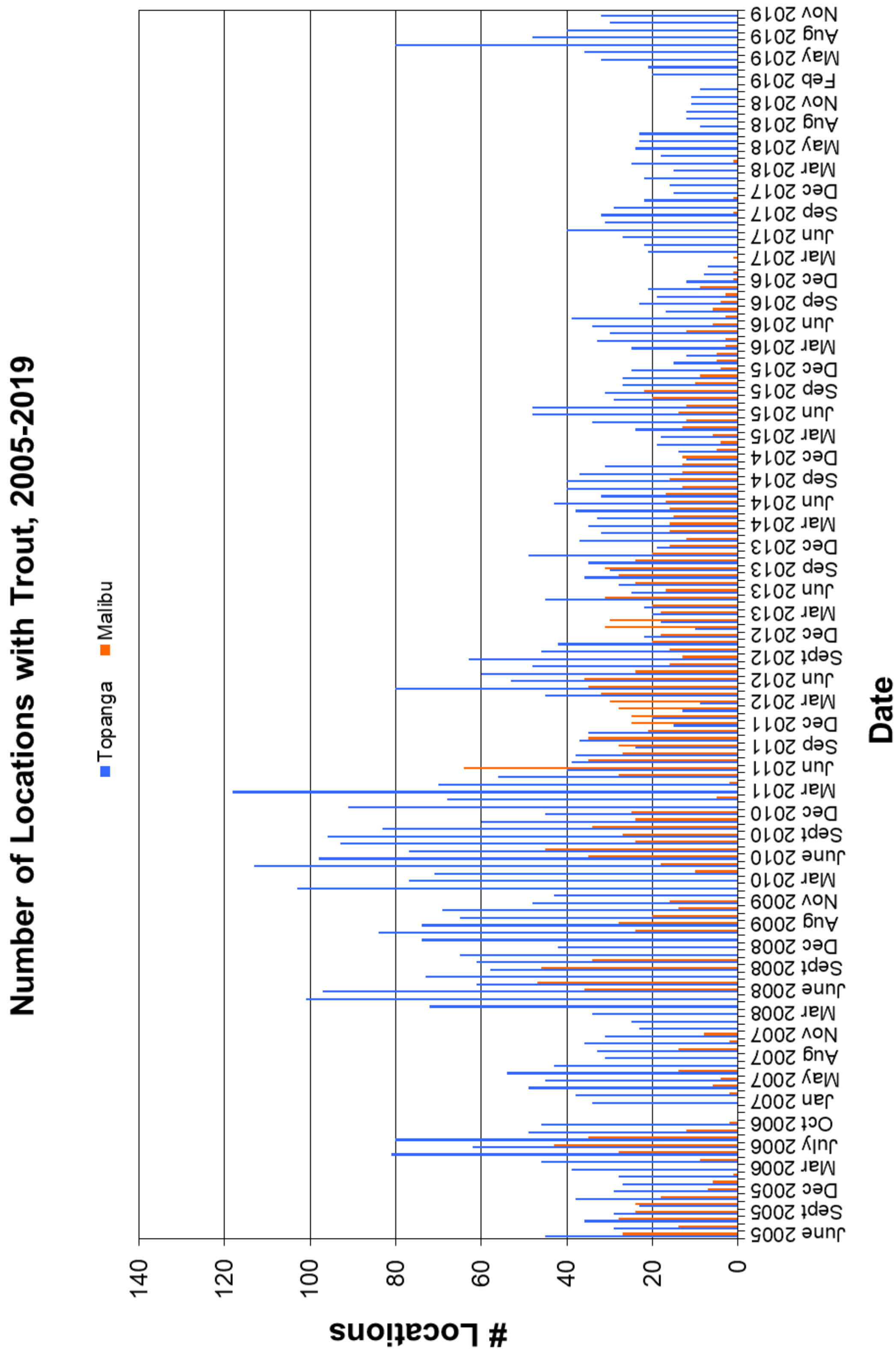


Figure 4.3. Numbers of locations used by *O. mykiss* in Malibu and Topanga Creeks 2005-2019.

4.3. Instream Habitat Comparisons

Another goal of this study was to compare the suitability and availability of habitat in three representative coastal creeks. The criteria of length of creek available, habitat type distribution and condition, numbers of passage barriers, water quality, pool characteristics and numbers of *O. mykiss* observed were used for the comparison in 2017 and were updated in 2019. Given the episodic nature of rainfall events, southern California watersheds are characteristically low flow dominated, with changes to overall habitat occurring related to major drought, floods and wildfires, all of which occurred between 2017-2019.

Watershed size and flow variability, in addition to the sedimentation impacts following the Woolsey Fire (2018) appear to be significant limiting factors for the Arroyo Sequit watershed at present. When surface flows are sufficient and the connection to the ocean is established and maintained, then anadromous trout take advantage of the opportunity to enter Arroyo Sequit, as was observed following the instream barrier removals in 2016. However, the effects of the drought (2012-2018) restricted surface flows to isolated refugia pools for much of the time and connection to the ocean was also quite limited. Following the Woolsey Fire, the rains in 2019 mobilized sediments and almost completely reconfigured the creek morphology, resulting in a almost 1.2 rkm reach in the lower reach between the campground and the ocean that prevented any passage movement in either direction. Given the dynamic nature of the creek response to this significant impact, it appears that systems of this size may be refugia only for limited time spans and as such have less effect on providing sufficient consistently available habitat for *O. mykiss* within a regional context.

The comparison of Topanga (a medium size watershed, 18 square miles) and Malibu (109 square miles) was most interesting. Even though there was approximately three times more physical creek habitat available in Malibu Creek, the number of *O. mykiss* residing in the creek was only half of that found in Topanga Creek. The number of locations used by *O. mykiss* in Malibu was also three times less than the number of locations used in Topanga Creek. The numbers of *O. mykiss* in Topanga Creek increased since 2001 when recolonization took hold.

It appears that the limited migration opportunities may encourage *O. mykiss* in Topanga to remain residents. The good to excellent water quality, habitat quality, lack of invasive aquatic species, and higher benthic macro-invertebrate diversity may contribute to the continued recruitment of young fish into the population.

By contrast, Malibu Creek supports flourishing populations of numerous invasive aquatic species (crayfish, carp, largemouth bass, catfish, etc.), has poor water quality and a limited benthic invertebrate community. Even with the more abundant physical habitat, more passage opportunities and a larger lagoon to allow for transition from fresh to saltwater, the impacts of these other factors appear to have reached a threshold where it is more difficult for *O. mykiss* to survive successfully.

So how do these factors influence the distribution of southern *O. mykiss* in the Santa Monica Bay? If Malibu Creek, the largest, potentially most suitable watershed, is rendered unsuitable due to anthropogenic influences, then restoration actions must be directed in one of two ways.

The impairments must be addressed and reduced to levels suitable for *O. mykiss*, and protection and enhancement of other potential *O. mykiss* habitats must also take priority.

There has been substantial support over the years for the preservation of *O. mykiss* in both Malibu and Topanga Creeks. Community support for restoration actions has been consistent and strong. The Malibu Creek Watershed Council and formerly the Topanga Creek Watershed Committee contributed significant time, energy and resources to planning and implementing restoration projects for both these watersheds. Despite some opposition to the restoration of Malibu lagoon, pending removal of Rindge Dam and the pending restoration of Topanga lagoon, we anticipate that there is sufficient will and funding to implement changes necessary to ensure the continued survival of *O. mykiss* in both of these watersheds.

While the challenge to reclaim Malibu Creek for *O. mykiss* is great, the consequence of not trying is dire to the species both locally and regionally. Due to the *O. mykiss* population crash witnessed during this study, immediate action is needed to stabilize the Malibu Creek *O. mykiss* population by providing access above Rindge Dam. This will enable the fish to access two additional tributaries and will more than triple the current available habitat. Considering the limited opportunities within the Santa Monica Mountains to dramatically enhance *O. mykiss* access to habitat, making the watersheds that currently support *O. mykiss* available is crucial to protecting the remaining population in southern California. Table 4.2 compares the overall conditions of each of the three watersheds.

Table 4.2. Comparison of Physical Characteristics of Study Areas, Arroyo Sequit, Malibu and Topanga Creeks.

Variable	**Arroyo Sequit 2006**	**Arroyo Sequit 2019**	**Malibu 2006**	**Malibu 2017**	**Malibu 2019**	**Topanga 2006**	**Topanga 2017**	**Topanga 2019**
Watershed Size	10.98 sq miles		109 sq miles			18 sq miles		
Percent developed	3.23%		22%			15%		
Stream Length Available in Study Area	3200 meters	3200 meters	4800 meters	4800 meters	4800 meters	5300 meters	5300 meters	5300 meters
Invasive Aquatic Species	No	No	Yes	Yes	Yes	No	Yes	Yes
Percent of Pool Habitat in Study Area	25.5%	2%	28 %	64%	23%	26%	56%	46%
Avg Pool Volume	82 m^3		2093 m^3	1794 m^3	1837 m^3	172 m^3	131 m^3	137 m^3
Estimated area of channel in study reach (length x avg width)	12,800 m2	8,411 m^2	67,200 m^2	34,047 m^2	40,250 m^2	26,500 m^2	29,798 m^2	40,066 m^2
Avg Number Juvenile Trout	0	0	29	0	0	62	70	156
Avg Number of Intermediate Trout	0	0	32	1.5	0	68	20	43
Avg Number of Adult Trout	1	0	18	1	0	40	8	7
Avg Number of Locations with Trout	1	0	18	1	0	45	23	35

4.4. Migration Patterns and Role of Lagoon Connectivity

Passage limitations are a major concern in Arroyo Sequit, Malibu and Topanga Creeks in most years. For *O. mykiss* to enter or leave each system, both stream flow levels and lagoon-ocean connectivity need to be aligned. Between 2011 and 2019, these conditions rarely occurred. Each of these creeks has a lagoon that is constrained by development associated with Pacific Coast Highway and parking lots. CDPR owns all these areas and is responsible for restoration.

It is not clear when overall conditions within the Arroyo Sequit watershed will recover sufficiently from the Woolsey Fire (2018) to again provide suitable habitat for supporting *O. mykiss*. Coordination with Los Angeles County Road Maintenance is needed to develop a restoration plan for the Culvert Pool under Mulholland Highway. Several upstream developments are also being proposed that might also degrade the habitat for *O. mykiss* by armoring or channelizing sections of the creek running through private property upstream of the park boundary. A coordinated effort to integrate protection for those stream reaches and remove all barriers in order to preserve the opportunity for *O. mykiss* re-establishment, is critical, especially considering the impacts from the Woolsey Fire.

Other than our snorkel observations, no information on *O. mykiss* migration patterns for Malibu Creek are available, and snorkel surveys are not possible during some winter months due to high flows and compromised visibility. The restoration of Malibu Lagoon was completed in fall 2012, resulting in over two acres of increased potential habitat that could support smolt growth and sustain adults passing through. Post-construction fish surveys observed a single anadromous adult *O. mykiss* using the lagoon in May 2014. The summer-fall dry downs throughout the study reach were a significant problem. The augmentation flows released by Tapia Water Reclamation Facility were simply not sufficient to maintain surface connectivity, although they did help maintain depths in most refugia pools. The critical importance of these flows was observed in summer 2016, when the faulty gauge resulted in no augmentation flows until September. While most of the large refugia pools survived, they were disconnected for several months. This resulted in extremely low numbers of *O. mykiss* surviving. Even with restored connectivity in 2017, few *O. mykiss* found their way into Malibu, and none have been observed since spring 2018.

Plans for the restoration of Topanga Lagoon were held up by the need for a revised Topanga State Park General Plan, which was finally approved in 2012. Funding from the Coastal Conservancy was obtained in 2019 and the RCDSMM and CDPR continue to work on getting the next steps for restoration completed by 2022. The Caltrans bridge on Pacific Coast Highway has been listed as a priority for restoration, which when integrated into the overall lagoon design should facilitate progress.

4.5. Spawning

The number of anadromous adults observed is quite low, indicating that resident *O. mykiss* are responsible for keeping the population going. Prior to the onset of drought, the amount and quality of spawning gravel did not appear to be a limiting factor for fry production in any of these watersheds. However, since 2012, emergent wetland vegetation has increased within the wetted channels, and the amount of spawning gravel has declined as it is buried in roots.

Redd surveys conducted monthly in Malibu and bi-monthly in Topanga since 2010 documented few active nests (0-6 per year in Malibu, 0-4 per year in Topanga). Redds are fairly small (<1m) and the adults observed are most often clearly resident *O. mykiss* under 300 mm FL. Even when we have observed a redd being created by two or more adults, they are so cryptic that it is very difficult to find them subsequently, even when mapped. Often our clue that there was a redd is a congregation of YOY near suitable spawning gravel.

A lack of reproductive success or high fry mortality (or both) appeared to be a significant concern. In 2008, the numbers of young of the year in Malibu Creek peaked at over 2,300, which also corresponds to observations of four anadromous adults. This is significantly higher than the number of young expected or observed when no anadromous adults have spawned. According to Moyle (2002), resident fish produce fewer than 1,000 eggs per female, as compared to over 3,000 eggs produced by anadromous females. However, despite observing five anadromous adults in Malibu in 2014, there were few YOY observed (<30 average). During the drought, the number of YOY declined to none.

In Malibu Creek, large numbers of predatory non-native fish and crayfish are present, and although juvenile rearing habitat is available, competition from high numbers of non-natives is intense. Additionally, dense algal mats form, and in some years completely occupy shallow riffles and runs, which are the preferred rearing locations for juvenile *O. mykiss.* Finally, it may be that water temperatures are simply too high in the shallow areas preferred by YOY.

By comparison, there are fewer invasive fishes in Topanga Creek, but since 2012, the population of red swamp crayfish has exploded (Garcia et al. 2015). While drought and other factors probably contribute to the low abundance of young of the year *O. mykiss*, observations from snorkel surveys allowed us to also examine the habitat use by both YOY and crayfish. Field observations of YOY being attacked by crayfish in shallow riffle-run habitat suggest that predation is a real threat (RCDSMM *unpublished data*). The overall numbers of young of the year have been decreasing since 2012 here as well and only slightly rebounded following the rains of 2019.

4.6. Recruitment

As with young of the year, the abundance of 100-250 mm *O. mykiss* in Malibu Creek peaked and then dropped significantly, while the pattern in Topanga Creek was more consistent until it too dropped during the drought (Figure 4.4). While drought is clearly a major stressor, it is difficult to conclusively determine the cause of abundance loss, since a suite of potential variables can influence recruitment. In addition to the problems posed by potential predators, limited rearing habitat, and water quality issues, there was significantly more competition from invasive species in Malibu Creek than in Topanga Creek. Since 2012, the benthic macroinvertebrate community in Topanga Creek has changed, and overall abundance of some important prey species such as Baetidae mayflies appears to have declined (Montgomery et al. 2015). Reduced food sources and increased competition from invasives may be playing a role in the overall decline of intermediate size *O. mykiss* in both these systems.

Malibu Lagoon provides a more suitable transitional area for smolts to grow to size than Topanga Lagoon, although we have no direct observations due to water quality concerns for divers in Malibu. Bond et al (2008) and Kelley (2008) both observed smolts residing for more than a month in lagoons and growing prior to outmigrating, so the potential for similar use in Malibu is a reasonable assumption. Therefore, it is unclear whether the pattern of abundance for intermediate fish in Malibu Creek is a result of lack of recruitment, or outmigration. Few smolts have been observed in Malibu Creek, and the number observed in Topanga Creek of truly "smoltified" coloration is very low.

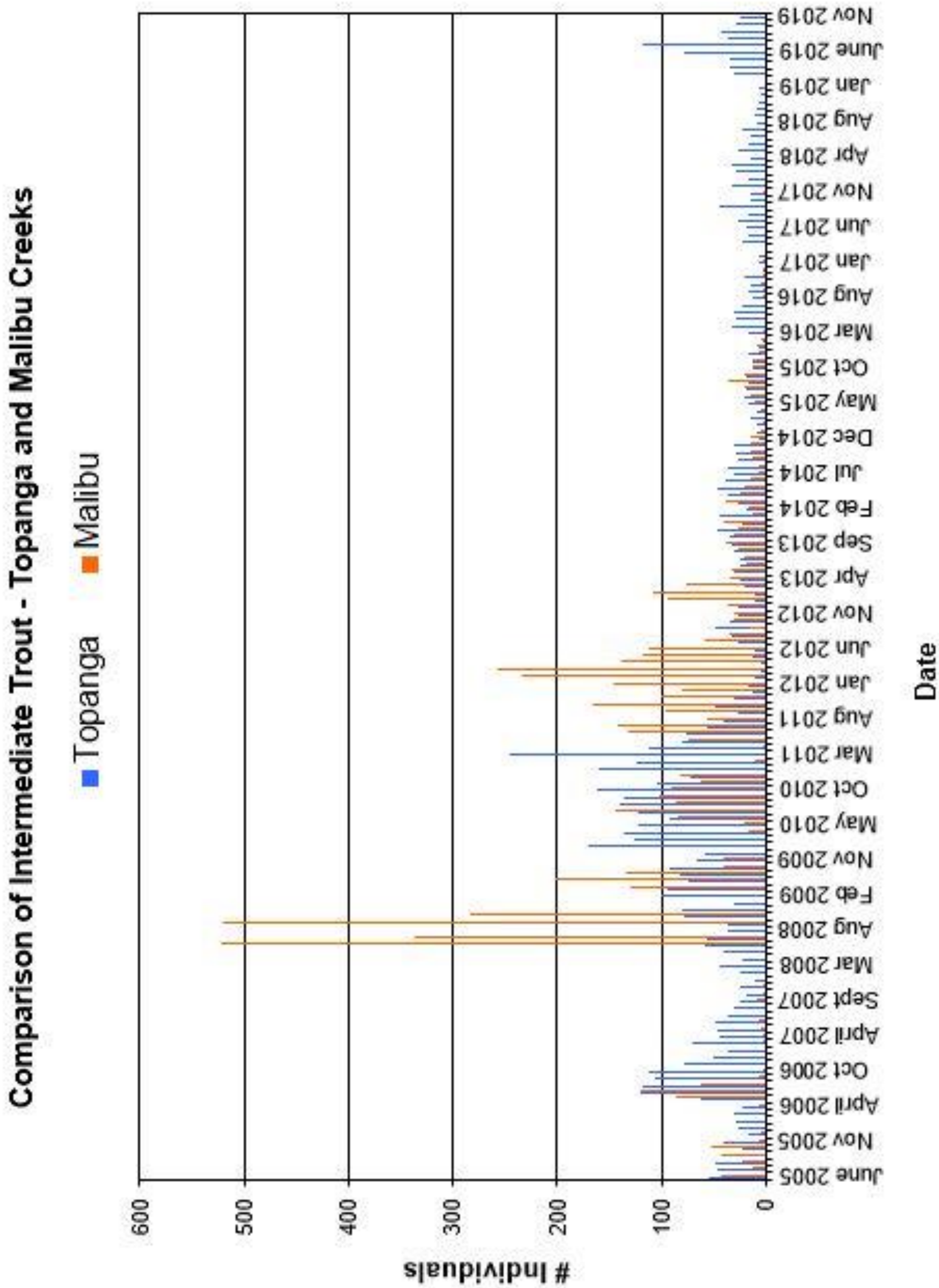


Figure 4.4. Comparison of Intermediate *O. mykiss* Malibu and Topanga Creeks 2005-2019.

4.7. Genetic Relatedness

Analysis of the samples collected in the Santa Monica Bay creeks over the past 19 years, allowed us to examine patterns of ancestry and population genetic structure with respect to two major lineages: native coastal steelhead lineage and hatchery rainbow trout lineage in Southern California (Abadía-Cardoso et al. 2016). Concordant analyses of population genetic structure and ancestry display strong evidence that Malibu Creek is of primarily native coastal steelhead lineage. This aligns with environmental conditions in this watershed, where connection to the ocean is more reliable and accessible for months during the winter season (RCDSMM unpublished data).

The ancestry of Topanga Creek is slightly less obvious, with phylogeographic analyses suggesting admixture with hatchery trout, while the clustering-based method appears to distinguish Topanga Creek from both the supposed hatchery and native lineage groups. However, in order to interpret these inferences of population genetic structure, it is important to understand the history of *O. mykiss* in Topanga Creek. In the early-1980s, several exceptional flood events occurred that dramatically altered creek structure and by 1997 *O. mykiss* were assumed extirpated from Topanga Creek (Bell et al. 2011). Evidence of recolonization by anadromous adults was recorded by the early-2000s, however population size remained quite low (0-2 anadromous adults recorded per year from 2001 – 2019: average population size ranged from low of 36 during drought year 2016 to high of 400 in 2010 when rainfall was above normal; RCDSMM unpublished data). With the genetic data available it appears most likely that Topanga Creek is of mixed ancestry, which is supported by admixture between Fillmore Hatchery – Coleman and Topanga Creek in the STRUCTURE plot, and the grouping of Fillmore Hatchery strains and Topanga Creek on the phylogeographic tree. How long ago the founder steelhead or rainbow trout acquired hatchery lineage and the contribution of mutation and forces such as genetic drift are unknown factors, although the primary assignment of individuals to the hatchery ancestry are approximately 15.6% of all samples. There have been no hatchery fish introduced into Topanga Creek since the mid-1980's.

Further informing this assessment are the results of the individual genetic assignment via mixture analysis, which repeatedly inferred the Santa Ynez – Hilton Creek population to be the population of origin for individuals sampled in Malibu and Topanga creeks. Given the distribution of *O. mykiss* throughout California and its propensity to stray between basins, which allows for gene flow between populations, within-basin population level assignment should be interpreted cautiously (Clemento et al. 2009; Abadía-Cardoso et al. 2016). Therefore, we cannot conclude Malibu and Topanga creeks to be most closely related to Santa Ynez – Hilton Creek, but rather surmise that the genetic lineage of Santa Ynez – Hilton Creek is likely most similar to that of Topanga and Malibu creeks. Hilton Creek in the Santa Ynez drainage is a routinely monitored system with unimpeded access to the ocean, and which supports a small, but persistent population of *O. mykiss* (Clemento and Garza 2018). For many years, Hilton Creek was subject to fairly regular hatchery stocking events due its direct proximity to Bradbury Dam (Garza and Clemento 2008). However even with this documented association of hatchery presence, recent investigations of population genetic structure and ancestry in this drainage found individuals were predominately of coastal steelhead ancestry, with low levels of hatchery introgression (Clemento and Garza 2018). Topanga appears to be illustrating similar patterns, although there has been almost no direct hatchery input into this watershed for over 30 years. This would therefore suggest Topanga and Malibu creeks are also predominately of native steelhead ancestry but present some degree of hatchery introgression. These individual-based assignment analyses suggest this hatchery introgression is more prevalent amongst Topanga Creek individuals.

With respect to iteroparity, the recovery of more female iteroparous spawners aligns with findings in other natural steelhead populations (Keefer et al. 2008; Seamons and Quinn 2010). Amongst anadromous salmonids, female repeat spawners have been historically more common than males, potentially due to increased post-spawning mortality amongst males by competition (Fleming and Gross 1994; Keefer et al. 2008; Seamons and Quinn 2010). The SNP-based pedigree reconstruction analysis provided estimates of sex and age-distribution and iteroparity amongst spawning adults in Topanga Creek. We must acknowledge, however, that these biological inferences are only a reflection of the individuals sampled, and then amongst those sampled, only those that reproduced successfully. Therefore, the incidences of iteroparity recovered by this analysis are undoubtedly a subset of all iteroparous spawning attempts in any given year. Nonetheless, the general trends are informative, especially since explicit, formal analyses of these life history characteristics have not been undertaken in the focal populations. Additionally, the finding that males most commonly spawn between ages 2-3, while females are more likely to spawn between ages 3-4 is consistent with previous studies of hatchery steelhead in California (Abadía-Cardoso et al. 2013).

Both Malibu and Topanga Creek retain greater than 65% frequency of the anadromous allele at both Omy5 loci and examination of smolts outmigrating from Topanga Creek supported this observation. This high level of retention may be due to the re-colonization of Topanga Creek in the 1980s by anadromous steelhead following extirpation (Bell et al. 2011) and subsequent additional influence from anadromous adults in 2010, and 2019 when spawning was documented. Ultimately, while possession of the anadromous allele does not necessarily guarantee anadromy in an individual, it does reflect how the population could respond to restoration attempts and how selection has impacted the population thus far. These allele frequencies therefore suggest individuals in Malibu and Topanga creeks have the capacity to express the anadromous phenotype should opportunities for migration arise.

The estimates of heterozygosity provide further insight into the genetic diversity and ancestry of the Santa Monica Mountains populations. For example, the observed heterozygosity in the Malibu Creek population is significantly higher than the mean observed heterozygosity across all the native Southern California baseline populations (p-value = 0.000013). However, this almost anomalously high level of heterozygosity in Malibu Creek may be due to small sample size (n = 15). Observed heterozygosity in the Topanga Creek population is comparable to the Southern California populations, and while not significantly different (p-value = 0.105), it still exceeds the mean observed heterozygosity amongst all Fillmore Hatchery strains. Thus, both Malibu and Topanga Creeks appear to harbor a level of genetic diversity comparable to that seen amongst populations of predominately native steelhead lineage.

This holistic and high-resolution investigation of population genetic structure and ancestry, paired with parentage and family structure analyses, confirms the important role the Santa Monica Mountains Biogeographic Population Group (BPG) plays in contributing to the long-term viability of the Southern California DPS. Concordant results across multiple analyses display strong evidence of native coastal ancestry within Malibu Creek, suggesting this population should be prioritized for conservation. And while hatchery introgression was detected in Topanga Creek, population genetic diversity and genetic markers for anadromy suggest Topanga Creek contributes important genetic resources towards the development of a sustainable network of *O. mykiss* populations in southern California.

The U.S. Federal Recovery Plan for the southern California Steelhead DPS (NMFS 2012) explicitly calls for discrete population restoration to create a network of genetically diverse populations, which express all potential life history strategies. The identification of a putatively native population (Malibu Creek) and mixed ancestry population (Topanga Creek) addresses this objective and demonstrates the value of protecting both anadromous and resident forms in these systems. Therefore, efforts to protect and rehabilitate populations in the Santa Monica Mountains BPG, alongside populations within the remaining BPGs of the Southern California Coast Steelhead Recovery planning area, will facilitate connectivity, resilience and recovery of endangered steelhead throughout southern California.

4.8. Role of Temperature

Fish typically maintain body temperatures that match that of their surrounding environment, and experience non-equilibrium states when they move between regions of differing temperature. Optimal temperatures for *O. mykiss* to support spawning, rearing, growth and smolt migration range from 10-16ºC, but physical acclimation and/or genetic selection may extend that up to as high as 22ºC (McEwan and Jackson 1996; Farrell et al. 2015; Richter and Kolmes 2005). Although increased summer water temperature can be a limiting factor for salmonids, *O. mykiss* are distinct in their ability to withstand higher temperatures; a critical thermal maximum of 26.7ºC has been reported by multiple sources (CDWR 1988; Carter 2005). Sloat and Osterback (2013) observed a thermal threshold for *O. mykiss* persistence in Santa Paula Creek of 31.5ºC.

Critical thermal maximum is based on acclimatization over a relatively short time period and is considered higher than what a fish could tolerate for hours to days and still swim. The temperature at which limited growth, mortality, and other negative effects are induced can be influenced not only by acclimation temperature, but also covariate stressors such as low dissolved oxygen content, and food availability (Matthews and Berg 1997; Currie et al. 1998; Boughton et al. 2007; Le Blanc et al. 2011; Farrell et al. 2015). Abundant food availability has been attributed to continued growth past in higher temperatures (Spina 2007; Krug et al. 2012). However, if food resources become limited, then tolerance of higher temperatures decreases (Sloat and Osterback 2013). Incipient lethal temperatures are identified as the temperature at which over 50% of fish exposed to that temperature die.

Most studies examine effects of increased maximum temperatures, but few studies have examined the effect of gradually increasing minimum temperatures, which could raise the lower limit of temperature ranges needed for recovery from either short-term or chronic sub-lethal exposure to high temperatures, as well as potentially alter the composition of BMI communities that provide important food resources, and increase habitat suitability for competitive invasive species. The increasing minimal temperatures in both Malibu and Topanga Creeks could also affect egg survival and emergence of fry during the critical spring months. Myrick and Ceck (2000) found that when temperatures exceeded 15ºC, this life stage was negatively impacted. The effects of exposure to sub-lethal temperatures are not well studied, but a behavioral response to warm temperatures suggests that *O. mykiss* will move to refugia locations that have cooler temperatures if they are available (Sloat and Osterback 2013). LeBlanc et al. (2011) additionally found that thermal stress translated into social stress, which resulted in subordinate individuals being restricted to lower quality habitat and was also associated with impaired fitness overall. Increased levels of diseases are also associated with warmer water temperatures (Noga 2000). For instance, the common ectoparisitic protozoan *Ichthyophthirius multifiliis*, (usually referred to as Ich) is widespread in freshwater systems and associated with increased stress and impaired immunity (Noga 2000). We observed 10 infected individuals in Malibu and four in Topanga Creek prior to 2015, but few infected individuals have been observed since that time.

Water temperature ranges for Arroyo, Malibu and Topanga Creeks have been documented since 2009, and while maximum temperatures in the summer months occasionally reach as high as 26ºC, average temperatures typically are within the published tolerance range for *O. mykiss* (10-22ºC)(McEwan and Jackson 1996; Richter and Kolmes 2015). Analysis of summer water temperatures in these creeks (Figure 4.5) indicates that although there has been no significant increase in average maximum and average mean temperatures, however, average minimum temperature in Topanga Creek significantly increased between 2011 and 2016 from a low of 14ºC to 18.8ºC. Average minimum temperatures in Malibu Creek have remained consistently around 18ºC, but in 2015 increased to 19.8ºC. In 2019, average max, minimum, and mean water temperatures decreased in Malibu, and most notably Topanga creek following above normal rainfall. Although anadromous *O. mykiss* were not observed in Topanga during 2019, resident *O.mykiss* abundance increased. The increase in resident *O.mykiss* could potentially be influenced by the greater amount of rainfall and/or lower water temperatures observed in 2019. Continued monitoring would be necessary to elucidate these trends in future years.

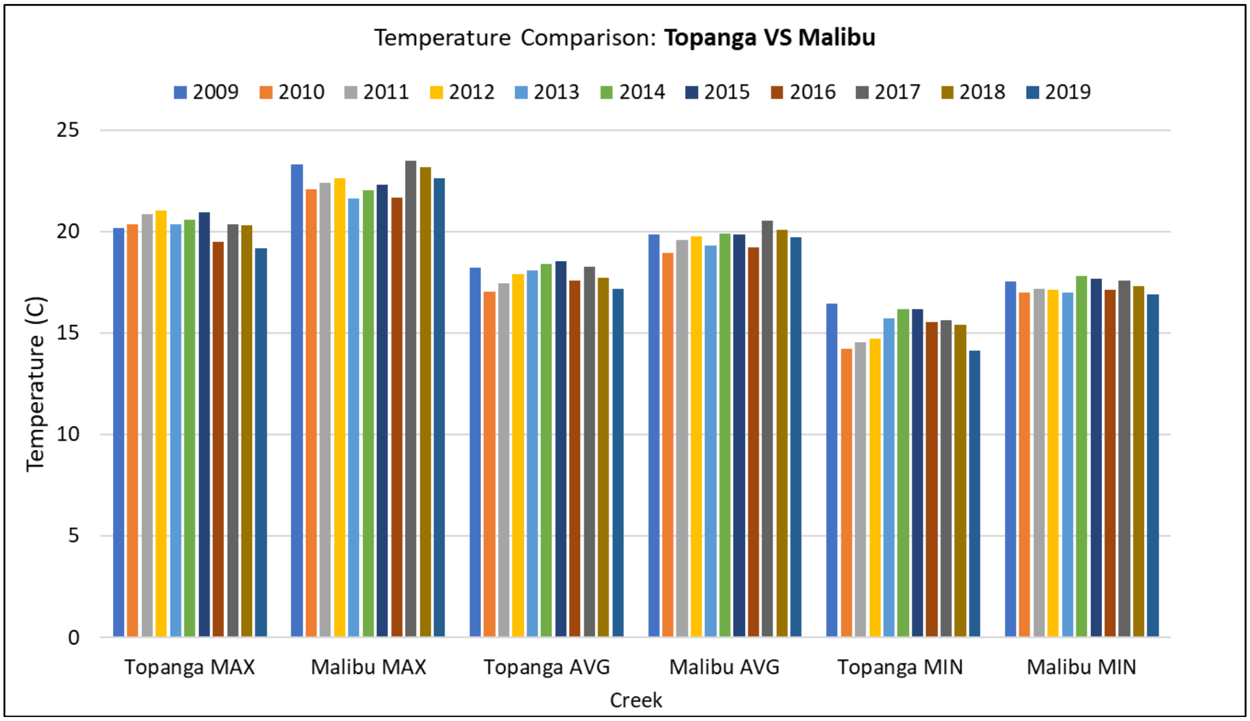


Figure 4.5. Comparison of Average Maximum, Average Mean and Average Minimum Summer Water Temperatures in Malibu and Topanga Creeks (2009-2019).

In Topanga Creek, groundwater seeps and springs have been mapped and appeared to be important moderators of overall creek temperatures (Tobias 2006). However, during the intense drought this moderation of temperature by groundwater slightly waned showing an increase in average minimums, but no significant increase in average mean or maximums. Our data suggests that thermal mixing occurs throughout the creek, such that there is no significant difference between pools with or without seep input. Similar to the temperature effects seen by severe drought over prolonged years, high rainfall years increase surface flows and dilute the input of the seeps resulting in overall water temperature increases. Examination of the number of hours when temperatures exceeded 23°C indicate that these conditions occurred in the high rainfall year 2005 (61.58”), with the effects lingering into 2007. Only two pools in Topanga had any time over 23°C in other years up to 2012, none in 2013-2014 but most pools had at least 1 day exceeded 23°C in 2015, and 4 pools in 2017-2018. In 2019, the number of pools in Topanga with temperatures exceeding 23°C dramatically reduced. During low flow conditions, cooler groundwater dominated overall temperatures with lower maximum and average temperatures as a result. However, as the drought continued, it appeared that groundwater inputs declined even though withdrawals from wells is extremely limited. Minimum water temperatures slowly increased from an average of 14°C to 16°C until 2018.

The water temperature pattern in Malibu Creek is different from that observed in Topanga Creek, potentially due to overall larger pool size and depth, as well as addition of augmentation flows released from the Tapia Water Reclamation Facility whenever flows drop below 2.5 cfs at the stream gauge upstream of Rindge Dam. No data on groundwater influence on temperature is available for Malibu Creek.

Since 2005, many of the larger pools in Malibu Creek have been isolated and disconnected during summer months. Even though they have greater pool volume than any of the pools found in Topanga Creek, average maximum, average and minimum temperatures are significantly higher than overall water temperatures in Topanga Creek. The lower temperatures observed in 1.0 rkm Start Pool suggest that either a local undocumented seep and/or input of cooler subsurface flow are important controls of water temperature at that location.

Additionally, the proportion of time when water temperatures exceeds 23°C in Malibu Creek pools has also increased overall since 2011. With the exception of 1.0 rkm Start Pool, the other five pools measured have had more days extending from June - October with between 4-24 hours of temperatures 23°C or higher (see Figure 3.20). This suggests that what appear to be large refugia pool habitats are thermally unsuitable to support *O. mykiss* during summer. Comparison of surface to bottom temperatures in some of the deeper pools suggests that they are well mixed and have little stratification. This could help explain the dominance of warmer water non-native species and the low summer numbers of *O. mykiss* observed.

Higher temperatures, combined with increased algae growth promoted by the high levels of nitrates and phosphates in Malibu Creek can cause low levels of dissolved oxygen by limiting the utilization of nutrients, encouraging algal blooms, and increasing subsequent eutrophic conditions. The reduction of dissolved oxygen levels could be a severe stressor for *O. mykiss*, who typically suffer when levels fall below 5 mg/l, especially in warm water temperatures due to increased metabolic demand for oxygen (McEwan and Jackson 1996; Farrell et al. 2015). No temperature or dissolved oxygen data was available for 2006, the year when a major die-off of all aquatic organisms was observed in Malibu Creek (Dagit et al. 2009a), but the patterns observed since that time suggest that perhaps an extended period of high temperatures and associated low dissolved oxygen levels may have been important stressors, although that still does not explain why the fish turned yellow. Even 1.0 rkm Start Pool, which maintained lower temperatures and rarely has temperatures over 23°C, still experienced extended periods of low dissolved oxygen levels (See Appendix D).

Another recently identified concern is the temperatures of the augmentation flow releases from Tapia Water Reclamation Facility. Millions of gallons per day have been added to help support *O. mykiss* during the low flow summer months and it is not clear what if any effect introduction of waters ranging from 20-25°C (LVMWD unpublished data) might have on pools located downstream of Rindge Dam. Further information on the dynamics of upper watershed water temperatures and how they translate into overall temperature as flows move downstream is needed to help understand this issue.

Recent work suggests that previously held notions concerning thermal limits and tolerance of *O. mykiss* needs to be reconsidered (Spina 2007; Sloat and Osterback 2013; Farrell et al. 2015). Using locations primarily within Topanga Creek between 2002-2004, Spina consistently found that *O. mykiss* between 100-280 mm total length were able to not only tolerate, but also continue feeding despite temperatures of 17.4-24.8°C, which have previously been thought to impede physiological processes and ultimately result in either the fish seeking cold-water refugia, or dying. Because these fish were reared in the stream under these stressful thermal conditions, it is not clear if they have some genetic adaptation allowing them better tolerance, or that conditions in the creek do not provide any other options. It did not appear that cold-water refugia were available during the summer in Topanga Creek. Even though *O. mykiss* are often found in pools having groundwater influence, there is no significant temperature difference on average between these pools and those without groundwater influence (Tobias 2006).

In-situ experiments with *O. mykiss* in the Tuolumne River examined thermal performance to identify limits of aerobic capacity and thermal limits (Farrell et al. 2013). They found that *O. mykiss* remained healthy and able to digest food up to temperatures of 23ºC. Based on their findings they suggest that the upper performance temperature limit of 22ºC, rather than the 18ºC limit currently used (EPA 2003) should be considered as the 7-Day Average of the Daily Maximum (7DADM). Pools in Malibu Creek had 7DADM between 19.9 and 25.5ºC. Temperature data has been collected in Malibu Lagoon since the restoration in 2012 but is not available at this time. Temperature has been collected erratically from Topanga Lagoon until 2012, related to the theft of the loggers. The limited data available suggests that Topanga Lagoon would be thermally stressful for *O. mykiss* except during high flow events, when the ocean connection is restored and flow is more constant.

4.9. Evaluation of Limiting Factors

The limiting factors identified by the Southern California *O. mykiss* Recovery Plan (NMFS 2012) for creeks in the Santa Monica Bay include passage restriction due to culverts, dams and instream crossings, poor water quality associated with urban and agricultural effluents, non-native species impacts, and development related impacts as well as impacts associated with urban development, and wildfires (Table 4. 3). It is interesting to note that drought is not listed as one of the threats analyzed in the Recovery Plan, but it played a major role as a limiting factor for seven years. Limiting Factors are further characterized based on specific impacts to *O. mykiss*.

Table 4.3. Limiting Factors affecting *O. mykiss* recovery (NMFS 2012).

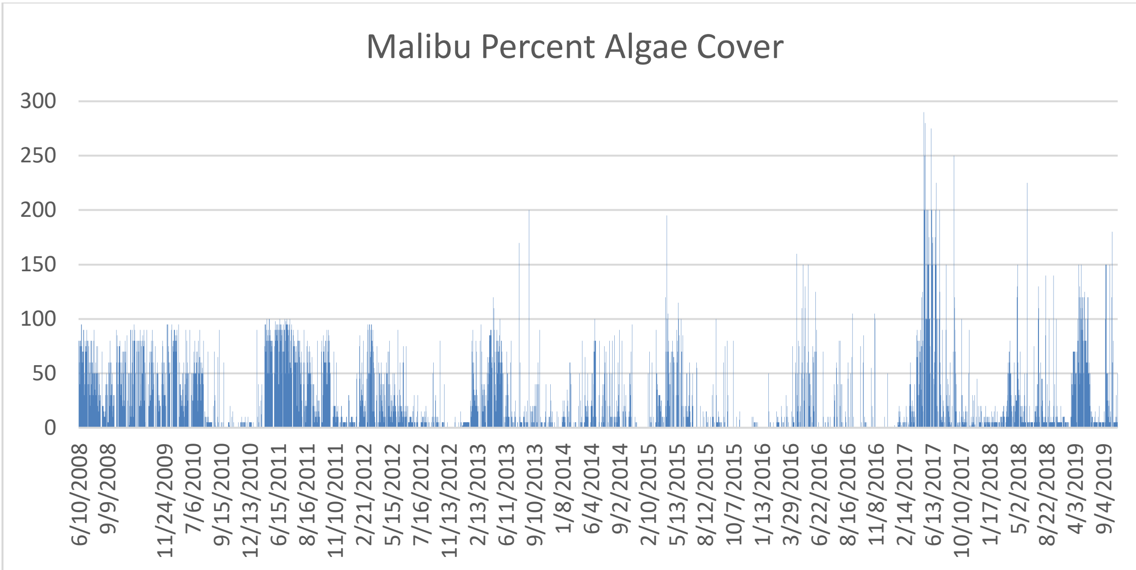
Threat	Arroyo Sequit	Malibu	Topanga
Agricultural development			
Agricultural effluents			
Culverts and road crossings	x	x	x
Dams and surface water diversions	x	x	
Flood control maintenance	x	x	x
Groundwater extraction			
Levees and channelization	x	x	x
Mining and Quarrying			
Non-native species		x	x
Recreational facilities	x	x	x
Roads	x	x	x
Upslope/upstream activities	x	x	x
Urban development	x	x	x
Urban effluents	x	x	x
Wildfires	x	x	x

Water quality (Agricultural and urban effluents)

Water temperature limitations are a known problem in southern California creeks. While overall maximum and average water temperatures did not change substantively during the drought, the continued incremental increase in minimum temperatures is reducing the diurnal temperature range and potentially reducing the nocturnal cool period that provides thermal refugia. It will be important to work with Las Virgenes Municipal Water District (LVMWD) to identify ways to cool the summer augmentation flows going forward.

Water quality continues to be a serious concern in Malibu Creek. This watershed experiences stormwater related pollution, but in Topanga, the input remains limited enough that nutrient loading is not yet significantly impacting stream health (Dagit et al. 2014). The mainstem of Malibu Creek concentrates runoff from the highly developed upper watershed, resulting in consistently high levels of nitrates and phosphates that exceed EPA standards. The relationship between nutrient loading and algal blooms is well documented, and the impacts to the creek during the summer months important for *O. mykiss* spawning and rearing are very real.

The role of nutrient loading was investigated in previous reports (Dagit et al. 2017) and due to lack of current information it is not possible to characterize the situation at present. Future targeted water quality testing especially post Woolsey Fire is in progress, but results are not yet available. Eutrophication levels were not quantified, but Malibu Creek experienced increased levels of algal growth associated with summer augmentation flows in contrast to Topanga, where there is no supplemental imported water. Seasonal decreases in algal cover were associated with cooler winter months, both with and without rain (Figure 4.6).



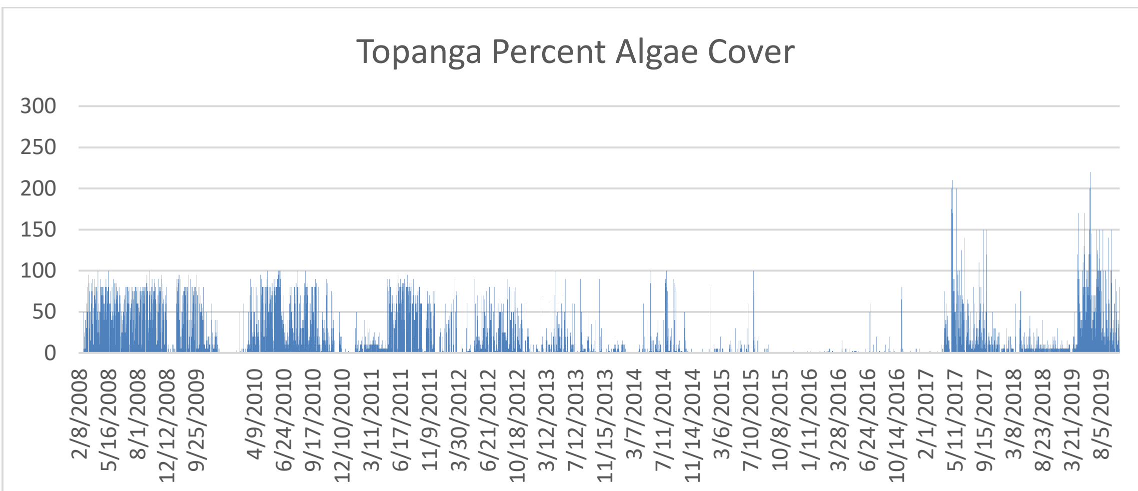


Figure 4.6. Comparison of percent algae cover Malibu and Topanga 2008-2019.

<u>Water quantity (Surface water diversions, flood control maintenance, groundwater extraction)</u>
There are relatively few surface water diversions or impacts from flood control maintenance (other than removal of riparian and instream vegetation), however Malibu in particular experiences higher levels of surface water runoff associated with urban development than either Arroyo Sequit or Topanga. There are few storm drains in either Arroyo Sequit or Topanga, but the suburban developments in the upper Malibu Creek Watershed rely on a system of storm drains and culverts to convey stormwater runoff directly into Malibu Creek. This increases the flows during the rainy season by augmenting releases from the Tapia Water Reclamation Facility, especially following the Woolsey Fire (2018) which burned much of the upper watershed. It also results in reduced canopy cover and less water update by riparian vegetation. There is thought to be limited groundwater extraction in the coastal Santa Monica Bay watersheds, however data on the number of wells is difficult to compile and examine and use of wells during the drought is thought to have increased (Los Angeles County Regional Planning pers. communication).

<u>Excessive sediment yield (Levees and channelization, roads, upslope/upstream activities, wildfires)</u>

While there has been progress made during the past 20 years in removing levees (Rodeo Grounds Berm removal in Topanga 2008), and addressing bank stabilization and upslope concerns in numerous locations throughout all three watersheds, these efforts were completely overwhelmed by the magnitude of sediment moved following the extensive Woolsey Fire (2018). The entire Arroyo Sequit watershed and over half of Malibu Creek watershed were burned, resulting in extensive downstream mobilization of loose materials during the rains in early 2019. This dramatic and catastrophic impact resulted in significant loss of habitat particularly in Arroyo Sequit. Even the relatively small Topanga fire (55 acres in 2017) resulted in mudslides impacting over 1 rkm downstream and dramatically reducing pool habitat. It is unclear how long it will take for these systems to recover. Cooper et al. (2015) found that even ten years later *O.mykiss* were not able to re-colonize burn areas where the population had been extirpated.

<u>Non-native species</u>

Invasive aquatic species pose a potentially significant threat to *O. mykiss* in the Santa Monica Bay. Although the majority of invasive species are confined primarily to Malibu Creek, red swamp crayfish were introduced in Topanga Creek in 2001 and fathead minnows became established in 2014. The population of these invasives fluctuates according to rain events flushing out the creek, but they are now definitely established. To date there has been no documentation of any invasive aquatic species in Arroyo Sequit Creek.

The numbers of individuals of each invasive aquatic species were not quantified during this study, although their presence and relative abundance was recorded. The abundance of invasive species varied seasonally, with more observed in the spring and summer, and fewer individuals seen in the fall and winter surveys. As has been previously noted, young of the year *O. mykiss* were most often found with the arroyo chub, fathead minnows and mosquitofish in more shallow habitats along the stream margins in Malibu Creek. Intermediate size *O. mykiss* would occasionally be observed swimming with bluegills, largemouth bass or green sunfish, although they were more commonly on the periphery of any school, preferring algae free gaps near bubble curtains. Adult *O. mykiss* were often found in the deep pools near large carp but did not appear to be schooling with them.

Crayfish were formerly the most abundant invasive species in Malibu Creek, with hundreds of individuals in almost every habitat type, although the overall numbers have been declining since 2015 (Refer to Figure 3. 27). The only areas where they were not numerous were in the larger, deeper pools, where they seem confined to the shallow edges. Their population was observed to peak in abundance during the summer, with few to no individuals observed during the colder winter months when flows were stronger. This is consistent with the life history of these species, which are known to take refuge in banks or under boulders.

Giant carp were the largest of the exotic fish species observed in Malibu Creek, with individuals in large pools that were almost a meter in length. Carp population size peaked at over 1,000 in 2017. Schools of huge adults have well defined territories in some of the pools (2.67 rkm

Grimmer Pool, 1.62 rkm Lower Twin Pool, 1.99 rkm Lunch Pool) and would actively bump divers during snorkel transects. Smaller size classes were also noted regularly.

Largemouth bass, green sunfish, bluegills, and catfish were mostly observed in same species schools of between three to twenty individuals. All of these were found throughout the Malibu Creek study reach in a variety of habitat types, although the bass are by far the most abundant (Figure 3.31).

Since 2005, the number of bullfrogs in Malibu Creek has also increased both in abundance, peaking in 2017 and distribution, as they are now found throughout the entire study reach (Figure 3.34).

There is tremendous concern about the possible spread of the New Zealand mud snail, and thus a rigid protocol was followed to ensure that the water quality monitoring, snorkel surveys, or seine events did not inadvertently act as vectors moving this species from Malibu to either Arroyo Sequit or Topanga Creek, both of which remain free of this invasive species. They were observed in a short 1.0 rkm reach of Topanga Creek in 2016 but have not been observed since the rains of 2017.

The combination of impaired water quality with large numbers of exotic generalist fish species that can thrive in warmer temperature conditions create a severe limitation for *O. mykiss* in Malibu Creek.

Increased relative abundance of Chironomids in all creeks seems to align with drought conditions. Griswold et al. (2008) found that BMI community composition was altered by drought periods, favoring smaller-bodied species with shorter life cycles, which might help to explain this phenomenon. The interchangeability of taxa lost with Chironomids, in terms of nutritional provision for *O. mykiss*, is unknown.

5. SUMMARY

The coastal streams of the Santa Monica Bay historically provided sufficient habitat to support a number of satellite *O. mykiss* populations, which are essential for maintaining a regional metapopulation long term. These satellite populations are subject to elimination from disturbances both natural (drought, floods, and fires), and anthropogenic (passage barriers, habitat degradation, pollution). The complex life history strategies of these fish make *O. mykiss* challenging to manage, and difficult to monitor. The key to maintaining a viable metapopulation is to maintain and expand the opportunities for re-colonization and access of anadromous adults, as well as enhancing freshwater habitats to support reproduction by resident fish. The 19 years of monitoring population abundance and distribution of *O. mykiss* in the Santa Monica Bay provides critical information necessary for understanding the status of the population and responding appropriately to threats.

The seven-year drought had a significant impact on the abundance and distribution of *O. mykiss* in the Santa Monica Bay. Abundance, reproduction and distribution all declined throughout the study creeks. While episodes of drought are not uncommon throughout the evolutionary history of *O. mykiss*, this drought event has been more extreme due to the combination of lack of rain and increased air temperatures (NMFS 2016). Whether the population can recover remains to be seen, but continued monitoring is the only way to find out.

Ultimately, the persistence of *O. mykiss* is tied to a complex suite of variables associated with its life history (both resident and anadromous), habitat availability and suitability. Depending on the conditions in any given year, the success of one life history strategy versus the other is tied to habitat and environmental stressors, reinforcing the concept that both life history strategies are important factors in the species survival. Although we still don't understand the variables affecting the ocean stage of *O. mykiss* life history, providing access to suitable freshwater habitat for spawning and rearing is essential for the resilience and recovery of the species.

Genetic analysis of over 1,000 tissue samples from the Santa Monica Bay revealed that native anadromous ancestry is dominant, with Malibu showing little to no hatchery fish ancestry and Topanga showing some introgression and admixture. Both populations retained a high percent of hererozygocity and the allele associated with anadromy. The contribution made by resident *O. mykiss* especially in Topanga Creek which demonstrated the genetic pattern following re-colonization provides important information to help guide future efforts to return *O. mykiss* to creeks where they have been extirpated such as following the Thomas Fire (2017) and Woolsey Fire (2018).

Protecting the existing populations, especially in Topanga Creek, from future extirpation, and improving the survivability of *O. mykiss* in Malibu Creek are the fundamental priorities for sustaining the existing populations in the Santa Monica Bay. The potential for catastrophic events to extinguish these local populations is high, and had the Woolsey Fire reached Topanga Creek, we might have documented extirpation throughout the Santa Monica Bay. Only by addressing the water quality, habitat availability opportunities, and potentially initiating a genetically informed broodstock management can we provide a small measure of insurance that may be the difference for allowing this species to survive into the future.

Recommendations

One objective of this project was to identify possible actions that could address limiting factors, reduce annual abundance variability, and prevent or minimize local extirpation of *O. mykiss* in the Santa Monica Bay. To that end, we offer the following recommendations:

- **Continue long-term population monitoring to document changes over time.**

The episodic colonization of Arroyo Sequit, the die-off of all fish in Malibu Creek in 2006 (Dagit et al. 2009a), and the documented extirpation of *O. mykiss* in Topanga Creek (Bell et al. 2011), followed by subsequent re-colonization, highlights the extreme variability of these populations over time. A long-term data set covering many years and encompassing a variety of catastrophic events that can significantly impact the fish (such as droughts, fires, and floods) is the only proven basis for developing realistic management goals.

During the 15-year monitoring of Arroyo Sequit and Malibu and 19-year monitoring in Topanga, we documented population response to extreme drought, floods, and wildfires. The response of these small populations was variable and unexpected, such as the total loss of *O. mykiss* in Malibu Creek. Without regular, consistent observations, species on the brink of extinction can disappear without notice. The best way to understand the trends and variability of *O. mykiss* populations in the Santa Monica Bay is to continue regular documentation.

- **Restore fish passage in all potential *O. mykiss* creeks within the Santa Monica Bay.**

The Southern California Steelhead Recovery Plan (NMFS 2012) identifies both Malibu and Topanga Creeks as Core 1 populations. Although Malibu does maintain connectivity and contain suitable habitat, the limitations related to water quality, water temperature, and competition from invasive species are extreme. Restriction of habitat due to the presence of Rindge Dam is also an important limiting factor. Removal of the dam and other identified upstream barriers continue to be a high priority, as does addressing the water temperature, water quality, and altered hydrologic regime concerns.

Topanga Creek, although smaller and less accessible, maintained a variable population between 2001-2019 that expanded during wet years and declined in response to drought. The resident *O. mykiss* in Topanga are critical for maintaining a genetic presence in the Santa Monica Bay, and provide stability to the metapopulation.

The role of Arroyo Sequit is not clear, but recovery of the high quality refugia habitat in the upper tributaries following the Woolsey Fire (2018) has high potential to support *O. mykiss* and the accessibility documented in 2017 following barrier removal suggests that this could become important habitat again. Addressing the remaining barrier located at the culvert under Mulholland Highway will be the next challenge. The Recovery Plan (NMFS 2012) does not list the potential contributions from Big Sycamore, Trancas and Zuma Creeks, all of which could potentially be restored to provide additional connectivity and suitable habitat within public ownership.

- **Restore Topanga, Trancas and other coastal lagoons.**

Restoration planning for Topanga Lagoon was initiated in 2000, but due to a variety of issues went dormant until 2019, when funding from the Coastal Conservancy became available to restart the process. The RCDSMM, working with CDPR and other stakeholders are preparing to address remaining questions on hydrology, hydraulics, fish passage constraints, sea level rise issues and the integration of other programmatic elements associated with recreation use and emergency services. The goal is to develop suitable alternatives for environmental review and permitting by 2022.

As of 2019, Caltrans has listed restoration of fish passage in Big Sycamore, Las Flores, Solstice, Trancas and Topanga as high priorities. The Pacific Coast Highway (PCH) Bridge at Trancas is being replaced and expanded to facilitate lagoon restoration. The culvert at Solstice Creek under PCH is progressing toward preparation for construction.

- **Remove Rindge Dam in Malibu Creek and other upstream barriers.**

Restoring access to upstream habitat by the removal of Rindge Dam and additional upstream barriers in Malibu Creek are in progress. It is hoped that the upstream barriers above the dam will be removed prior to the dam removal. CDPR is currently spearheading that effort.

- **Consider developing a genetically informed captive broodstock program to preserve genetic diversity.**

Over 25 years of habitat and fish passage restoration has not resulted in a measurable recovery of *O. mykiss* throughout the DPS (Dagit et al. 2020). While we consider a genetically informed captive broodstock program to be an act of last resort, the potential extirpation of *O. mykiss* from local coastal creeks throughout the Santa Monica Bay in the immediate future is quite real. We need to take all possible actions to prevent the total loss of these locally significant populations Should climate change associated droughts continue as predicted, this may be the only choice left if we are to prevent extirpation.

- **Continue regular and intensive sampling of lagoons to determine residency and growth prior to smolting.**

Seining has been conducted annually in the fall in all the coastal lagoons from Big Sycamore to Topanga, to document over summer survival. Prior to the onset of the drought, Arroyo Sequit, Las Flores, Solstice, and Zuma had remnant lagoons, but no fish were observed. Tidewater gobies (*Eucyclogobius newberryii*) were documented in Big Sycamore in 2013, but not since. Killifish (*Fundulus parvipinnis*) and staghorn sculpin (*Leptocottus armatus*) were documented in Trancas. Topanga supported tidewater gobies, grunion, and the occasional *O. mykiss* smolt. Since the drought, these systems have had variable volumes of water (Dagit et al. 2018b; Alvarez and Dagit 2019) and no fish were observed. Following the Woolsey Fire (2018) and subsequent rains, sediment deposition has severely impacted Arroyo Sequit, Solstice, Trancas and Zuma Creeks not only reducing water depth, but also restricting connectivity upstream.

Quantitative fish surveys have been conducted semi-annually in Malibu Lagoon as part of the post-construction monitoring program but will cease in 2019. To date, no *O. mykiss* smolts have been observed in the lagoon, however, the restoration provides additional suitable habitat and use by smolts is possible. A single anadromous adult was observed in May 2014. None of this information would be available without continued regular monitoring.

- **Continue efforts to minimize or avoid water quality impairments, especially increased water temperature.**

Prior to the drought, water quality in Arroyo Sequit and Topanga Creeks remained suitable to support *O. mykiss,* but the continuous threat of pollution from upstream development remains in both watersheds. Maintaining good water quality by restricting development that will increase impairments is critical. Turbidity and sedimentation are a serious post fire concern in Arroyo Sequit, where surface water flows are still extremely turbid. In Topanga, a 55-acre fire in 2017 caused a mudflow that has led to sediment deposition in pools downstream for almost 1 rkm.

Both situations contribute to impaired water quality for *O. mykiss* and further monitoring is needed to determine if any actions can be taken to address these problems.

Increasing minimum summer water temperatures and decreasing flows, including the almost total desiccation of Arroyo Sequit and much of lower Topanga during the drought (Dagit et al. 2017a) are serious concerns. While it is not possible to add water to these streams, implementing all measures possible to reduce any drawdowns from upstream wells that supply groundwater to seeps and springs is critical. Obtaining that information is very difficult and will require a collaborative effort from CDPR, Los Angeles County Regional Planning and well managers.

Levels of nitrates and phosphates in the lower reach of Malibu Creek have historically been problems, and efforts are underway to address them by Las Virgenes Municipal Water District. Reduction in nutrient input levels into Malibu Creek is a critical step towards improving water quality and creek health. More information is needed in order to assess the influence of the high temperature water releases on the refugia pools below Rindge Dam, where *O. mykiss* may reside. Strategies for reducing summer water temperature stress from those releases should be examined.

- **Support restoration of riparian canopy lost in the drought and Woolsey Fire (2018).**

Between the drought and the Woolsey Fire, over 100,000 riparian trees died along the creeks in the Santa Monica Mountains (Dagit et al. 2017c). The RCDSMM, Los Angeles County, CDPR and NPS are currently working on a plan to prioritize restoration planting areas that are expected to remain suitable riparian habitat in the face of projected climate change. It is not yet clear what restoration actions will be needed, and where those actions will be directed, but there has been only limited recovery and recruitment along the creeks post fire.

- **Further investigate the impacts of invasive species such as the red swamp crayfish on *O. mykiss*.**

Low flow conditions with warm summer temperatures provide advantageous conditions for invasive species and more challenges for *O. mykiss*. Monitoring the abundance and distribution of invasives such as crayfish in relation to that of *O. mykiss*, as well as in response to removal efforts will help further our understanding of both direct and indirect effects associated with these species. We have been collaborating with Dr. Courtney Davis and Madison Cox to develop a mathematical model that could help explain the potential impacts of crayfish on O. mykiss populations. Preliminary model results have been presented as posters and a full manuscript is in preparation. Preliminary results are found in Appendix I.

- **Further investigate potential causes of seasonal and annual growth patterns (e.g. food availability, rainfall, density).**

By coordinating data collected by snorkel surveys with that collected during lifecycle monitoring PIT tagging events between 2008-2018, we were able to examine growth patterns during drought conditions and compare them with growth patterns previously identified (Dagit et al. 2017a). This limited snapshot provided important information on impacts to abundance and recruitment but having the opportunity to learn more about the response to above average rains in 2019 were missed due to discontinued funding. Obtaining funding to continue lifecycle monitoring in Topanga Creek is recommended.

- **Install an instream antenna array in Malibu and Topanga Creeks to check for tagged anadromous adults.**

Given the propensity of *O. mykiss* to stray into accessible creeks, it makes sense to install an instream antenna array possibly at the Cross Creek Road Bridge and in lower Topanga Creek to determine if PIT tagged individuals from Topanga or other creeks are taking advantage of the longer passage window available in Malibu Creek. The instream antenna array in Topanga Creek was discontinued due to lack of funding in 2018. CDFW will be installing the instream antenna in Topanga for 2019-2020.

- **Generate and maintain a strong public outreach and education program to support restoration actions that will lead to the recovery of the species.**

The restoration of Malibu Lagoon significantly improved habitat for *O. mykiss* but was subject to criticism. Providing accurate, timely information concerning the problems and benefits of restoration and preservation opportunities for all the Santa Monica Bay creeks is a logical way to maintain political will to plan and implement needed actions. A coordinated watershed approach to restoration is a proven way of generating restoration program support.

With the pending restoration planning efforts beginning for Big Sycamore, Solstice, Topanga and Trancas lagoons, a coordinated messaging effort should be developed and implemented.

Strategically placed signs should be displayed, and educational outreach materials should be distributed by CDPR to all park visitors and campers in order to inform the public not only about the potential impacts of New Zealand mud snails, but invasive exotic species. This could help minimize the threat of introduction.

It is not clear how long it will take for habitat recovery in Arroyo Sequit following the Woolsey Fire (2018) to allow re-colonization by *O. mykiss*. It took almost 10 years for the *O. mykiss* population in Topanga Creek to become re-established following extirpation in the 1970's drought (Bell et al. 2011) and it is struggling to recover from the seven-year drought. Loss of the fishes in Malibu Creek downstream of Rindge Dam in 2006 was sobering. Even though we may never determine the exact cause of that devastating event, it serves as a pointed reminder that maintaining critical habitat for *O. mykiss* is crucial to the survival of this species in the Santa Monica Bay and southern coastal region. Habitat restoration alone may not be enough to support recovery of these populations. A genetically informed captive broodstock management plan is needed so that all avenues for recovery can be implemented.

Taking every possible step to deal with catastrophic events, as well as identified anthropogenic problems and impairments, is the only realistic solution to avoiding a complete extinction of *O. mykiss*.

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