Final

SANTA CLARA RIVER

Waterbody Temperature Study

Prepared for
Santa Clarita Valley Sanitation District
Los Angeles County Sanitation Districts

March 2026

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ABBREVIATIONS

Abbreviation	Definition
Δ5°F limit	Basin Plan specification that the receiving water temperature shall not be altered by more than 5°F above the natural temperature
°C	degrees Celsius
°F	degrees Fahrenheit
AAS	absolute aerobic scope
ABA	Aquatic Biology Associates
Basin Plan	*Water Quality Control Plan for the Los Angeles Region*
BMI	benthic macroinvertebrates
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
CSCI	California Stream Condition Index
CT_{MAX}	Critical Thermal Maximum
District	Santa Clarita Valley Sanitation District
DO	dissolved oxygen
DS	downstream
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ESA	Environmental Science Associates
FAS	factorial aerobic scope
ft/sec	feet per second
GPS	Global Positioning System
H_0	null hypothesis
hybrid stickleback	partially armored threespine stickleback–unarmored threespine stickleback hybrid
LACSD	Los Angeles County Sanitation Districts
LARWQCB	Los Angeles Regional Water Quality Control Board
LiDAR	light detection and ranging
LOE	loss of equilibrium
LT50	median lethal temperature
mg/l	milligrams per liter
mgd	million gallons per day
MMI	Multimetric Index
MMR	maximum metabolic rate
NPDES	National Pollutant Discharge Elimination System
PATS	partially armored threespine stickleback

Abbreviation	Definition
RB	Saugus RSW-001
RC	Valencia RSW-001U
RD	Valencia RSW-002D
RE	Valencia RSW-003D
RMR	resting metabolic rate
SAS	Santa Ana sucker
Study	Santa Clara River Waterbody Temperature Study
SWAMP	Surface Water Ambient Monitoring Program
Tmin, Tmax	upper and lower thermal limits
Topt	optimum temperature
UC Davis	University of California, Davis
UILT	Upper Incipient Lethal Temperature
US	upstream
USFWS	U.S. Fish and Wildlife Service
UTS	unarmored threespine stickleback
UWCD	United Water Conservation District
WARM	warm freshwater habitat (beneficial use)
WRP	water reclamation plant

EXECUTIVE SUMMARY

Study Purpose

The Santa Clarita Valley Sanitation District (District) conducted the Santa Clara River Waterbody Temperature Study (Study) to evaluate the effects of effluent discharges from the Valencia and Saugus Water Reclamation Plants (WRPs) on aquatic life and the warm freshwater habitat (WARM) beneficial use in Reaches 5 and 6 of the Santa Clara River. The Study was initiated in response to renewed National Pollutant Discharge Elimination System (NPDES) permits issued by the Los Angeles Regional Water Quality Control Board (LARWQCB), which lowered the maximum allowable discharge and receiving water temperature from 86 degrees Fahrenheit (°F) to 80°F and eliminated prior exemptions for elevated ambient air temperatures. Additionally, the discharge cannot increase the receiving water temperature more than 5°F from natural conditions. The scientific basis for the 80°F limit and the associated 5°F maximum temperature increase (Δ5°F) objective is unclear

Study Approach

The District, with a technical team led by Environmental Science Associates and the UC Davis Fish Physiology Laboratory, evaluated river temperature patterns, aquatic habitat conditions, biological communities, species specific thermal tolerances, and potential temperature management strategies. The Study integrated 2 years of continuous temperature monitoring, intensive habitat mapping, biological surveys, laboratory thermal physiology experiments using partially armored threespine stickleback (PATS) as a surrogate for the endangered unarmored threespine stickleback (UTS), and river temperature modeling under multiple management scenarios.

Key Findings

Water Temperature Patterns

From October 2023 to September 2025, river temperatures exhibited strong seasonal and diurnal variability, closely tracking ambient air temperatures. Downstream of the Valencia WRP, summer daytime river temperatures regularly was at or above 80°F for short durations (1–12 hours), with peak temperatures typically reaching 82°F to 83°F and nighttime cooling to approximately 75°F. Temperatures higher than 80°F were rare upstream of the Valencia WRP, and average upstream temperatures were approximately 9°F lower than downstream. Temperature increases attributable to Valencia WRP discharge attenuated with distance downstream, with roughly half dissipated by the Castaic Creek confluence and most remaining temperature influence lost by Newhall Orchards. Spatial temperature mapping identified limited and highly localized thermal refugia downstream of the WRP, indicating that cooler microhabitats are generally scarce.

Hydraulic and Water Quality Conditions

Dissolved oxygen levels were consistently documented above thresholds protective of WARM beneficial use and were not observed during this study at levels that would limit aquatic life. Channel velocity and depth were generally greater downstream of the Valencia WRP and often unsuitable for UTS, limiting its likely distribution in this reach regardless of temperature. In contrast, these hydraulic conditions are more favorable for Santa Ana sucker (SAS). Channel morphology was highly dynamic over the Study period, reflecting seasonal flows and recent geomorphic resetting events, which strongly influence habitat availability, riparian shade, and temperature patterns.

Aquatic Communities

The fish community is dominated by non-native species, with UTS the only fish species native to the Santa Clara River watershed and the sole federally-listed endangered species present. Benthic macroinvertebrate and diatom communities reflected generally altered conditions across sites, driven primarily by natural channel instability and flow variability. No measurable degradation in biological condition attributable to WRP effluent was detected, with downstream scores comparable to or slightly higher than upstream scores.

Thermal Physiology of Stickleback

Laboratory studies demonstrated that thermal tolerance of PATS varies strongly by life stage and exposure duration. Juveniles exhibited the lowest tolerance, followed by adults, while embryos were the most thermally robust. Sustained exposure (1–2 weeks) to a constant temperature of 80°F resulted in high mortality, particularly for juveniles. In contrast, brief exposures to temperatures up to approximately 82°F were tolerated when fish had regular access to cooler temperatures, highlighting the importance of diurnal thermal refugia. Adults selected cooler water (mean 64°F; range 51°F to 75°F) in trial exposures (50°F to 86°F), indicating behavioral avoidance of warmer conditions above 75°F. No biological basis was identified for the Δ5°F criterion alone, as thermal response was driven more by absolute temperature, exposure duration, and variability than by incremental increases.

Management Scenario Modeling

Temperature modeling showed that, under existing conditions, temperatures are likely to be higher than both the 80°F threshold and greater than 5°F above the upstream temperature in the Santa Clara River during summer periods in both wetter and drier than average years. Partial reductions in Valencia WRP discharge or capping effluent temperature at 80°F reduced average downstream river temperatures but did not consistently prevent temperatures from being greater than 80°F or greater than 5°F above the upstream temperature. Regardless of scenario, temperatures increased immediately downstream of Valencia and continued to heat up to ambient conditions during the warmest summer days. Complete elimination of Valencia WRP discharge was the only scenario that met both objectives near the discharge point in all modeled conditions, although downstream warming from ambient conditions still occurred and sometimes led to natural temperatures over 80°F. Increasing riparian shading could substantially reduce temperatures but is not a durable or reliable management strategy given the river's natural geomorphic dynamism.

Study Implications

The study found no evidence that the current river temperatures downstream of the Valencia WRP are adversely affecting the BMI, algae or amphibian populations and communities, nor most fish populations within the study reach. During the Study period, water temperatures were within preferred ranges for UTS in winter and spring. In summer and fall, however, temperatures downstream of the Valencia WRP approached and at times were greater than the thermal limits of UTS (as evaluated using the surrogate PATS), depending on exposure duration.

The thermal tolerance studies conducted by the UC Davis Fish Physiology Laboratory indicate that adult PATS can tolerate temperatures above 80°F for periods of hours to days without mortality. Field observations were consistent with these results: adult and juvenile PATS were abundant in the river 29 miles downstream of the Valencia WRP (where the collection of PATS for laboratory studies occurred) even though daily temperatures there were greater than 80°F on 52 days between March and July 2025 collection events. Together, laboratory and field findings indicate that PATS (and thus UTS) can tolerate short-term excursions of 80°F during the warm-weather months of the year if diurnal thermal refugia are available during the evening and early morning. However, sustained excursions near or above 80°F pose substantial risk, especially to juveniles. Hydraulic habitat constraints further limit where UTS are likely to occur and therefore where thermal exposure is biologically relevant.

Collectively, these findings demonstrate that temperature variability, exposure duration, life stage sensitivity, and habitat suitability are critical factors in assessing WARM beneficial use support and that neither the 80°F absolute limit nor the Δ5°F criterion alone fully captures biological risk in this dynamic river system.

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STUDY SUMMARY

Santa Clara River Waterbody Temperature Study

Study Purpose

The Santa Clarita Valley Sanitation District (District) of the Los Angeles County Sanitation Districts (LACSD) owns and operates the Saugus and Valencia water reclamation plants (WRPs), located in the city of Santa Clarita, California. The Los Angeles Regional Water Quality Control Board (LARWQCB) recently renewed National Pollutant Discharge Elimination System (NPDES) discharge permits for the Valencia and Saugus WRPs, setting a new, more stringent maximum temperature effluent limitation of 80 degrees Fahrenheit (°F) that was reduced from the previous 86°F limitation and eliminated prior exemptions for elevated ambient air temperatures.

The 80°F limit is based on the LARWQCB's new interpretation and implementation of the water quality objective for temperature contained in the *Water Quality Control Plan for the Los Angeles Region* (Basin Plan), which states that waterbodies with a warm freshwater habitat (WARM) beneficial use designation shall not be raised above 80°F as a result of waste discharges. The Basin Plan also states that the receiving water temperature shall not be altered by more than 5°F above the natural temperature (referred to in this report as the "Δ5°F limit"). However, the scientific basis for the 80°F water quality objective and Δ5°F limit is unclear.

At the District's request, the LARWQCB provided time in the compliance schedule for the District to conduct temperature studies to evaluate the potential effects of temperature on the WARM beneficial use and to assess temperature management options. The District developed and implemented the Santa Clara River Waterbody Temperature Study (Study) to better understand how discharge temperatures from the Saugus and Valencia WRPs affect aquatic life and the WARM beneficial use in Reaches 5 and 6 of the Santa Clara River. This report describes the results of the Study.

Study Area

The Study Area is located in the upper Santa Clara River watershed and encompasses Reaches 5 and 6 of the Santa Clara River, extending from just upstream of the Saugus WRP to downstream to the Piru Dry Gap. These reaches exhibit highly dynamic hydrology, geomorphology and hence, habitat suitability. The Study Area has several reaches that typically dry out during the summer and then re-wet during the winter or following high flows. The main river corridor is subject to geomorphic "channel resetting" events approximately every 10 years that remove much of the riparian vegetation and existing channel and lead to a period when the river is a braided system with little cover or vegetation, before vegetation colonizes the floodplain and a new vegetation-lined channel forms. This dynamism means that habitat niches for a variety of native species are continuously being destroyed and reformed in new locations over time.

Study Objectives and Questions

The District retained a team led by Environmental Science Associates (ESA) with the Fish Physiology Laboratory at the University of California, Davis (UC Davis) to conduct the Study. The District and Study team developed an initial set of Study objectives with input from a Technical Advisory Committee as follows:

- **Objective 1**—Determine the wholly or partially aquatic-dependent taxa that are present, were historically present, or could be present given the current habitat conditions.
- **Objective 2**—For each taxon identified in Objective 1, describe the relationship between waterbody temperatures and the probability (or likelihood) that different aquatic life stages are supported.
- **Objective 3**—Determine how the relationships between waterbody temperature and the support of aquatic life vary based on the taxon's location in the Santa Clara River and seasonality.
- **Objective 4**—Determine the critical exposure times, durations, and/or frequencies associated with the temperature relationships described in Objectives 2 and 3.
- **Objective 5**—Determine how other physical factors in the Santa Clara River (e.g., shading, availability of substrate, dissolved oxygen, evapotranspiration, flow, groundwater upwelling) can mediate temperatures and potential effects on biological communities.

Over the course of the Study, these objectives gave rise to a series of Study questions that became the focus of the technical studies. These study questions are listed below:

1. How does temperature vary spatially and temporally in the Study Area of the Santa Clara River, at time scales ranging from diurnal to seasonal?
2. How much, and over what distance, does discharge from the Valencia WRP change water temperatures in the Study Area? What are the seasonal and diurnal waterbody temperatures of the river without discharge?
3. What are the target taxa representative of the WARM beneficial use in the Study Area?
4. How do differing levels and durations of exposure to higher water temperature affect target taxa?
5. How effective are different potential management strategies (e.g., reducing the volume or cooling the temperature of WRP effluent) likely to be at reducing the overall temperature in the Study Area or meeting current temperature objectives?
6. How do other parameters that affect aquatic habitat (dissolved oxygen [DO] and physical habitat) vary upstream and downstream of the WRPs?
7. What is the current benthic macroinvertebrate (BMI) community composition around the WRPs?

Technical Studies

The objectives and questions have been investigated by the following actions:

- Installing temperature monitors and loggers in the Study Area for 2 years to assess temporal and spatial patterns upstream and downstream of the Saugus and Valencia WRPs.

- Conducting intensive mapping of temperature and other factors that affect aquatic habitat (DO, velocity, depth, substrate, and cover) around the Valencia WRP to understand differences upstream and downstream of the WRP and determine whether there are patches of cooler water within the warmer downstream reach that might provide thermal refugia.
- Characterizing the aquatic-dependent community in the Study Area and assessing their thermal preferences and tolerances based on available data in the literature.
- Conducting BMI surveys in the Study Area and analyzing historic BMI data to assess whether water temperature affects stream condition and food supply for aquatic organisms.
- Performing laboratory experiments on the partially armored threespine stickleback (PATS), a species that is closely related to the federally listed unarmored threespine stickleback (UTS), to assess its response to elevated water temperatures and identify the limits of its thermal tolerance.
- Modeling potential management scenarios for two 6-month periods that represent wetter and drier than average conditions, to determine the effects of various management actions on river temperatures downstream of the Valencia WRP.
- Modeling river temperatures without WRP discharge to understand the “natural condition” of seasonal and diurnal waterbody temperature.

Key Findings of the Study

Water Temperature

River temperatures showed strong seasonal and diurnal variation that closely corresponded with ambient air temperatures, with warmer summer conditions and cooler winter conditions evident throughout the Study Area and Study period. During the Study period (October 2023 to September 2025), mean daily temperatures upstream of the Valencia WRP ranged from 55°F in the winter to 73°F in the summer, while temperatures immediately downstream of the Valencia WRP ranged from 65°F in the winter to 80°F in the summer. A temperature difference greater than 5°F upstream and downstream of the Valencia WRP was observed consistently during the 2-year Study period.

Continuously measured instantaneous temperatures just downstream of the Valencia WRP were higher than 80°F on more than 100 days during summer and fall 2024 and more than 75 days during summer and fall 2025, for periods of 1 to 12 hours. Temperatures above 80°F typically began in June and occurred almost daily between July and mid-September in both 2024 and 2025. Peak temperatures were around 82°F to 83°F during the warmest periods of July and August of both 2024 and 2025, while nighttime temperatures dropped to about 75°F. By contrast, there were only three excursions of 80°F upstream of the Valencia WRP during the 2-year Study period (in July 2024). River temperatures upstream of the Valencia WRP are generally cool due to groundwater upwelling.

River temperatures gradually cooled with distance downstream of the Valencia WRP. About half the river temperature increase that occurred from the Valencia WRP discharge was lost by the Castaic Creek confluence (2.5 miles downstream of the WRP), and most of the remaining river temperature increase was lost by Newhall Orchards (10 miles downstream). Although it is common for temperatures to decrease downstream of the Valencia WRP, during very hot summer days the temperature can increase, as a result of solar radiation and air temperatures that warm the river downstream of the WRP.

Although historic field surveys provide anecdotal evidence of cooler groundwater upwelling downstream of the Valencia WRP that could create thermal refugia, spatial mapping conducted for this Study found little evidence of such cool water. The few cooler pockets observed were confined to a few square feet. Gradual downstream cooling of the river between the Valencia WRP and the Ventura County line occurs by a combination of mixing with cooler upwelled groundwater and surface tributaries and evaporation. Under some summer conditions, the river was observed to warm downstream of the Valencia WRP due to high ambient air temperatures and solar radiation.

During the Study period, there was a pronounced lack of lateral (i.e., bank to bank) mixing of water for a distance of 300 to 700 feet downstream of the Valencia WRP discharge point, with 10°F differences between water on the left and right banks until the effluent became fully mixed with water from upstream of the discharge point. This highlights the need for temperature monitoring downstream of the Valencia WRP to account for spatial variations across the channel’s cross section. However, the extent and persistence of lateral temperature gradients may vary from year to year depending on factors such as flow conditions, channel morphology, riparian vegetation, and broader climatic conditions. Stratification of river temperature may also provide for additional suitable habitat and cooler refugia for stickleback further downstream of the discharge.

At PATS collection sites in the lower Santa Clara River, mean daily water temperatures were 60°F to 65°F in March 2025 and about 70°F in July 2025, with July diurnal fluctuations from around 62°F to around 823°F when both juvenile and adult PATS were present.

Other Water and Channel Characteristics (Non-temperature)

DO levels were measured upstream and downstream of the Valencia WRP using instantaneous grab measurements and continuous 24-hour monitoring in different seasons. Daytime DO was typically 8–9 milligrams per liter (mg/l) upstream and 7–8 mg/l downstream, while nighttime lows were around 6 mg/l, with downstream values about 1 mg/l lower. All DO values were greater than the U.S. Environmental Protection Agency (EPA) threshold of 5 mg/l for WARM beneficial use (EPA 2021); thus, DO is not limiting the WARM beneficial use in the Study Area.

Velocity and depth varied across the channel and were generally greater downstream of the Valencia WRP discharge, resulting in habitat conditions that are largely unsuitable for UTS. As a result, UTS are unlikely to be present in this reach. Channel conditions, including channel width and degree of channelization and vegetation conditions, also influence velocity and depth, and therefore the availability of shallow, slow-flowing river habitat. The river exhibits highly dynamic behavior, with pronounced seasonal variability and multiple interacting factors driving changes in channel form, flow conditions, and thermal regimes. Other channel habitat features such as substrate and cover varied greatly over time and space. High winter flows in 2023–2024 scoured riparian vegetation and caused dramatic channel shifts that were still evolving into summer 2025. The channel evolved from a single, vegetated low-flow thread in late 2023, to unvegetated braided channels in summer 2024, and then gradually narrowed into fewer, deeper channels in 2025 as vegetation recolonized. These natural morphological and vegetation changes, along with WRP discharges, likely influence river temperature and habitat conditions.

Aquatic-Dependent Species in the Study Area

The fish community in the upper Santa Clara River Study Area is dominated by non-native species. Only three species—UTS, Santa Ana sucker (SAS), and arroyo chub—are native to Southern California. UTS is federally listed and state-listed as endangered and is the only fish species in the Study Area native to the Santa Clara River Watershed. UTS was selected as the target taxon for thermal investigation based on several factors, including its endangered status, its status as the only locally native fish, and available information suggesting it may be more thermally sensitive than other native fish species.

Many non-native species in the Study Area have higher reported thermal tolerances than UTS. Some may prey on UTS or consume similar invertebrate prey. Elevated temperatures could indirectly affect UTS by giving their predators and competitors a thermal advantage. However, predation from non-natives fishes occurs at all temperatures, including those within the thermal tolerance or preference range of UTS, and the degree to which UTS are limited by predation is unknown.

Benthic macroinvertebrates and benthic diatoms, which support aquatic food webs and reflect ecological condition, were evaluated using historical (2004–2022) and 2025 data collected upstream and downstream of the Valencia WRP and Saugus WRP. California Stream Condition Index (CSCI) results indicate generally altered biological conditions across sites. The sand-bedded channel and highly variable flows in the Study Area inherently limit BMI diversity and favor taxa that tolerate disturbance. CSCI values for BMI and benthic diatoms showed no measurable effect of Valencia WRP effluent discharge on BMI and benthic diatom condition, with downstream scores comparable to or slightly higher than upstream scores.

Stickleback Thermal Tolerances

The UC Davis Fish Physiology Laboratory conducted laboratory experiments on adult, juvenile, and embryonic threespine stickleback in 2024 and 2025 using PATS as a surrogate for the federally listed UTS. Fish were acclimated for 2 weeks under constant or diurnally cycling temperatures before testing. Adult PATS were assessed for acute (Critical Thermal Maximum [CT_{MAX}]) and chronic (Upper Incipient Lethal Temperature [UILT]) thermal tolerance, metabolic performance, and thermal preference. Juveniles were tested for acute tolerance (CT_{MAX}). Embryos were assessed for hatching success and size across incubation temperatures.

PATS were collected from the lower Santa Clara River (well downstream of the influence of the WRPs), where summer temperatures fluctuated widely (approximately 60°F to 65°F nightly lows and 80°F to 83°F daily highs). Juveniles exhibited higher mortality during summer collections, suggesting increased sensitivity to capture and handling at moderate water temperatures (73°F).

Acclimation survival revealed the strong influence of temperature regime. Adult survival was 100 percent survival during the 2-week acclimation period at constant 60°F and 77°F, but declined sharply at constant 78°F and 80°F (33 percent), while juveniles showed 100 percent survival at 66°F but only approximately 50 percent survival at 73°F. In contrast, adults acclimated to diurnally cycling temperatures averaging 78°F (73°F to 83°F) had much higher survival (83 percent), highlighting the importance of periodic access to cooler temperatures (in the low 70°Fs), although mortality increased during the second week, suggesting cumulative stress.

Adult CT_{MAX} ranged from 89.6°F to 93.6°F, with higher values at higher acclimation temperatures, while juvenile CT_{MAX} were approximately 2°F lower. The CT_{MAX} values measured for PATS by UC Davis are comparable to those for UTS reported by Feldmeth and Baskin (1976) when methodological differences are considered.

Chronic tolerance (UILT) declined rapidly with temperature. Models indicated high survival (95 percent) at a 3-day exposure at a constant 83.0°F or a single 24-hour exposure at a constant 85.8°F, but substantial mortality (50 percent) with a 6-hour exposure at 88.8°F. Repeated or prolonged exposures to high temperatures substantially increase mortality risk.

Adult PATS maintained metabolic capacity across a range of temperatures up to near lethal temperatures (over 80°F). Warm acclimation shifted metabolic performance to higher temperatures and increased thermal limits but reduced overall aerobic capacity, indicating a tradeoff between thermal tolerance and metabolic performance. Aerobic scope was maximized above 70°F (peaking around 80°F to -85°F) and declined precipitously as temperatures approached lethal limits.

Thermal preference trials (range 50°F to 86°F) showed that adults selected relatively cool water (mean 64.4°F, range about 51°F to 75°F), indicating behavioral avoidance of warmer conditions when available. Overall, results indicated that sustained temperatures near or above 80°F pose high mortality risk, while brief exposures to temperatures in the low 80°F were tolerated when adequate diurnal thermal refugia are present.

Incubating embryos were remarkably tolerant. Hatching success was not temperature-dependent up to the maximum tested temperature of 77.0°F. However, hatchlings from warmer incubation temperatures were smaller. Across all experiments, juveniles exhibited the lowest thermal tolerance of any life stage.

PATS are unlikely to survive extended exposure (1–2 weeks) at a constant temperature of 80°F. However, temperature cycling experiments and field observations indicate that brief exposures to temperatures up to 82°F can be tolerated when adequate diurnal thermal refugia are available. Although juveniles were not tested under cycling conditions, their abundance at the site where PATS were collected from the river suggests they may also tolerate short-duration, exposure to temperatures up to 82°F if diurnal thermal refugia are available during the evening and early morning. Overall, these findings emphasize that exposure duration and thermal variability are critical determinants of PATS thermal tolerance near or above 80°F.

Modeling Potential Management Approaches to Lowering Temperatures in the Santa Clara River

ESA constructed a temperature model of the portion of the Study Area from just upstream of the Valencia WRP to close to the Ventura County line, using the publicly available CE-QUAL-W2 water quality simulation model. The model was used to assess several potential approaches to meeting the 80°F and Δ5°F limits: reducing effluent by 50 percent and 100 percent, preventing effluent water temperatures from becoming greater than 80°F, and increasing shading of the river. The management solutions were modeled under both drier than average (2022) and wetter than average conditions (2024) to account for varying levels of dilution from ambient flows upstream of the Valencia WRP. Key findings included:

- Under existing WRP discharge and river conditions, river temperatures are above 80°F for several days to weeks each summer, even at higher than average upstream flow rates that provide some cooling from dilution. There were 146 modeled excursions of 80°F or warmer in 2022 (a year with unusually low flows from upstream to dilute WRP effluent) and 84 modeled excursions in 2024 (a year with higher than average flows from upstream of the WRP).
- Upstream and downstream temperature differences were greater than the Δ5°F limit for all times simulated in both wetter and drier than average water years under existing conditions.
- Reducing Valencia WRP discharges to 50 percent of their existing level was effective in preventing average water temperatures from exceeding the 80°F limit in the wetter than average year modeled (2024); however, the reduction had almost no effect with an upstream river flow of 0.4 cubic foot per second (2022) because of the greater volume of effluent relative to background flow. Maximum daily water temperatures were greater than 80°F on 65 and 152 days in 2022 and 2024, respectively. This scenario did not meet the Δ5°F limit in either year.
- Capping Valencia WRP discharge to 80°F was also effective in reducing the average temperature during the summer; however, the cap had little effect in reducing the number of days when the maximum temperature was greater than 80°F. The maximum river temperature was greater than 80°F on 141 days in 2022 and on 32 days in 2024 – indicating that downstream river temperatures are highly influenced by ambient conditions. This scenario did not meet the Δ5°F limit in either year simulated.
- Completely eliminating the Valencia WRP discharge was the only management scenario that met the proposed regulations in the vicinity of the WRP in both years simulated. In the modified 2022 scenario, the river temperature was still greater than 80°F farther downstream on a small number of days because of warming from ambient conditions.
- Canopy shade has an increasingly large effect on river temperature with increasing length of channel shaded, potentially reducing summer water temperatures by 7°F if the entire channel between the Valencia WRP and the Castaic Creek confluence (2.5 miles downstream) were shaded to 100 percent canopy cover compared to its existing level of shade. However, the river’s natural dynamism means that the riparian corridor is eroded out roughly every decade or so, setting cover to almost zero until vegetation reestablishes and shades the river again. As a result, reliance on canopy shading is impractical and does not represent a realistic or durable solution for managing river temperatures.

Study Implications

The study found no evidence that the current river temperatures downstream of the Valencia WRP are adversely affecting the BMI, algae or amphibian populations and communities, nor most fish populations within the study reach. During the Study period, water temperatures were within preferred ranges for UTS in winter and spring. In summer and fall, however, temperatures downstream of the Valencia WRP approached and at times were greater than the thermal limits of UTS (as evaluated using the surrogate PATS), depending on exposure duration.

The thermal tolerance studies conducted by the UC Davis Fish Physiology Laboratory indicate that adult PATS can tolerate temperatures above 80°F for periods of hours to days without mortality. Field observations were consistent with these results: adult and juvenile PATS were abundant in the river 29 miles downstream of the Valencia WRP (where the collection of PATS for laboratory studies occurred) even though daily temperatures there were greater than 80°F on 52 days between March and July 2025 collection events. Together, laboratory and field findings indicate that PATS (and thus UTS) can tolerate short-term excursions of 80°F during the warm-weather months of the year if diurnal thermal refugia are available during the evening and early morning. However, sustained excursions near or above 80°F pose substantial risk, especially to juveniles. Hydraulic habitat constraints further limit where UTS are likely to occur and therefore where thermal exposure is biologically relevant.

Collectively, these findings demonstrate that temperature variability, exposure duration, life stage sensitivity, and habitat suitability are critical factors in assessing WARM beneficial use support and that neither the 80°F absolute limit nor the Δ5°F criterion alone fully captures biological risk in this dynamic river system.

CHAPTER 1
Introduction

1.1 Purpose and Need

The Los Angeles Regional Water Quality Control Board (LARWQCB) recently renewed National Pollutant Discharge Elimination System (NPDES) discharge permits[1] for the Valencia and Saugus Water Reclamation Plants (WRPs) and set a new, more stringent maximum daily temperature effluent limitation of 80 degrees Fahrenheit (°F), reduced from the previous 86°F limitation[2] and eliminating prior exemptions for elevated ambient air temperatures. The 80°F limitation[3] also applies to the receiving water downstream of the discharge points.

The Santa Clarita Valley Sanitation District (District) of the Los Angeles County Sanitation Districts (LACSD) owns and operates the Saugus and Valencia WRPs, located in the city of Santa Clarita, California. The WRPs collect and treat wastewater from Santa Clarita and nearby areas of unincorporated Los Angeles County and discharge tertiary-treated disinfected effluent to Reaches 5 and 6 of the Santa Clara River as defined by the *Water Quality Control Plan for the Los Angeles Region* (Basin Plan). The Valencia WRP discharges approximately 14 million gallons per day (mgd) of treated effluent to Reach 5 of the river, while the Saugus WRP discharges approximately 4 to 5 mgd to Reach 6. These values correspond to approximately 21.7 cubic feet per second (cfs) from the Valencia WRP and 7.7 cfs from the Saugus WRP. For comparison, dry-season flows immediately upstream of the Valencia WRP are typically around 1 to 2 cfs, while flows immediately downstream of the Valencia WRP are 21 to 22 cfs before groundwater exchanges and tributaries further modify the flow rate. Flows in the upper Santa Clara River can vary significantly depending on season, short- and long-term precipitation patterns, groundwater interactions and pumping, surface water releases from storage reservoirs, and other local vegetation and geological conditions that influence infiltration, runoff, and channel connectivity.

The 80°F limit is based on the LARWQCB's new interpretation and implementation of the water quality objective for temperature contained in the Basin Plan,[4] which states that waterbodies with a warm freshwater habitat (WARM) beneficial use designation shall not be raised above 80°F as a result of waste

1 Los Angeles Regional Water Quality Control Board Orders R4-2022-0174 and R4-2022-0175.

2 Compliance with the 86°F limitation in the receiving water is currently assessed with temperature readings collected from monthly grab samples. Based on the typical sample collection time of mid-morning, the temperature reading recorded for the receiving water is approximately the mean daily temperature for the day of measurement.

3 Compliance with the 80°F limitation compliance monitoring is assumed to also rely on monthly grab measurements.

4 The *Water Quality Control Plan for the Los Angeles Region*, referred to herein as the "Basin Plan," contains water quality standards for surface and groundwaters in the Los Angeles Region. The Basin Plan is designed to preserve and enhance water quality and protect the beneficial uses of all regional waters. Specifically, the Basin Plan: (i) designates beneficial uses for surface and groundwaters, (ii) sets narrative and numerical objectives that must be attained or maintained to protect the designated beneficial uses and conform to the state's antidegradation policy, and (iii) describes implementation programs to protect all waters in the region.

discharges. The Basin Plan also states that the receiving water temperature shall not be altered by more than 5°F above the natural temperature (referred to in this report as the "Δ5°F limit"). Both Reaches 5 and 6 of the Santa Clara River have a WARM beneficial use designation. The Basin Plan defines WARM beneficial use as "Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates." Native fish that have historically occurred in these reaches include Santa Ana sucker, arroyo chub, and unarmored threespine stickleback (UTS), which is federally and state listed as endangered.

However, the scientific basis for the 80°F water quality objective is unclear. Given the varying conditions among and within waterbodies, as well as the varying species present, a single temperature objective of 80°F for WARM beneficial uses across the entire Los Angeles Region is not appropriate. Similarly, the scientific basis for broadly applying the Δ5°F limit, without consideration of season, aquatic species, or specific waterbody conditions, remains unclear.

Because effluent discharged from the District's WRPs is frequently greater than the 80°F temperature limit during the summer and fall months and the WRPs cannot immediately comply with the new limitations, the LARWQCB included an 8-year schedule in the WRPs' 2022 NPDES permits to address the work required to bring each WRP into compliance. At the District's request, the LARWQCB provided time in the compliance schedule for the District to conduct temperature studies to evaluate the potential effects of temperature on the WARM beneficial use and to assess temperature management options.

The District developed and implemented the Santa Clara River Waterbody Temperature Study (Study) to better understand how discharge temperatures from the Saugus and Valencia WRPs affect aquatic life and the WARM beneficial use in Reaches 5 and 6 of the Santa Clara River. This report describes the results of the temperature and biological studies conducted. The results of the District's studies of potential management options are reported elsewhere.

1.2 Study Area and Environmental Setting

The Study Area is located in the upper Santa Clara River watershed (**Figure 1-1**). The Santa Clara River is a highly modified, primarily sand-bedded system characterized by frequent hydrologic intermittency and seasonal disconnection (Stillwater Sciences 2011; Shihadeh et al. 2017). The Study Area encompasses Reaches 5 and 6 of the Santa Clara River, extending from the Saugus WRP downstream to the Piru Dry Gap (**Figure 1-2**). The river in the Study Area comprises both intermittent and reaches where groundwater/surface water interactions vary spatially and seasonally between gaining and losing conditions. These reaches are described below.

Upstream of the reach boundary where the Saugus WRP discharges into the Santa Clara River near the Bouquet Canyon Road Bridge, the river is intermittent with no flow being the most common condition. Flows upstream of Bouquet Canyon Road occur either following intense wet season rainfall or during dry season periods when long-term precipitation has been substantially average over several years. More typically, the riverbed upstream of the Saugus WRP is dry for most of the year and all flow in the Santa Cara River downstream of the Saugus WRP originates from the WRP. In this upstream reach, the riverbed consists of braided sand and fine gravel, and vegetation is sparse and scrubby, reflecting the lack of year-round surface water and shallow groundwater. Because this reach dries frequently and lacks emergent wetland vegetation, it is unlikely to support UTS and other native fish except during unusually wet periods or high-flow events, when fish are washed in from upstream tributaries.

Discharge from the Saugus WRP creates a perennial channel for about 1 mile between the Bouquet Canyon Road Bridge and a point about 1,000 feet upstream of the McBean Parkway Bridge. This reach supports a riparian corridor under most conditions. During typical dry-season conditions, nearly all flow in this channel originates from Saugus WRP effluent. As flow moves downstream, it infiltrates into the riverbed and after about 1 mile the channel typically runs dry with all flow going subsurface during the dry season. Although perennial, this reach is generally hydrologically isolated by dry gaps from upstream and downstream reaches and is therefore unlikely to provide persistent habitat for UTS or other native fish.

Percolation of the Saugus WRP flows into the riverbed creates a dry gap around the McBean Parkway Bridge under most conditions. However, during watershed runoff or elevated groundwater levels, surface flow occasionally reconnects across this gap. As a result, this reach is considered intermittent and variable in extent. Dynamic patches of riparian vegetation occur in this reach periodically colonizing and then disappearing in response to variable wet and dry conditions as well as natural scour processes that erode the riparian corridor approximately every 10 years. The dry gap is unlikely to support UTS or other native fish, except during periods of unusually prolonged connected surface flows, as occurred in 2024.

Downstream of the McBean Parkway Bridge, groundwater gradually re-emerges into the bed of the Santa Clara River, and during the wet season surface flows may join the channel from San Francisquito Canyon. The location where groundwater re-emerges to create connected surface flow downstream varies by around 1 mile from year to year in response to long-term rainfall and groundwater patterns. Under very wet conditions, surface flow may extend across the dry gap, whereas during prolonged droughts the dry reach may extend nearly to the Interstate 5 Bridge about 1 mile downstream of the McBean Parkway Bridge. With increasing distance downstream (approaching Interstate 5), the riparian corridor becomes denser and more persistent, and the low-flow channel becomes a more defined topographic feature.

From the variable point where groundwater wets the low-flow channel to the Valencia WRP discharge, flow is typically perennial and ranges from 0.5 cfs to 4 cfs during the dry season, based on LACSD monthly flow records over the last 20 years. The channel in this reach is typically a single or double thread channel with several back channels and off-channel alcoves with emergent wetland vegetation, providing areas of suitable UTS habitat. Because groundwater is the main water source in this reach, temperatures are typically cooler than elsewhere on the river.

Downstream of the Valencia WRP, the river continues to be perennial due to the combination of groundwater upwelling and WRP effluent, which contributes around 20 cfs of flow under typical conditions. The river is normally perennial from around the Interstate 5 Bridge to the Piru Dry Gap, about 10 miles downstream. Under average climatic conditions, the river gains a few cfs of groundwater for the first few miles downstream of Interstate 5 during the winter and loses a similar volume to groundwater during the summer. During prolonged droughts, losing conditions persist for a greater portion of the year, and gaining conditions become shorter in duration. Additional surface water inputs occur from several tributaries including Castaic Creek, which also conveys periodic water supply transfers from Castaic Lake to downstream users.

Approaching the Piru Dry Gap, the river transitions to more persistent losing conditions and may run dry during typical dry seasons. Vegetation cover reflects this shift, transitioning from riparian woodland to scrub and exposed bare sand approaching the dry gap.

Dry-season flows in the Study reach between the Saugus WRP and the Castaic Creek confluence are strongly influenced by WRP effluent and, to a lesser degree, by groundwater upwelling, and typically range from 0 to 30 cfs. Wet season flows are considerably more variable, with baseflows between large runoff events ranging from 30 to 50 cfs and peak flows exceeding 1,000 cfs in most winters. Flows over 5,000 cfs occur approximately every 5 years and flows over 10,000 cfs occur roughly every 10 years.

Review of historical aerial photos indicates that the riparian corridor between the Saugus WRP and Interstate 5 is patchy and dynamic on an almost annual basis, whereas the riparian corridor between Interstate 5 and the Ventura County line is wider and more persistent. However, the entire riparian corridor around the low-flow channel is periodically scoured out during geomorphic “resetting” events that occur roughly every 10 years. These events result in a bare, braided sand channel form with a very wide, shallow and exposed channel. The channel becomes highly laterally unstable, with channel braids migrating and avulsing rapidly due to the lack of stabilizing vegetation. During the year or so after each resetting event, the channel is very exposed and lacks cover or emergent vegetation, and so is likely unsuitable for UTS. Over time and in the absence of further high flows, vegetation colonizes the sand bars and gradually stabilizes the various channel braids into more defined channels, with some shallow secondary channels having emergent vegetation that may be suitable UTS habitat. With additional time, the smaller secondary channels become more vegetated and flow may be forced into one or two main channels, which then deepen and narrow as vegetation encroaches on their banks. This process occurs naturally with willow-cottonwood riparian stands in the Study reach but can be more pronounced when *Arundo donax* colonizes the river. Under some circumstances, *Arundo*-driven flow concentration can create a single, fast, deep channel that is likely unsuitable for UTS.

One such resetting event occurred during the study period in the winter of 2023, associated with flows around 4,000 cfs. This event completely reset the channel corridor between the Valencia WRP and the Castaic Creek confluence, causing the channel to avulse by 300 to 400 feet in several locations (e.g., next to the Valencia RV Resort) and removing a 300- to 400-foot-wide swath of riparian vegetation around the channel. Over the following year, the channel continued to migrate within the denuded area by an additional 300 feet in several reaches before transitioning to more gradual channel evolution as riparian vegetation recolonized the sand bars and stabilized the channel.

Water temperature in the river is influenced by multiple factors, including ambient air temperature, solar radiation, evaporative cooling, and riparian shading. Groundwater upwelling— particularly near Interstate 5 just upstream of the Valencia WRP—contributes to localized cooling, while effluent discharges from the Valencia and Saugus WRPs contribute to increased temperatures. These thermal influences fluctuate across both space and time, making it impractical to apply a single water quality objective uniformly throughout the receiving water.

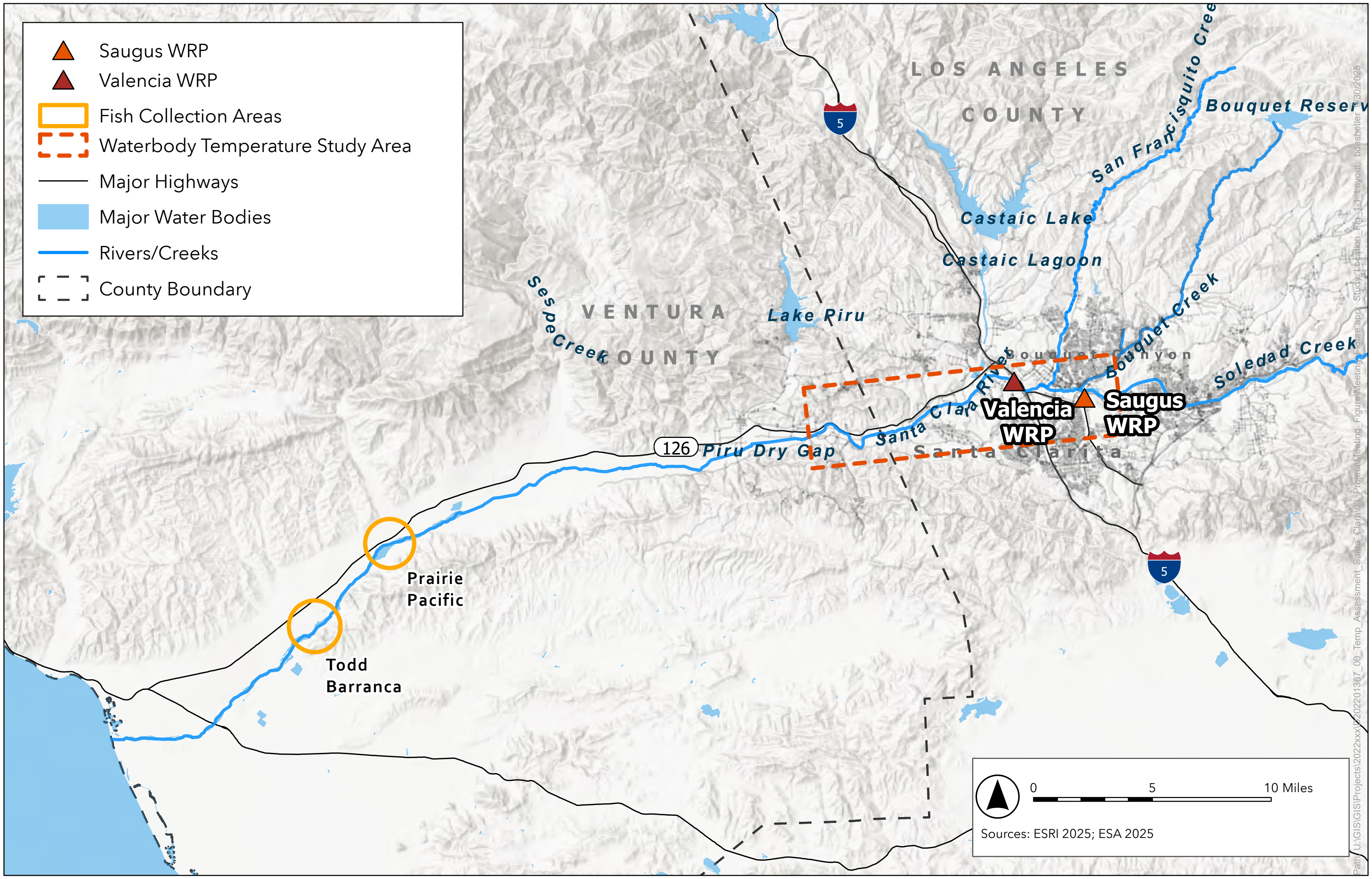

Figure 1-1
Study Location

ESA

Figure 1-2
Study Area

CHAPTER 2
Study Overview

2.1 Study Objectives

The Study aims to determine which water temperatures (or temperature ranges) are protective of the WARM beneficial use in the Santa Clara River. The findings are intended to inform the appropriate temperature objectives for the Study Area and/or permit limits for the WRPs.

The District developed a set of Study objectives in 2022 with feedback from technical advisers at the Southern California Coastal Water Research Project; from a Technical Advisory Committee consisting of representatives with expertise in the Santa Clara River including staff from the U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, U.S. Environmental Protection Agency, State Water Resources Control Board, LARWQCB, National Marine Fisheries Service, and Santa Clarita Valley Water Agency; and from a broader stakeholder advisory group that included representatives from other interested public agencies, environmental groups, and indigenous tribal groups.

The Study objectives are as follows:

- **Objective 1**—Determine the wholly or partially aquatic-dependent taxa that are present, were historically present, or could be present given the current habitat conditions.
- **Objective 2**—For each taxon identified in Objective 1, describe the relationship between waterbody temperatures and the probability (or likelihood) that different aquatic life stages are supported.
- **Objective 3**—Determine how the relationships between waterbody temperature and the support of aquatic life vary based on the taxon's location in the Santa Clara River and seasonality.
- **Objective 4**—Determine the critical exposure times, durations, and/or frequencies associated with the temperature relationships described in Objectives 2 and 3.
- **Objective 5**—Determine how other physical factors in the Santa Clara River (e.g., shading, availability of substrate, dissolved oxygen, evapotranspiration, flow, groundwater upwelling) can mediate temperatures and potential effects on biological communities.

2.2 Study Approach

In 2023, the District retained Environmental Science Associates (ESA) with research partners at the University of California, Davis (UC Davis) to conduct the Study, as described in the Study Workplan (Workplan) (**Appendix A**). The Study examines biological factors (taxa and physiology) and physical factors (hydrologic, thermal, dissolved oxygen, and habitat). As a first step, ESA reviewed available information to determine which aquatic-dependent taxa are present, were historically present, or could be present in the Study Area (**Appendix B**). In addition, UC Davis and ESA reviewed thermal physiology literature, including thermal tolerance data, and information on the effects of water temperature on certain taxa (**Appendix C**). Based on those reviews, priority focal taxa were selected to represent the successful protection of the WARM beneficial use, and data gaps in the thermal physiology and tolerances of those taxa were identified.

To fill remaining data gaps and address other Study objectives, ESA and the District developed a Workplan with feedback from the Technical Advisory Committee (ESA 2024). The Workplan consists of several Study elements and data collection activities, including high-resolution temporal and spatial temperature monitoring (Chapter 3), temperature modeling (Chapter 4), monitoring and analysis of benthic macroinvertebrates (Chapter 5), and laboratory physiology studies to assess thermal tolerances of threespine stickleback (Chapter 6). The Study objectives and associated technical studies are shown conceptually in **Figure 2-1**.

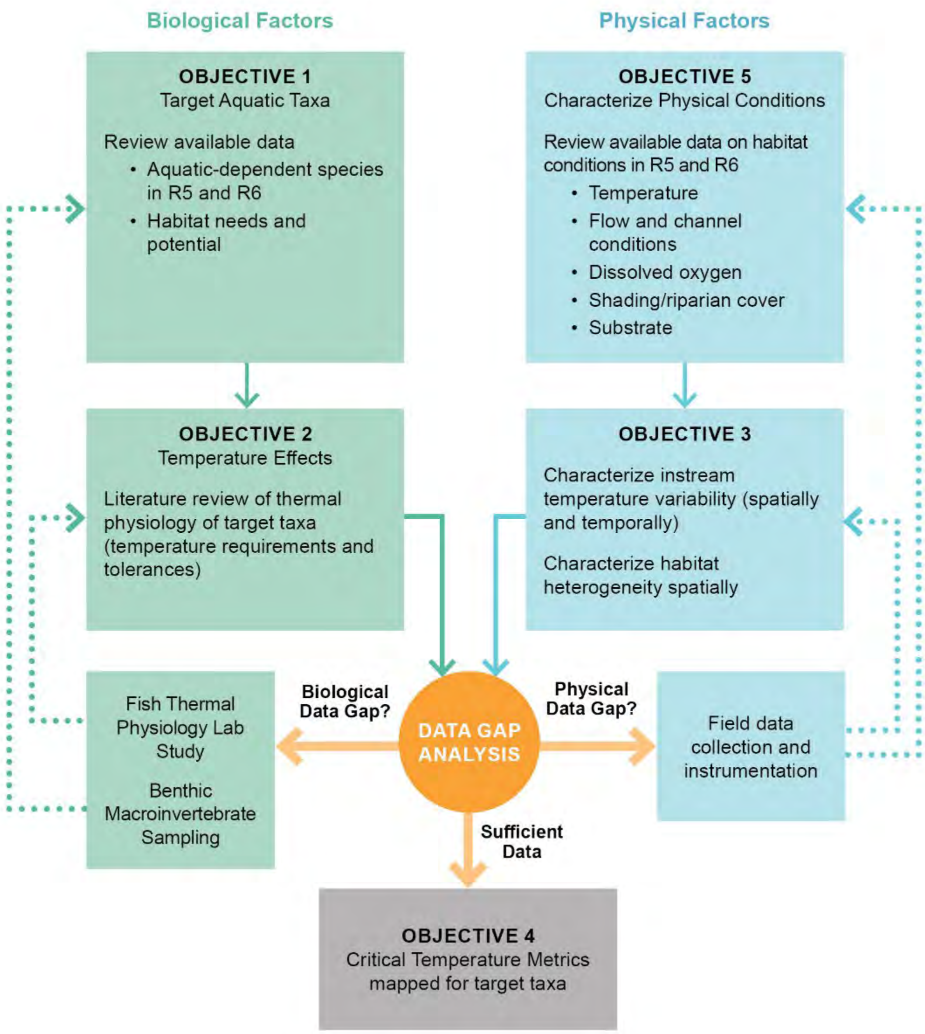

Figure 2-1
Conceptual Diagram of Study Objectives and Technical Studies

Two elements from the original Workplan were modified in response to changing river conditions during the Study period. First, the Workplan originally proposed expanding a habitat suitability model of the Study Area previously developed by ESA for Santa Clarita Valley Water to assess conditions upstream and downstream of the Valencia WRP. This approach was changed following a channel-resetting geomorphic event during the winter of 2023 and subsequent channel evolution in 2023–2024. These processes rendered the existing bathymetric data for the reach between the Valencia WRP and Castaic Creek—derived from a 2018 light detection and ranging (LiDAR) surface—obsolete. As a result, resources originally allocated to habitat suitability modeling were redirected toward development of a river temperature model downstream of the Valencia WRP to evaluate potential management actions under current channel conditions.

Second, monitoring and modeling efforts increasingly focused on the vicinity of the Valencia WRP rather than the Saugus WRP. Under normal flow conditions, there is no dry-season flow in the Santa Clara River upstream of the Saugus WRP. All flow between the Saugus WRP and the McBean Parkway Dry Gap consists of WRP effluent that typically infiltrates into the riverbed, resulting in hydrologic disconnection from the greater Santa Clara River under most conditions and eliminating an upstream reference point for water temperature comparisons. While water temperature and benthic macroinvertebrate (BMI) data were collected downstream of the Saugus WRP, the majority of temperature monitoring and all modeling efforts were concentrated around the Valencia WRP. The Valencia WRP accounts for the majority of effluent from the combined WRP operations and, unlike Saugus, is hydrologically connected to the greater Santa Clara River under most condition.

2.3 Study Questions

Several questions emerged as the Study evolved, based on initial review of available information, assessment of current river conditions and monitoring data, and input from the Technical Advisory Committee. These questions provide a guiding framework and progression for the technical studies described in the following sections. The Study addresses the following primary questions:

1. How does temperature vary spatially and temporally in the Study Area of the Santa Clara River, at time scales ranging from diurnal to seasonal?
2. How much, and over what distance, does effluent from the Valencia WRP raise water temperatures in the Study Area?
3. What are the target taxa representative of the WARM beneficial use in the Study Area?
4. How do differing levels and durations of exposure to higher water temperature affect target taxa?
5. How effective are different potential management strategies (e.g., reducing the volume or cooling the temperature of WRP effluent) likely to be at reducing the overall temperature in the Study Area or meeting temperature objectives?

In addition to these primary questions about water temperature, the Study examined the following:

6. How do other parameters that affect aquatic habitat (dissolved oxygen [DO] and physical habitat) vary upstream and downstream of the WRPs?
7. What is the current benthic macroinvertebrate community composition around the WRPs?

2.4 Technical Studies

The Study objectives and questions have been investigated by:

- Installing temperature monitors and loggers in the Study Area for 2 years to assess temporal and spatial patterns upstream and downstream of the Saugus and Valencia WRPs.
- Conducting intensive mapping of temperature and other factors that affect aquatic habitat (DO, velocity, depth, substrate, and cover) around the Valencia WRP to understand differences upstream and downstream of the WRP and determine whether there are patches of cooler water within the warmer downstream reach that might provide thermal refugia.
- Characterizing the aquatic-dependent community in the Study Area and assessing their thermal preferences and tolerances based on available data in the literature.
- Conducting BMI surveys in the Study Area and analyzing historic BMI data to assess whether water temperature affects stream condition and food supply for aquatic organisms.
- Performing laboratory experiments on the partially armored threespine stickleback (PATS), a species that is closely related to the federally listed unarmored threespine stickleback (UTS), to assess its response to elevated water temperatures and identify the limits of its thermal tolerance.
- Modeling potential management scenarios for two 6-month periods that represent wetter and drier than average conditions, to determine whether the management actions would have brought temperatures into compliance with the current temperature objectives.
- Modeling river temperatures without WRP discharge to understand the “natural condition” of seasonal and diurnal waterbody temperature.

2.5 Document Structure

This Final Study Report includes the following elements:

- **Chapter 1**, ***Introduction***, presents the purpose and background of the Study.
- **Chapter 2**, ***Study Overview***, provides the Study objectives and approach of the technical studies conducted.
- **Chapter 3**, ***Water Temperature and Physical Habitat Monitoring and Mapping***, characterizes the spatial and temporal variability of surface water temperature and DO, and presents a high-resolution spatial temperature map that includes the effects of WRP discharge and physical habitat conditions. This element will provide data to meet Objectives 3 and 5 (Study Questions 1, 2, and 6).
- **Chapter 4**, ***Temperature Modeling***, describes the development of a numerical flow and temperature model to simulate existing conditions and potential management actions (e.g., reductions or cooling of WRP discharges). This element synthesizes information to meet Objective 4 (Study Question 5).
- **Chapter 5**, ***Aquatic Biological Resources***, characterizes target taxa that represent the WARM beneficial use in the Santa Clara River and existing information on thermal tolerance. This element satisfies Objective 1 (Study Questions 3 and 7).

- **Chapter 6**, ***Stickleback Thermal Physiology Study***, describes a laboratory study conducted by UC Davis to characterize the thermal tolerances of threespine stickleback from the Santa Clara River. This element provides information to meet Objectives 2 and 4 (Study Question 4).
- **Chapter 7**, ***Study Conclusions***, synthesizes the technical studies and addresses the Study questions.
- **Chapter 8**, ***References***, lists the references cited in this report.

Further information is provided in the following appendices:

- Appendix A, *Study Workplan*
- Appendix B, *Aquatic Taxa Literature Review*
- Appendix C, *Thermal Tolerance Literature Review*
- Appendix D, *Thermal Physiology of Partially Armored Threespine Stickleback*

2.6 Temperature Data and Conversions

Temperature data are presented in this Study report primarily in degrees Fahrenheit (°F), rather than degrees Celsius (°C). While the authors acknowledge that the scientific literature sources often use °C to report temperature data, °F was considered appropriate for this report primarily to align with the format and system used in the National Pollutant Discharge Elimination System (NPDES) permit/Basin Plan thresholds, which are reported in Fahrenheit (i.e., the 80°F threshold and Δ5°F limit). An earlier draft of this report provided English/metric conversions for all temperature data, but the result was visually distracting and difficult to read; the decision was made to use °F consistently throughout to provide a more streamlined and easier-to-read report.

For reference, **Table 2-1** provides a cross-walk of Fahrenheit to Celsius conversions for the temperature range most relevant to the analysis in this Study report.

TABLE 2-1
TEMPERATURE DATA CONVERSIONS: FAHRENHEIT TO CELSUS

Fahrenheit (°F)	Celsius (°C)	Fahrenheit (°F)	Celsius (°C)
45	7.2	70	21.1
50	10	75	23.9
55	12.8	80	26.7
60	15.5	85	29.4
65	18.3	90	32.2

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CHAPTER 3
Water Temperature and Physical Habitat Monitoring and Mapping

3.1 Background and Purpose

As part of its National Pollutant Discharge Elimination System (NPDES) compliance monitoring for the Santa Clara River, LACSD has been conducting grab measurements of temperature,[5] flow, and additional water quality properties upstream and downstream of the Saugus and Valencia WRPs for more than 20 years. In July 2022, LACSD added continuously logging HOBO® temperature sensors at the Saugus RSW-002D (RB), Valencia RSW-001U (RC), Valencia RSW-002D (RD), and Valencia RSW-003D[6] (RE) stations to better characterize temperatures in a daily cycle and between grab sampling events.

The temperature sensors are typically deployed in the late spring once the chance of a peak flow has passed. They remain in the river during the summer and fall low-flow season, when water temperatures are highest, and are removed in the late fall or winter when high flows are forecast. Once removed for a high-flow winter event, the sensors have typically been kept out of the river channel until the likelihood of another high flow has passed.

As part of this Study, additional temperature sensors were deployed and intensive dissolved oxygen (DO) monitoring was conducted in the Study Area. The purpose of the expanded monitoring was fourfold:

- Characterize temporal patterns in water temperature between the Saugus WRP and the Ventura County line to provide more detailed insight into annual and diurnal temperature variability.
- Characterize temporal patterns in DO levels to evaluate how temperature fluctuations may affect DO concentrations and aquatic habitat conditions.
- Provide data to parameterize and validate a temperature model of the river that can be used to assess potential management actions.
- Survey temperatures around the Valencia WRP to identify cooler areas that might function as thermal refugia for fish.

Additional temperature sensors were installed approximately 10 miles downstream of the Study Area to measure water temperature between March and August 2025 at sites where threespine stickleback were

5 All temperatures referred to in this chapter are water temperatures, unless otherwise specified.

6 Data collection at RE was very intermittent due to significant channel migration that made anchoring a HOBO® temperature sensor impossible at times.

collected by Environmental Science Associates (ESA) and UC Davis for the fish thermal physiology study. Those results are presented in Section 6.3.1, *Fish Collection Field Observations.*

Data were collected using two approaches:

- Continuous monitoring using additional HOBO® temperature sensors between the Saugus WRP and the Ventura County line between October 2023 and September 2025, supplemented by several 24-hour periods of continuous monitoring of DO.
- Quarterly intensive spatial mapping of temperature and other physical properties (velocity, depth, substrate, and cover) affecting aquatic habitat, conducted between October 2023 and February 2025.

3.2 Review of Previous Temperature Studies

This Study builds on several prior studies of temperature in the Santa Clara River, which are briefly described below:

- The U.S. Geological Survey measured and modeled temperatures in and beneath the Santa Clara River and used measured temperatures as a tracer to understand surface water–groundwater exchanges (Constantz et al. 2002). That study provided data on temperatures and exchange rates across groundwater and the river, but it was confined to a small location and time.
- LACSD has monitored temperature and other properties in the Study Area for more than 20 years (weekly samples through June 2022, monthly samples from July 2022 through present). This dataset provides an excellent medium-term record of seasonal and spatial temperatures in the river, but because the measurements are from grab samples, they do not allow diurnal variations to be discerned.
- In 2019, ESA collected a pair of temperature profiles along the Santa Clara River for LACSD. These profiles provide a good spatial snapshot of how river temperatures change downstream of the Valencia WRP; however, the study was limited to two monitoring dates.
- In July 2022, LACSD added continuously logging HOBO® temperature sensors at the Saugus RSW-002D (RB), Valencia RSW-001U (RC), Valencia RSW-002D (RD), and Valencia RSW-003D (RE) stations to better characterize temperatures in a daily cycle and between grab sampling events.
- The Santa Clarita Valley Water Agency is currently monitoring temperatures of shallow groundwater at two locations in the Study Area to better understand interactions between groundwater and surface water.

3.3 Temperature and Dissolved Oxygen Monitoring Methods

3.3.1 Temperature Sensors

A total of 30 HOBO® temperature sensors were deployed over the course of the Study between October 2023 and September 2025 (**Figure 3-1**). **Figure 3-2** shows representative channel conditions in the reaches upstream and downstream of the Valencia WRP.

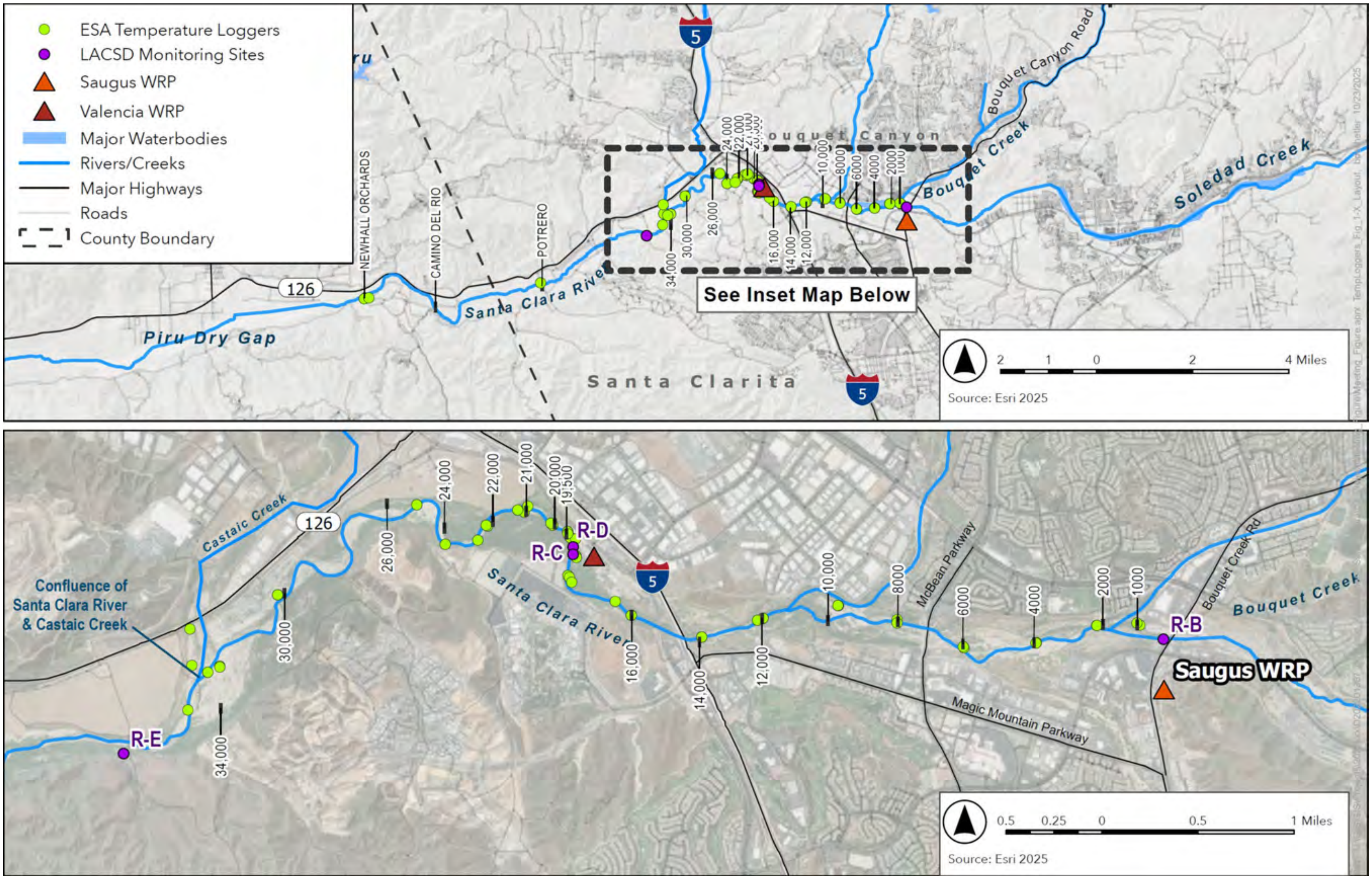


Figure 3-1

Locations of Temperature Sensors (numbers indicate distance [in feet] downstream of the Bouquet Creek Road Bridge)

Figure 3-2

Typical Channel Conditions Upstream (top) and Downstream (bottom) of the Valencia Water Reclamation Plant, October 2023

Maintaining sensors in the mobile sand channel of the Santa Clara River was challenging, and several installation methods were used over the course of the Study. Where suitable trees were present, the most durable installations were completed by attaching the temperature sensors via cables to submerged tree roots (**Figure 3-3**) or wedged tree snags that were embedded in the channel banks or bed. However, channel avulsions between October 2023 and February 2024 removed most vegetation around the low-flow channel and caused the channel to move 200 to 300 feet in many locations. Where there were no suitable submerged tree roots, deployments were attempted that involved attaching the sensors to bankside trees with long cables; however, these deployments typically had short lives (1 to 4 weeks), because the sensors were either stolen or buried in sand or debris that formed around the installations. Mid-channel installations that used helical anchors were generally not successful for more than a month during low flows given the mobile sand bed, while installations on fence posts driven into the channel bed lasted 2 to 3 months but did not survive high flows because of debris wracking around the posts.

As an example of the challenges faced, one installation site near the Castaic Creek confluence experienced 200 feet of lateral channel migration in 4 weeks. This site evolved from being the outside bend of the active channel to becoming a buried inside bend point bar during a period of low to moderate flows (20 to 50 cubic feet per second [cfs]) after the main channel avulsions in winter 2024, as the channel continued to adjust and new vegetation established on point bars. Over the duration of the Study, many sensors were lost, buried, or affected by channel migration.

As the Study team developed a better understanding of how water temperatures varied along the river and which installation methods were most durable, the Study re-focused on maintaining a smaller number of sensors in representative and stable locations, rather than having a large number of sensors with intermittent data. **Table 3-1** shows the locations and durations of the measurements.

3.3.2 Dissolved Oxygen Monitoring

Dissolved oxygen (DO) is a measure of how much oxygen is dissolved in the water—the amount of oxygen available to living aquatic organisms. The amount of DO is affected by abiotic factors (temperature, water stratification and mixing, surface area) and biotic factors (aquatic plants and animals, floating plant cover, and decaying biological material). Cold water can hold more DO than warm water. DO levels in surface waters usually follow a daily cycle (EPA 2021). Aquatic organisms consume oxygen via respiration throughout the entire day. During daylight hours, aquatic plants and algae release oxygen into the water via photosynthesis. At night when photosynthesis ceases, DO levels decline, typically reaching the lowest concentrations before dawn. Oxygen reduction also occurs when the demand for oxygen by biological and chemical processes exceeds the oxygen input from aeration, often due to abundant vegetation, algal blooms, or high organic matter (e.g., fertilizers, sewage). The decay of plants and breakdown of organic matter by bacteria can deplete oxygen.

Most DO data collected on the Santa Clara River to date have come from point measurements (i.e., grab samples) taken during daylight hours. Continuous measurements require deployment of DO sensors.

Figure 3-3
Installation of a Temperature Logger on a Submerged Tree Anchor

TABLE 3-1
MEASUREMENTS DURING THE PERIOD OF RECORD FOR TEMPERATURE SENSORS IN THE STUDY AREA

Distance Downstream of Saugus Outflow [ft]	Location	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25	Oct-25
1,000	Below Saugus Outfall																									
2,000																										
4,000																										
6,000																										
8,000	McBean Parkway																									
10,000																										
12,000																										
14,000																										
16,000																										
18,000	Above Valencia WRP																									
19,000 (Outfall)	Valencia WRP Outfall																									
RC (LACSD)	Upstream of Outfall																									
19,000 (Control)	Air Temperature																									
19,500	Below Valencia WRP																									
RD (LACSD)	Downstream of Outfall																									
20,000																										
21,000																										
22,000																										
24,000																										
26,000																										
30,000																										
34,000	Above Castaic Confl.																									
34,000	SR 126 Underpass																									
40,000	Potrero																									
Newhall	Near Ventura County																									
Prairie Pacific	Santa Paula, CA																									
Todd Barranca	Santa Paula, CA																									

NOTES: Confl. = Confluence; ft = feet; LACSD = Los Angeles County Sanitation Districts; SR = State Route; RC = Valencia RSW-001U; RD = Valencia RSW-002D; WRP = Water Reclamation Plant
SOURCE: Data compiled by Los Angeles County Sanitation Districts in 2023–2025

To determine how DO levels varied during the day, the Study team deployed continuous DO sensors and loggers for 24 hours on four occasions associated with the intensive water temperature mapping described below (Section 3.5). DO sensors were deployed a few hundred feet upstream and 1,000 feet downstream of the Valencia WRP. The more distant downstream location was selected to ensure that effluent from the Valencia WRP was well mixed with water from upstream by the time the flow reached the point of measurement. A DO and temperature sensor was placed at each location in the afternoon on the day before the quarterly intensive temperature mapping effort took place; each sensor was removed on the following day after mapping was complete.

3.4 Monitoring Results

3.4.1 Seasonal Temperature Trends

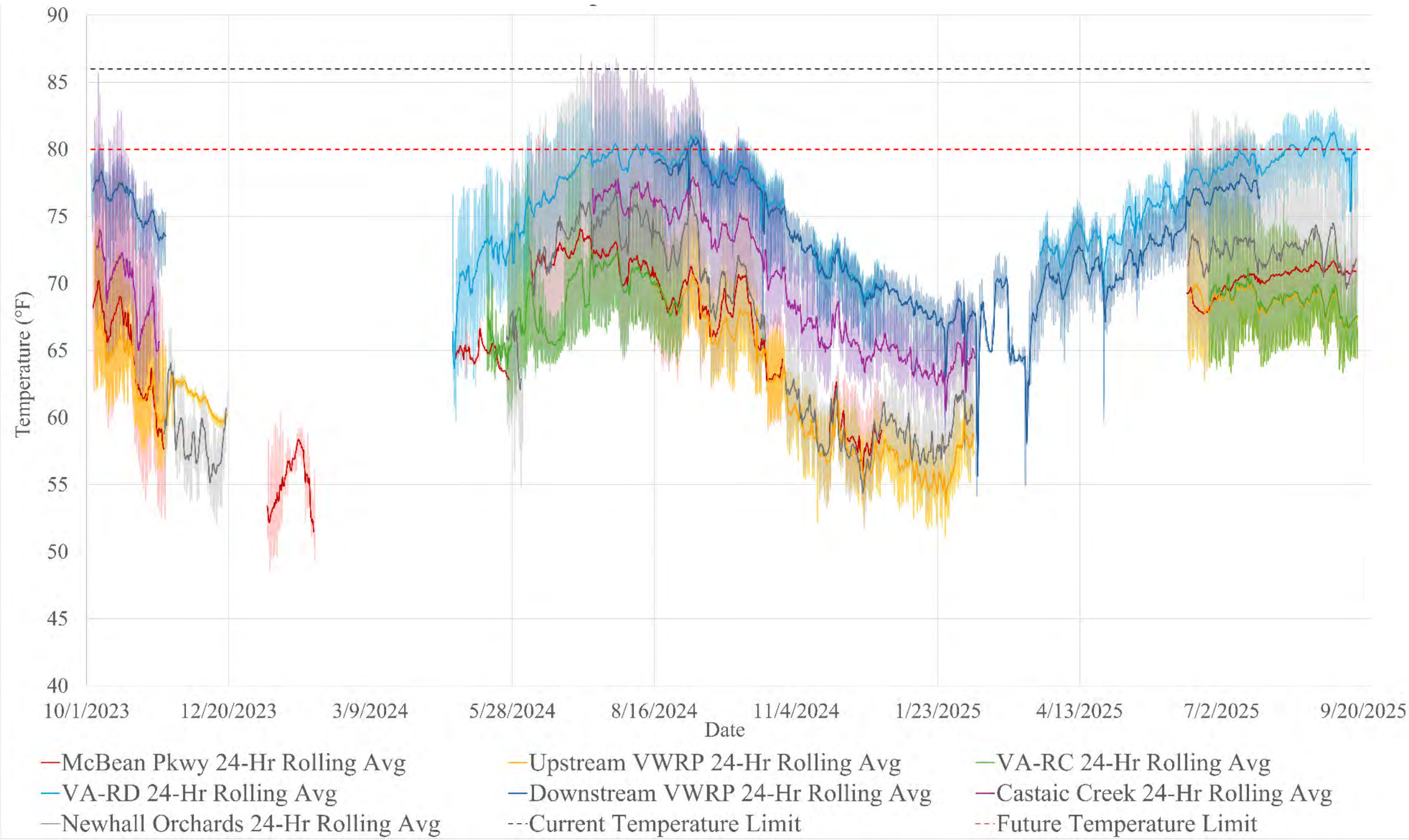
Figure 3-4 shows a subset of temperature sensors that represent several key locations in the Study Area. The solid lines show 24-hour moving mean water temperatures, while the transparent lines show temperatures at 15-minute intervals. From upstream to downstream:

- Red lines represent McBean Parkway, 2.2 miles upstream of the Valencia WRP.
- Green lines are from the RC station, immediately upstream of the Valencia WRP discharge point.
- Light blue and dark blue lines are from sensors located either immediately downstream of the Valencia WRP (light blue) or a few hundred feet downstream of the Valencia WRP (dark blue).
- Purple lines are from just upstream of the Castaic Creek confluence, approximately 2.5 miles downstream of the Valencia WRP.
- Gray lines are from Newhall Orchards, 10 miles downstream of the Valencia WRP.

The sensors were installed in October 2023, likely after water temperatures had peaked for the year and begun to fall.

Daily mean water temperatures in October 2023 were around 65 degrees Fahrenheit (°F) to 70°F upstream of the Valencia WRP and 75°F to 80°F a few hundred feet downstream of the WRP outlet. Temperatures had fallen by about 5°F to 6°F by Castaic Creek. Most of the temperature sensors had either been removed for safety or were lost in winter 2023–2024, but the sensor at McBean Parkway (approximately midway between the Saugus WRP and the Valencia WRP) recorded the lowest temperatures in January and February 2024, with daily means around 52°F to 55°F. The unusually high diurnal range on this sensor suggests that either water levels were very low or the sensor may have come out of the water column between February and May.

Peak daily mean temperatures in 2024 occurred in late July and early August. Mean daily temperatures were 70°F to 72°F both at McBean Parkway and immediately upstream of the Valencia WRP, increased to around 79°F to 81°F immediately below the Valencia WRP, and then dropped to around 75°F to 77°F by the Castaic Creek confluence. The river was approximately 1°F to 2°F cooler 10 miles downstream of the Valencia WRP at Newhall Orchards.



NOTES: Due to continuously changing channel conditions and sensor recovery, the sensor deployment locations vary slightly. Upstream sensors were deployed approximately 350 to 1,000 feet upstream of the Valencia WRP. Downstream sensors were deployed approximately 300 to 500 feet downstream of the Valencia WRP. Castaic Creek confluence sensors were approximately 2.5 miles downstream of the Valencia WRP (Station 34,000 below the Saugus WRP).

Figure 3-4

Temperature Logger Records, Water Years 2024 and 2025

Minimum daily mean water temperatures in 2025 occurred in February. Mean daily temperatures were around 55°F upstream of the Valencia WRP and rose to 65°F to 70°F immediately below the WRP, before falling to around 63°F to 65°F by the Castaic Creek confluence and to 57°F to 60°F by Newhall Orchards.

In summer 2025, daily mean river temperatures peaked in August and September. Temperatures at McBean Parkway peaked at around 72°F, those just upstream of the Valencia WRP were in the 68°F to 70°F range, and those just downstream of the Valencia WRP reached 81°F and were greater than 80°F for several days at a time. No data were available for Castaic Creek because of the inability to maintain a logger in this very dynamic channel location, but river temperatures at Newhall Orchards were around 72°F to 73°F, about 7°F cooler than just below the Valencia WRP.

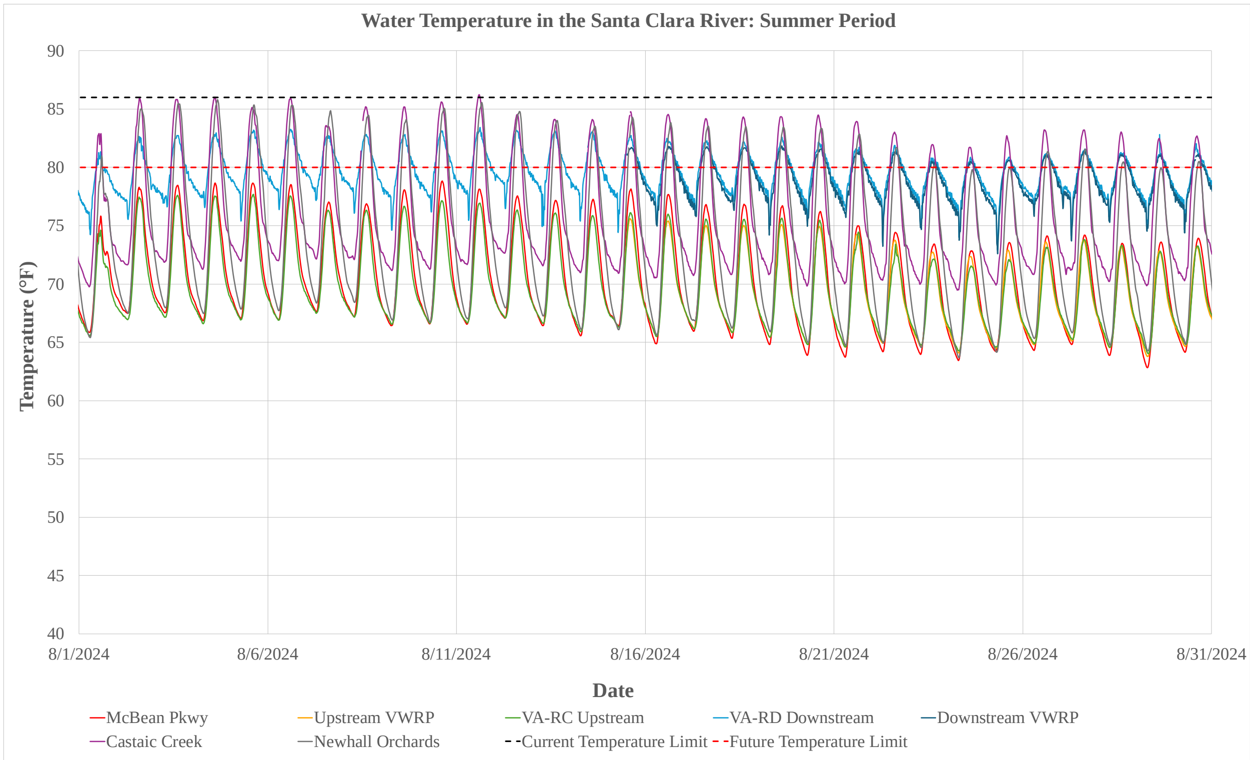
Reviewing the entire Study period for which data are available just upstream and downstream of the Valencia WRP, the average water temperature was 9°F higher downstream of the WRP.

3.4.2 Diurnal Temperature Trends

Characterizing diurnal temperature patterns is useful to provide context for point measurements or daily averages, and to inform the study of the thermal tolerance of fish. Although mean temperatures vary as described above, diurnal temperatures fluctuate around those means and differ between locations. As an example of diurnal fluctuations in a range of conditions, **Figure 3-5** shows instantaneous temperatures during some of the warmest and coldest mean temperatures recorded during the Study period.

During summer 2025, water temperatures immediately upstream of the Valencia WRP had a 10°F to 12°F daily range (typically 66°F to 77°F in the warmest part of July), peaking at around 2 p.m. and reaching the minimum at around 7 a.m. The temperature of effluent from the Valencia WRP was much more consistent, varying by about 2°F (typically 79°F to 81°F). Flow a few hundred feet downstream of the Valencia WRP reflected both water sources and had a range of about 5°F to 7°F (typically 76°F to 83°F during the warmest period). During the warmest periods, the river warmed up by 2°F to 3°F between the point just below the Valencia WRP and the Castaic Creek confluence, with daytime peaks of 85°F at the confluence, while nighttime lows at that location were lower than at the Valencia WRP, at 73°F to 74°F. Water temperatures by Newhall Orchards also had higher daytime peaks than just below the Valencia WRP, up to 84°F to 85°F, but had even lower nighttime lows of 66°F to 67°F. These data highlight that on hot, sunny days, the river can heat up from natural sources downstream of the Valencia WRP. With respect to the proposed Basin Plan threshold of 80°F, temperatures just downstream of the Valencia WRP were greater than 80°F more than 100 times during the summer and fall of 2024 and more than 75 times during the summer and fall of 2025. Temperatures over 80°F began in June and occurred almost daily between July and the middle of September in both 2024 and 2025. Peak temperatures were around 82°F to 83°F during the warmest periods of July and August of both summers, while nighttime temperatures dropped to about 75°F. By contrast, there were only three excursions of 80°F upstream of the Valencia WRP during the 2-year Study, in July of 2024.

Discharge of effluent from the Valencia and Saugus WRPs varies during the day in response to the input of municipal wastewater from the sewer system as well as plant operations, including a period of around 15 minutes each night when effluent ceases to backwash the filters. These operations can be seen in the downstream temperature traces as a dip in temperature of 2°F to 3°F. Occasional longer shutdowns, continuing for several hours, can be detected at the Castaic Creek confluence and farther downstream.



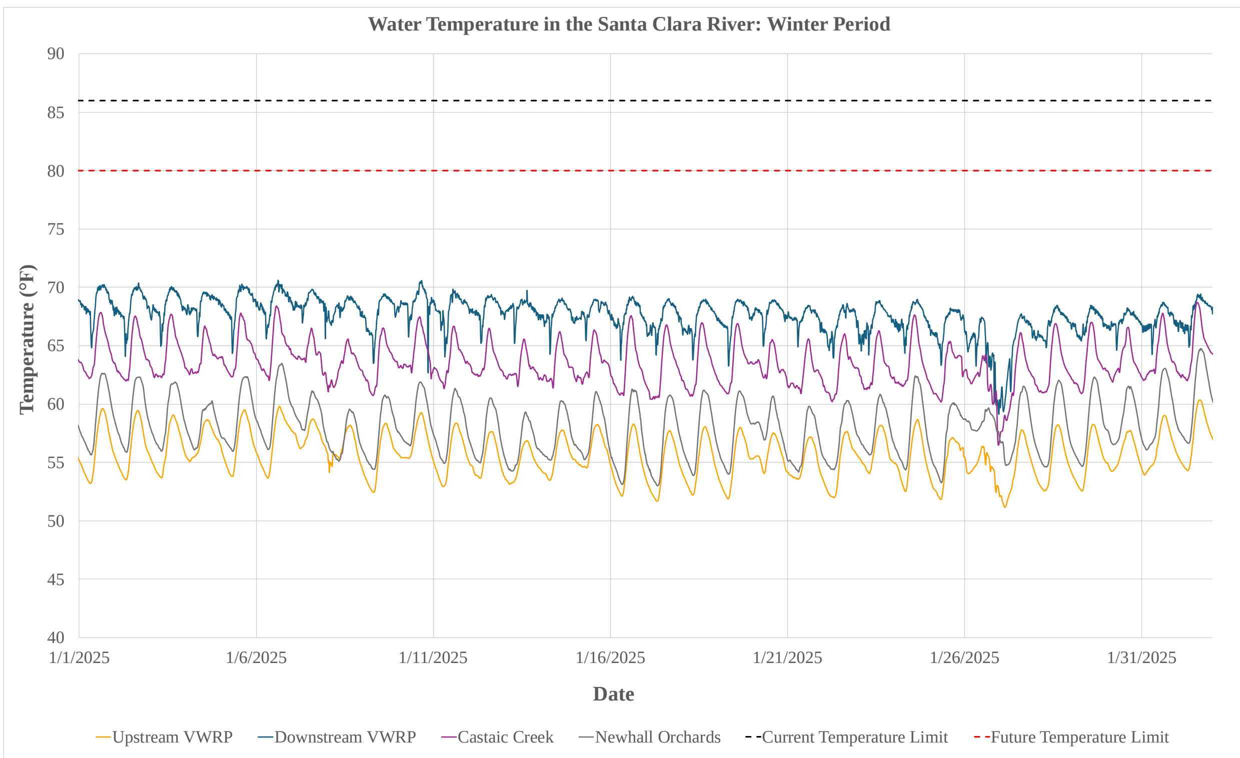


Figure 3-5

Continuous Temperature Records around the Valencia Water Reclamation Plant for Summer and Winter Conditions

During winter 2025, the diurnal range of temperatures was much less than during the summer. Temperatures upstream of the Valencia WRP ranged from 53°F to 59°F, while temperatures immediately downstream of the WRP were mostly in the 65°F to 70°F range. By the Castaic Creek confluence, the river had cooled to around 61°F to 68°F, generally losing about half its temperature gain from the Valencia WRP over those 2.5 miles. By Newhall Orchards, the river had cooled an additional 6°F or so and was very similar to the temperature upstream of the Valencia WRP.

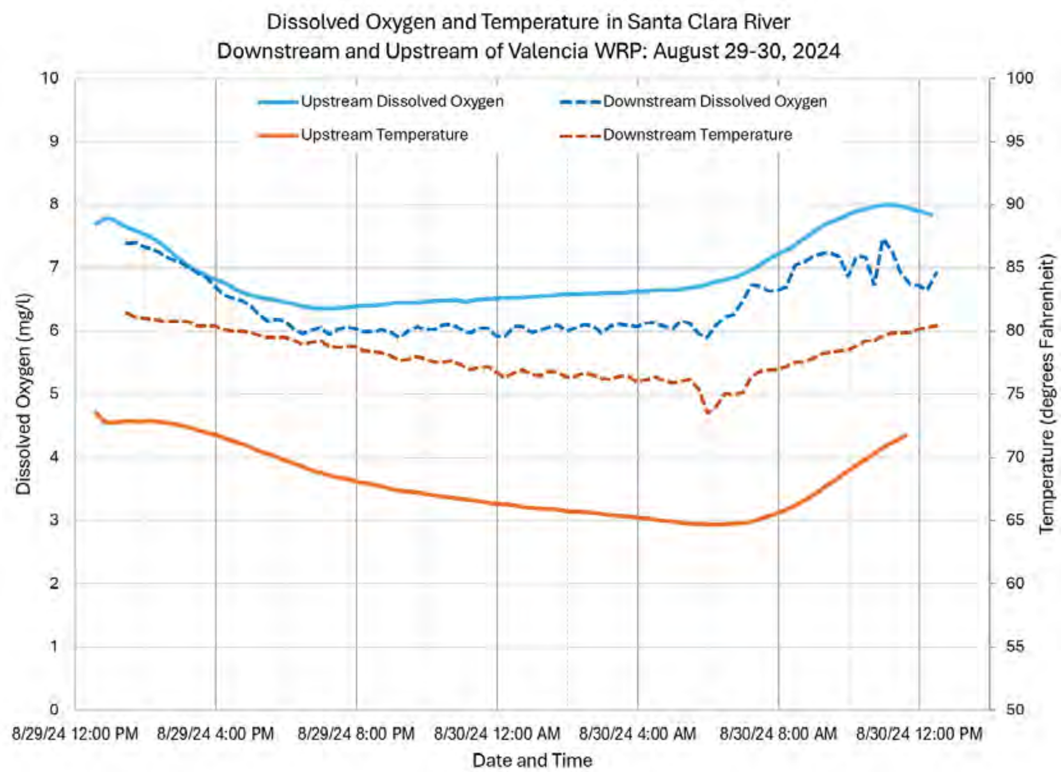
Although the narrower variance in diurnal temperature downstream of the Valencia WRP is partly attributable to the low variability in effluent temperatures, the total volume of water also has a strong influence on the magnitude of diurnal fluctuations. Combining the monitoring data with temperature modeling described in Chapter 4, the Study team found that greater volumes of water had more thermal inertia and experienced smaller diurnal fluctuations in temperature. This is described in more detail in Chapter 4, *Temperature Modeling*.

3.4.3 Diurnal Dissolved Oxygen Trends

Diurnal DO was measured four times: April 18–19, 2024; August 29–30, 2024; November 9–20, 2024; and February 12–13, 2025. **Figure 3-6** shows an upstream and downstream plot from August 2024 and February 2025 to illustrate the range of conditions.

The data collected August 29–30, 2024, were selected as the representative warm-weather example; this was the mapping period with the highest overall water temperatures during the Study period. DO levels upstream of the Valencia WRP ranged from a high of 8.0 milligrams per liter (mg/l) at around 11 a.m. to a low of 6.4 mg/l at around 7 p.m. Downstream of the Valencia WRP, DO levels ranged from a high of 7.4 mg/l at 11 a.m. to 5.9 mg/l at several times between 7 p.m. and 6 a.m. On average, the DO level was 0.5 mg/l lower downstream of the Valencia WRP than upstream. DO levels downstream of the Valencia WRP exceeded 6.0 mg/l, except during four 5-minute intervals when they were 5.9 mg/l. During the same period, water temperatures upstream of the Valencia WRP ranged from a low of 65°F to a high of 74°F (mean 68°F), while downstream of the Valencia WRP, temperatures ranged from 74°F to 82°F (mean of 78°F).

February 12–13, 2025, was selected as the representative cold-weather example; this was the mapping period with the coldest water temperatures. DO levels upstream of the Valencia WRP ranged from a high of 8.1 mg/l at around 7 a.m. to a low of 7.4 mg/l at around 6 a.m. Downstream of the Valencia WRP, DO levels ranged from a high of 7.8 mg/l at 8 a.m. to 6.8 mg/l around 2 a.m. On average, the DO level was 0.6 mg/l lower downstream of the Valencia WRP than upstream. During the same period, water temperatures upstream of the Valencia WRP ranged from a low of 55°F to a high of 59°F (mean 58°F), while downstream of the Valencia WRP, temperatures ranged from 61°F to 69°F (mean of 67°F).



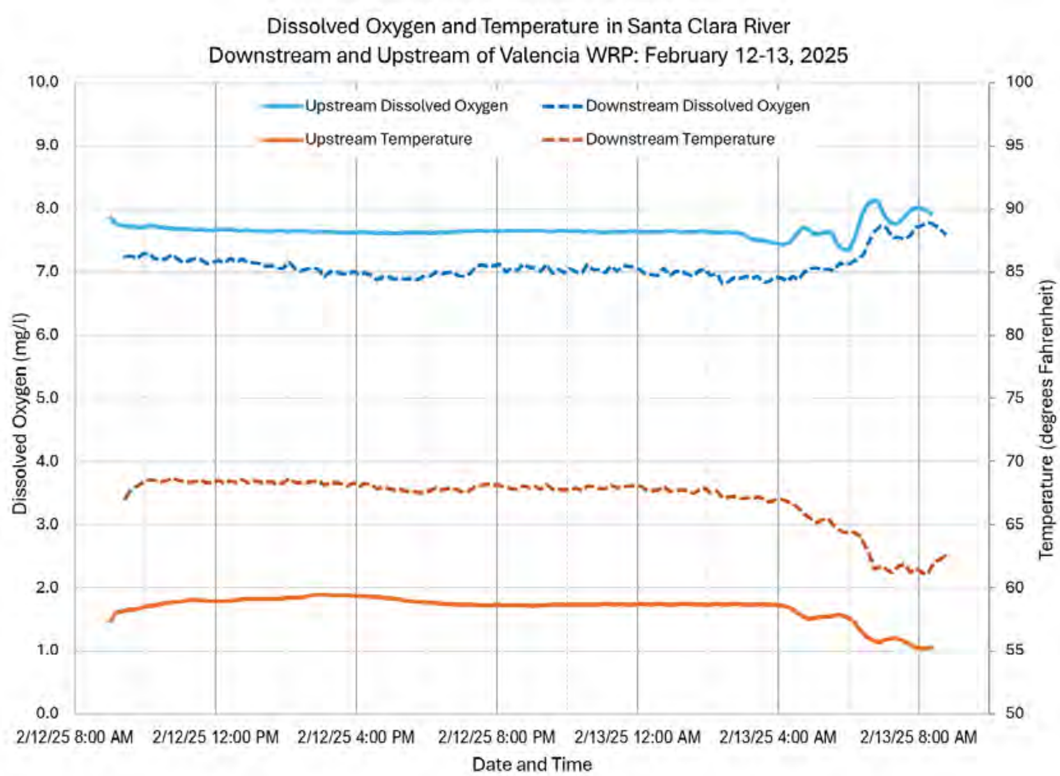


Figure 3-6

Continuous Temperature and Dissolved Oxygen Record around the Valencia Water Reclamation Plant for Summer (top) and Winter (bottom) Conditions

3.4.4 Spatial Trends

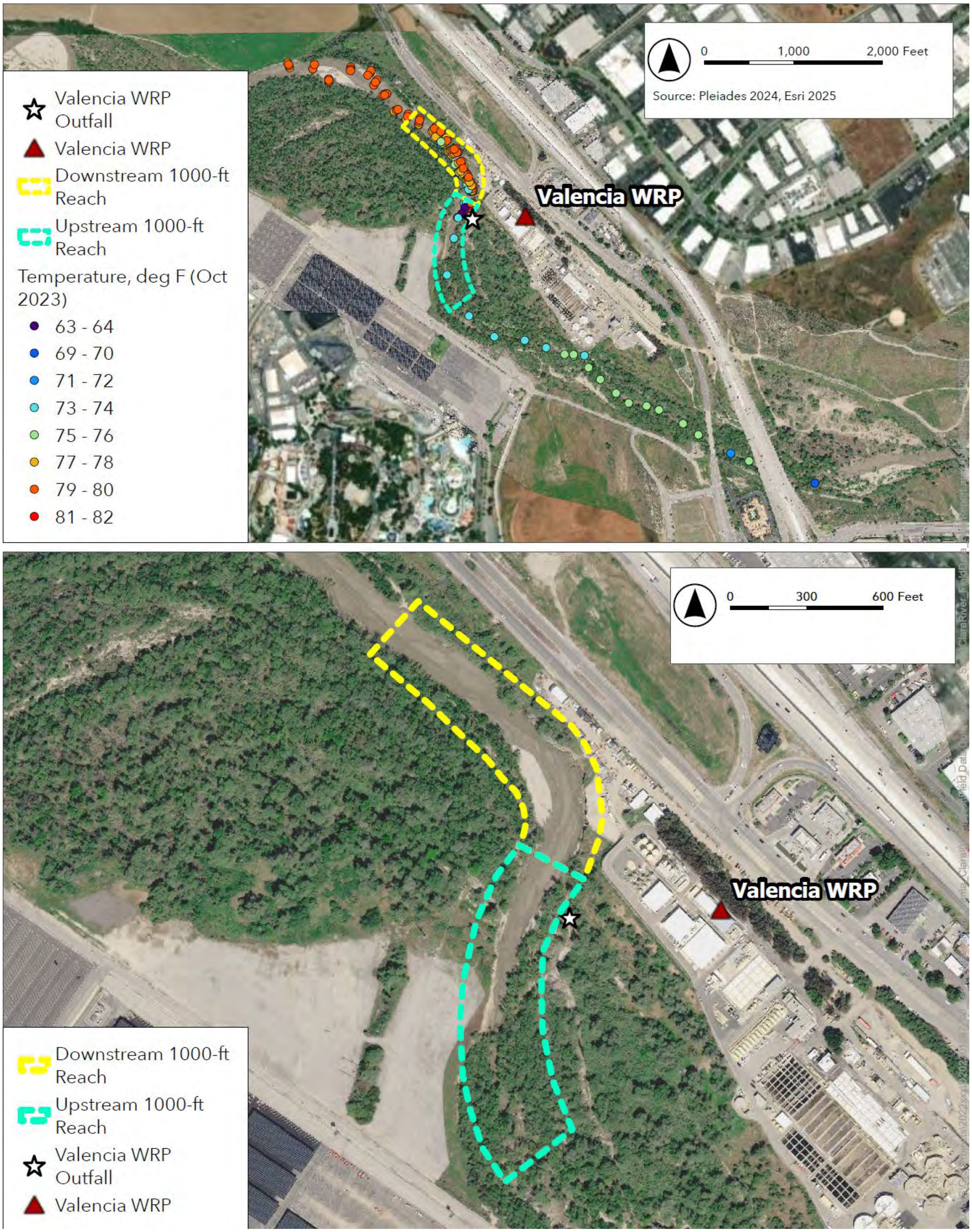
During the 2 years of intensive monitoring, the temperature of the Santa Clara River in the reach immediately downstream of the Valencia WRP was typically about 6°F to 12°F higher than the temperature upstream of the WRP in the summer, and 10°F to 14°F higher in the winter. Moving downstream, temperature progressively cooled by around 5°F to 6°F by the Castaic Creek confluence and by a further 3°F to 4°F by Newhall Orchards. As described in more detail in Chapter 4, *Temperature Modeling*, cooling downstream of the Valencia WRP likely occurs through a combination of radiation and evaporation with mixing of cooler water from groundwater upwelling and surface water from local tributaries such as Potrero Creek and Long Canyon Creek. Castaic Creek is an additional source of cooler water, especially when reservoir releases are made to supply downstream water users (typically during the winter and spring but sometimes extending into the early summer).

3.5 Temperature and Physical Habitat Mapping Methods

Starting in October 2023, ESA conducted intensive point mapping of temperature around the Valencia WRP on a quarterly basis. This mapping effort involved taking individual point measurements along the river, with an emphasis on detecting spatial variability in temperature. The initial purpose of the mapping was to identify whether temperatures were relatively homogeneous within reaches of the Santa Clara River at the scale of a few thousand feet, or whether there were areas of cooler water that might function as thermal refugia for aquatic species. Fisheries biologists conducting studies along the river had anecdotally noted the presence of cooler areas. These cooler areas might be expected based on the observed upwelling of water from groundwater, which is generally cooler than ambient river temperatures during the summer.

On October 22, 2023, ESA conducted a reconnaissance habitat mapping effort and collected 113 measurements within 2,000 feet downstream of the Valencia WRP and 28 measurements within 2,000 feet upstream (see upper panel in **Figure 3-7**). Additional more widely spaced measurements were made for about 2 miles upstream and downstream of this area. After the reconnaissance habitat mapping, subsequent efforts reduced the extent of the mapping and increased the density and type of measurements, for the following reasons:

- Although the reconnaissance effort identified some very localized areas of cold water upwelling in side channels downstream of the Valencia WRP, more substantial patches were not uncovered. However, there was significant lateral variability in water temperatures in the first 500 feet or so of the channel downstream of the Valencia WRP because of the slow mixing of the WRP effluent with water from upstream.
- Conducting mapping over several miles of channel meant that measurements were taken over many hours, during which time ambient river temperatures varied by 6°F to 10°F, reducing the value of the data to assess spatial variability.
- After the initial presentation of temperature results, the Technical Advisory Committee requested that DO, water velocity and depth, channel substrate, and canopy cover be added to the mapping task. Incorporating these additional water quality and habitat parameters would increase the time needed to make measurements, which would compound the problem of temperature varying during the field day unless the sampling area was reduced.



NOTE: Data from the upper panel are temperatures measured during the October 2023 reconnaissance.

Figure 3-7

Extent of the Reconnaissance (top) and Upstream and Downstream Mapping Reaches

Based on these observations, the field team reduced the mapping footprint to two reaches: the upstream mapping reach, which extended 1,000 feet upstream of the Valencia WRP discharge point; and the downstream mapping reach, which extended 1,000 feet downstream of the Valencia WRP outlet (see lower panel in Figure 3-7). Initially, these reaches were measured by a single team working from upstream to downstream. After two mapping efforts, however, it became apparent that temperature increases during the field day still represented a problem. Therefore, the remaining efforts were conducted by two field teams working simultaneously to record data from the upstream and downstream reaches.

DO was measured using a handheld YSI DO and temperature meter that was calibrated at the start of each day. Velocity was measured using a Marsh McBirney Flo-Mate 2000 and an OTT MF Pro electromagnetic velocity meter. Because of the very shallow conditions (typically 4 to 12 inches), a single velocity measurement was taken at 60 percent of the total depth to capture a representative average velocity. Substrate was estimated qualitatively, divided into silt, sand, gravel and cobble. Cover was also estimated qualitatively based on the percentage of the sky with canopy cover at each measurement point.

Ultimately the field teams were able to make all temperature and DO measurements in less than an hour, reducing the problem posed by ambient changes over time. Parameters that were less variable[7] on a diurnal basis (depth, velocity, substrate, and canopy cover) were measured in a second pass after the temperature and DO had been recorded. **Figure 3-8** shows the field team making depth and velocity measurements on one of the transects.

Figure 3-8
Spot Measurements of Velocity and Depth Upstream of the Valencia Water Reclamation Plant

7 Depth and velocity downstream of the Valencia WRP vary because daily wastewater discharges fluctuate in response to customer discharges and WRP operational practices such as filter backwashing.

3.6 Mapping Results

3.6.1 October 2023 Reconnaissance Mapping

On October 22, 2023, ESA conducted a reconnaissance effort to map temperature, depth, and DO with 113 measurements made in the 2,000 feet downstream of the Valencia WRP and 28 measurements in the 2,000 feet upstream. Temperature results are shown spatially in Figure 3-7; **Figure 3-9** provides a closer view of the reach downstream of the Valencia WRP.

The reconnaissance started in the morning when temperatures were coolest and generally moved from the upstream reach to the downstream reach. As a result, measurements upstream and downstream of the Valencia WRP were not concurrent. Some additional spot measurements were made while team members walked to and from the ends of each reach at the beginning and end of the day. Because temperatures rose during the day, direct comparisons between upstream and downstream temperatures should be treated with caution. However, lateral comparisons of temperature along cross sections can be made with more confidence because these measurements were made within a few minutes of each other.

Temperatures upstream of the Valencia WRP were mostly between 73.0°F and 74.5°F, as defined by the 25th and 75th percentiles. Temperatures downstream of the WRP were 77°F on average, with a 25th percentile of 77°F and a 75th percentile of 78.5°F. As with the upstream reach, there were some cooler outliers with points in the range of 63°F to 75°F.

The downstream temperatures showed two spatial patterns that were not influenced by the timing of the observations. The most noticeable pattern was a marked lack of lateral mixing in the first 600 to 700 feet downstream of the Valencia WRP: Cooler water from upstream, in the 72°F to 73°F range, dominated the left (southwest) side of the Santa Clara River channel, while warmer water from the Valencia WRP, in the 78°F to 79°F range, dominated the right (northeast) side of the channel. Because of the braided nature of the channel, the two water sources remained relatively separate for several hundred feet until they progressively mixed and a more even cross-sectional distribution was observed. As mentioned below in Section 3.7, *Monitoring and Mapping Discussion*, the NPDES water quality sampling at the RD monitoring station (about 100 feet downstream of the Valencia WRP discharge point) occurs within this poorly mixed zone and thus is prone to collecting unrepresentative data, depending on the location along the channel cross section where the spot measurement is made. This is compounded by the fact that the channel braids are dynamic, so a sampling location defined by a Global Positioning System (GPS) coordinate could be on the left bank (cooler than fully mixed water) one month and on the right bank (warmer than fully mixed water) the next.[8]

[8] Note that LACSD samples water temperature in the middle of the channel cross section and the middle of the water column to obtain average conditions.

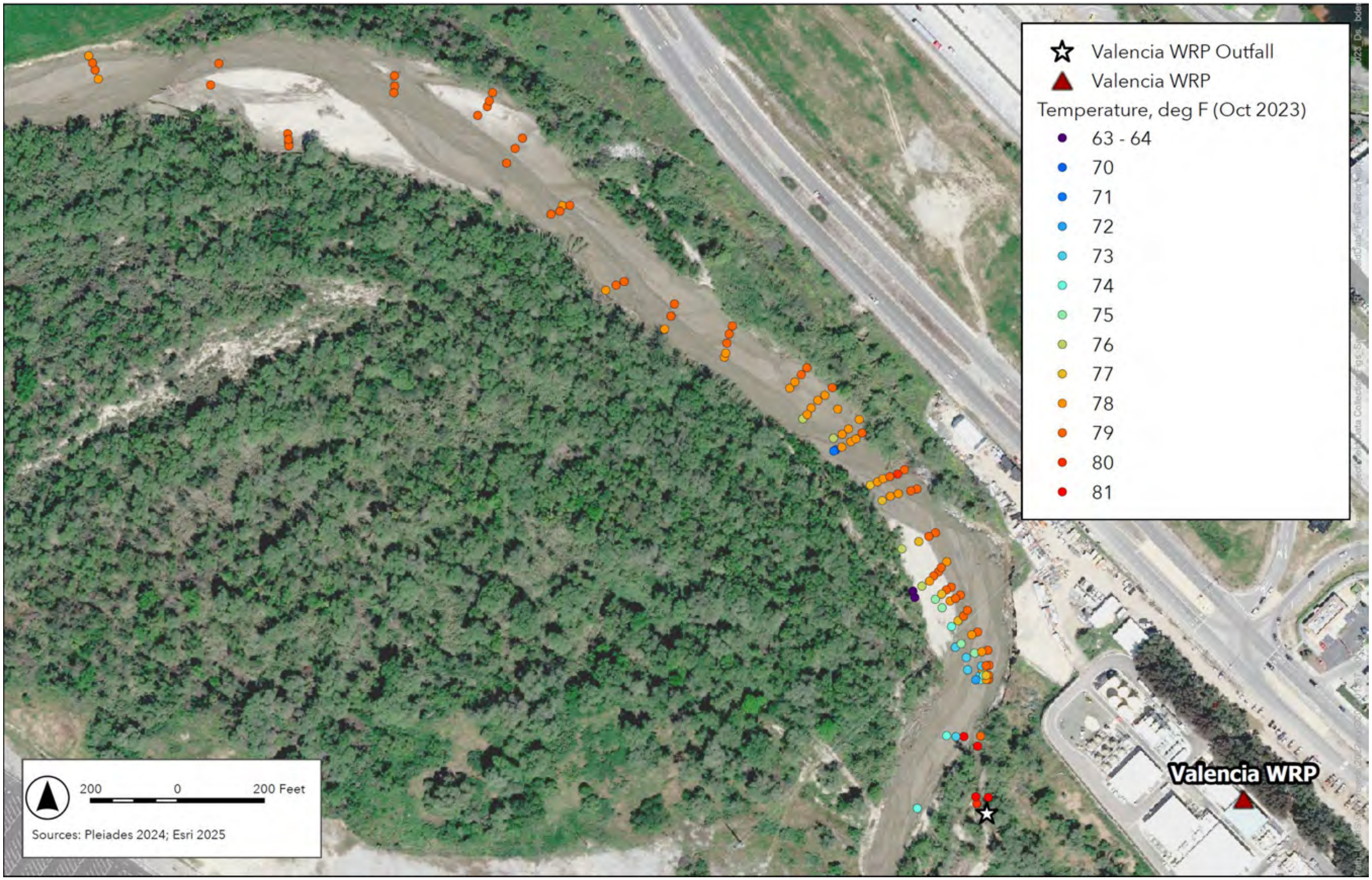


Figure 3-9
Close-Up of Temperature Variability in the Downstream Reach of the Valencia Water Reclamation Plant in October 2023

The second spatial pattern observed was that some areas of lower temperature may represent groundwater upwelling, but that these areas were very localized and covered only a few dozen square feet. For example, in some side channels close to the left bank, temperatures of 63°F to 64°F were found, with DO values of 0.5 to 1.2 mg/l. The combination of low temperature and low DO levels is suggestive of groundwater upwelling. From a habitat perspective, these side channels are very small areas and the low DO level likely makes them unsuitable for fish thermal refugia.

Because of an equipment error, no DO measurements were taken upstream of the Valencia WRP. Measurements were taken downstream of the WRP and were mostly in the 6.6 to 6.9 mg/l range. As mentioned above, there were some outlier points in the downstream reach where both temperature and DO levels were very low, but these represent small areas where groundwater upwelling is assumed to occur.

Substrate and canopy were measured during the reconnaissance mapping. Upstream substrate was primarily sand (93 percent of points recorded), with some gravel (7 percent). Downstream, the substrate was coarser, especially close to the Valencia WRP discharge point, with 51 percent sand and 48 percent gravel. The coarser substrate seemed to mirror the higher velocities downstream resulting from the added discharge from the Valencia WRP. Canopy cover also differed markedly between upstream and downstream reaches. In the upstream reach most observations (43 percent of points) fell within the 25–50 percent canopy cover range and 32 percent of points had less than 25 percent cover. In contrast, the downstream reach was more exposed, with 68 percent of points recording less than 25 percent canopy cover and a further 26 percent of points in the 25–50 percent range.

3.6.2 April 2024 Mapping

Additional mapping was conducted on April 19, 2024. In response to comments from the Technical Advisory Committee, the sampling was expanded to include velocity, depth, substrate, and canopy cover, since these affect aquatic habitat suitability along with temperature and DO. As described in Section 3.5, *Temperature and Physical Habitat Mapping Methods*, the spatial areas were reduced to focus on the 1,000 feet upstream and downstream of the Valencia WRP.

During the April 2024 mapping, the flow rate upstream of the Valencia WRP was 28 cfs,[9] the discharge from the WRP was 13 to 16 cfs, and the downstream flow rate was 41 to 44 cfs. Data were collected between about 10 a.m. and 2 p.m., during which time ambient water temperatures in a logger located just upstream of the Valencia WRP rose from 61°F to 73°F and temperatures in a logger just downstream of the WRP rose from 70.7°F to 75.4°F. Because measurements were made moving from upstream to downstream, some of the differences in temperature and DO levels are likely due to temporal changes during the sampling. Box and whisker plots showing the velocity and depth data are grouped into upstream and downstream areas (**Figure 3-10**). In these and the following box and whisker plots, the 25th, 50th, and 75th percentiles of a parameter are shown in the shaded boxes; the whiskers denote the maximum and minimum data values excluding outliers (defined as 1.5 times the interquartile range); and any individual points outside the whiskers are defined as outliers and shown individually.

9 Note that flows upstream of Valencia WRP in 2024 were unusually high compared to the last 20 years of LACSD monitoring; flows upstream of Valencia WRP are typically in the range of 1 to 4 cfs.

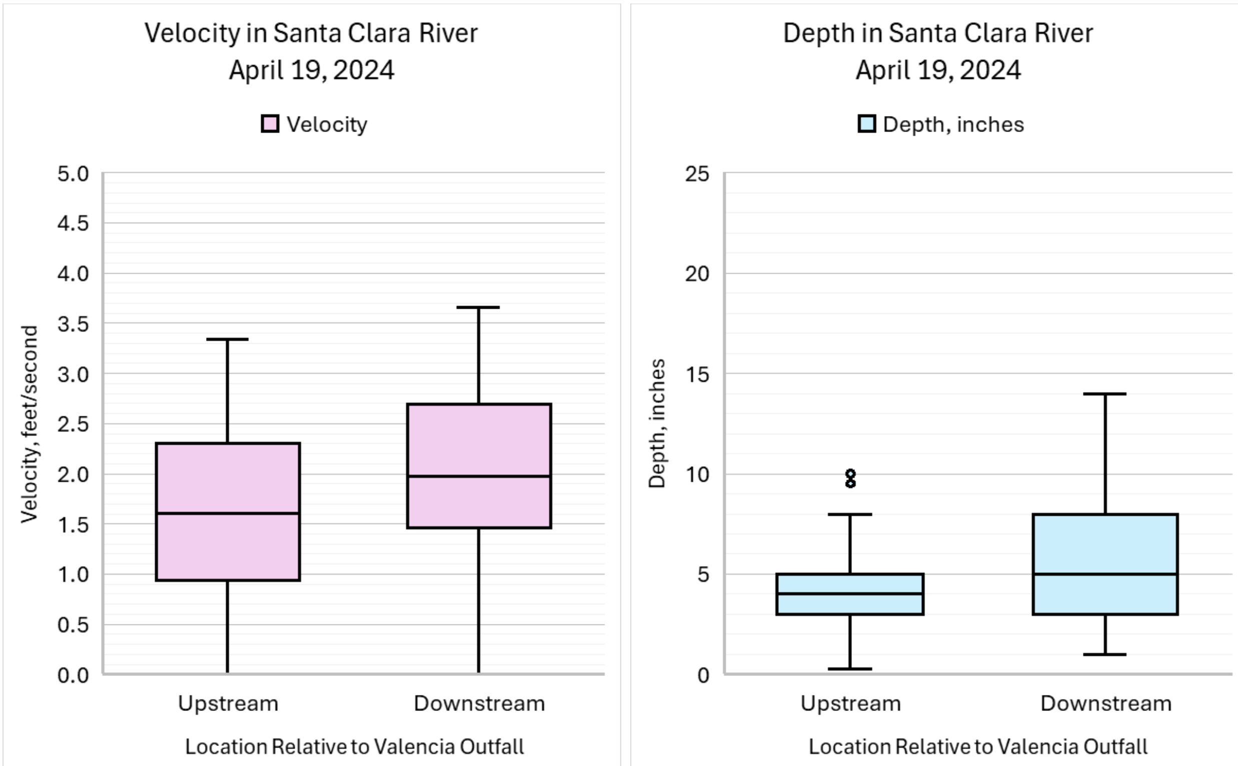


Figure 3-10
Velocities and Depths during the April 19, 2024, Mapping

In April 2024, upstream temperatures ranged from about 62°F to 64.5°F (25th and 75th percentiles), with a median value of 63°F. Downstream temperatures ranged from 70.5°F to 74°F with a median of 73°F. Comparing the cross sections immediately upstream and downstream of the Valencia WRP (which were measured within 1 hour of each other and thus were less affected by ambient temperature changes), the upstream cross section was about 69°F across its entire length while the downstream cross section ranged from 69°F on the left side to 73°F on the right side. As was the case during the October 2023 reconnaissance, the downstream reach exhibited marked lateral stratification, but the stratification extended over only about 350 feet before mixing occurred. Temperatures upstream of the Valencia WRP were more homogeneous, with typically less than 0.5°F difference across a cross section.

DO levels were higher than in October 2023, mostly between 7.95 and 8.05 mg/l in the upstream reach and 7.0 to 7.4 mg/l in the downstream reach. Unlike the reconnaissance, when the field team specifically searched for and mapped cold water upwelling areas, the April sampling did not reveal extreme values within the cross sections.

Velocity, depth, substrate, and canopy cover were also measured during the April 2024 mapping. Velocity and depth are shown in Figure 3-10. Using the 25th and 75th percentiles to describe the data, velocities in the upstream reach were lower—mostly between 0.9 and 2.3 feet per second (ft/sec)—because of lower discharge rates, and had a median value of 1.6 ft/sec. Velocities downstream were higher, from 1.5 to 2.7 ft/sec with a median of 2.0 ft/sec. Depths were 3 to 5 inches upstream (median 4 inches) and 3 to 8 inches downstream (median 5 inches) because of higher flows downstream. Substrate types in both reaches were very similar and dominated by sand (93 percent of observations upstream and 96 percent of observations downstream of the Valencia WRP) with the remainder being gravel.

Canopy cover was much lower in April 2024 than in October 2023, in part because of high-flow events that eroded both reaches between these dates, especially the downstream reach. Upstream of the Valencia WRP, 85 percent of the cross-sectional points had less than 25 percent canopy cover, while downstream the number was 98 percent of the cross-sectional points. This marked the lowest canopy cover of the Study in the downstream reach.

3.6.3 August 2024 Mapping

The upstream and downstream reaches were remapped on August 30, 2024. As in April 2024, mapping occurred between roughly 10 a.m. and 2 p.m., during which time water temperatures rose by about 10°F in the upstream reach and by 5°F in the downstream reach. Flows were 2.9 cfs upstream and 16 to 19 cfs downstream of the Valencia WRP.

Temperatures upstream of the Valencia WRP were very homogeneous, between 72.0°F and 72.5°F with no outliers. Downstream of the WRP, most temperatures ranged from 80.0°F to 80.5°F, but there was greater variability, reflecting the poor lateral mixing between effluent and flow from upstream. Specifically, temperatures varied by up to 10°F from the left bank (70°F) to the right bank (80°F) in the 400 feet downstream of the Valencia WRP before the flow became mixed.

DO levels were mostly between 8.5 and 9.2 mg/l upstream of the Valencia WRP and 8.0 to 8.2 mg/l downstream, but were well above the U.S. Environmental Protection Agency (EPA 2001) threshold for WARM beneficial uses. There were a few outliers downstream, possibly reflecting groundwater upwelling in side channels.

Velocity, depth, substrate, and canopy cover were measured during the August 2024 mapping. Velocity and depth are shown in **Figure 3-11**. Using the 25th and 75th percentiles to describe the data, velocities in the upstream reach were lower—mostly between 0.6 and 1.8 ft/sec—because of lower discharge rates, and had a median value of 1.3 ft/sec. Velocities downstream were higher, from 1.0 to 2.8 ft/sec with a median of 2.5 ft/sec. Depths were 3 to 7 inches upstream (median 5 inches) and 5 to 11 inches downstream (median 9 inches) because of higher flows downstream. Substrate types in both reaches were very similar and dominated by gravel (87 percent of observations upstream and 83 percent of observations downstream of the Valencia WRP) with the remainder being sand. The coarser nature of the substrate suggests that the finer sediment had been scoured off during high-flow events between the April and August sampling events.

The canopy cover was much denser in August than in April in the upstream reach but was still very exposed downstream. Upstream cover was relatively evenly split between less than 25 percent cover (37 percent of points), 25 to 50 percent cover (24 percent of points), and 75 to 100 percent (33 percent of points), while the downstream reach was dominated by less than 25 percent cover (86 percent of points). This reflects the downstream reach's slower recovery from the erosive flows of the prior winter, with the reach maintaining a dynamic braided form with poor vegetation establishment.

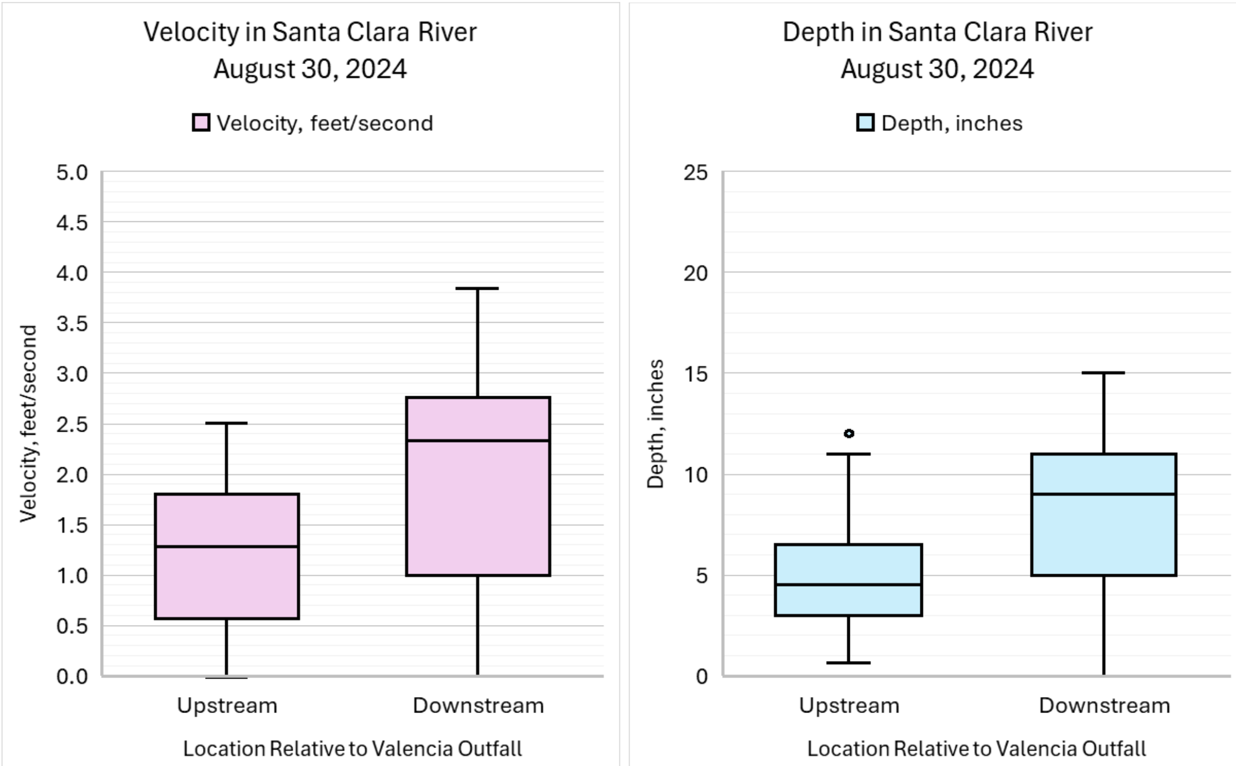


Figure 3-11
Velocities and Depths during the August 30, 2024, Mapping

3.6.4 November 2024 Mapping

Starting in November 2024, the mapping was reorganized to capture the upstream and downstream reaches simultaneously, making the comparison of temperature and DO measurements more meaningful. Temperatures and DO levels were recorded at both reaches between 11 a.m. and 1:15 p.m., with upstream flows of 6.5 cfs and downstream flows of 31.9 cfs. In the upstream reach, 25th- and 75th-percentile temperatures ranged from 57°F to 58°F (median of 57.5°F), while in the downstream reach, temperatures ranged from 71°F to 71.5°F (median of 71.5°F) (**Figure 3-12**). Temperatures across the mixing zone near the Valencia WRP ranged from 64.0°F to 74.5°F, but the river channel appeared to be fully mixed by 300 feet downstream of the WRP. DO levels were similar above and below the Valencia WRP: upstream, 8.6 to 8.9 mg/l with a median of 8.8 mg/l; and downstream, 8.6 to 8.8 mg/l with a median of 8.7 mg/l.

Substrate in November was markedly different between upstream and downstream, with mostly sand (66 percent) followed by cobble (28 percent) and gravel (6 percent), whereas downstream of the Valencia WRP, the mixture was 67 percent gravel with smaller amounts of sand (18 percent) and cobble (16 percent).

Velocity and depth (**Figure 3-13**) were lower in the upstream reach and higher in the downstream reach due to discharge from the Valencia WRP. The 25th and 75th percentiles for velocities ranged from 0.3 to 2.0 ft/sec upstream (median 1.3 ft/sec), while downstream velocity percentiles were 1.7 to 2.7 ft/sec (median of 2.1 ft/sec). Depths ranged from 5 to 8 inches (median of 6 inches) upstream and 7 to 12 inches (median of 11 inches) downstream.

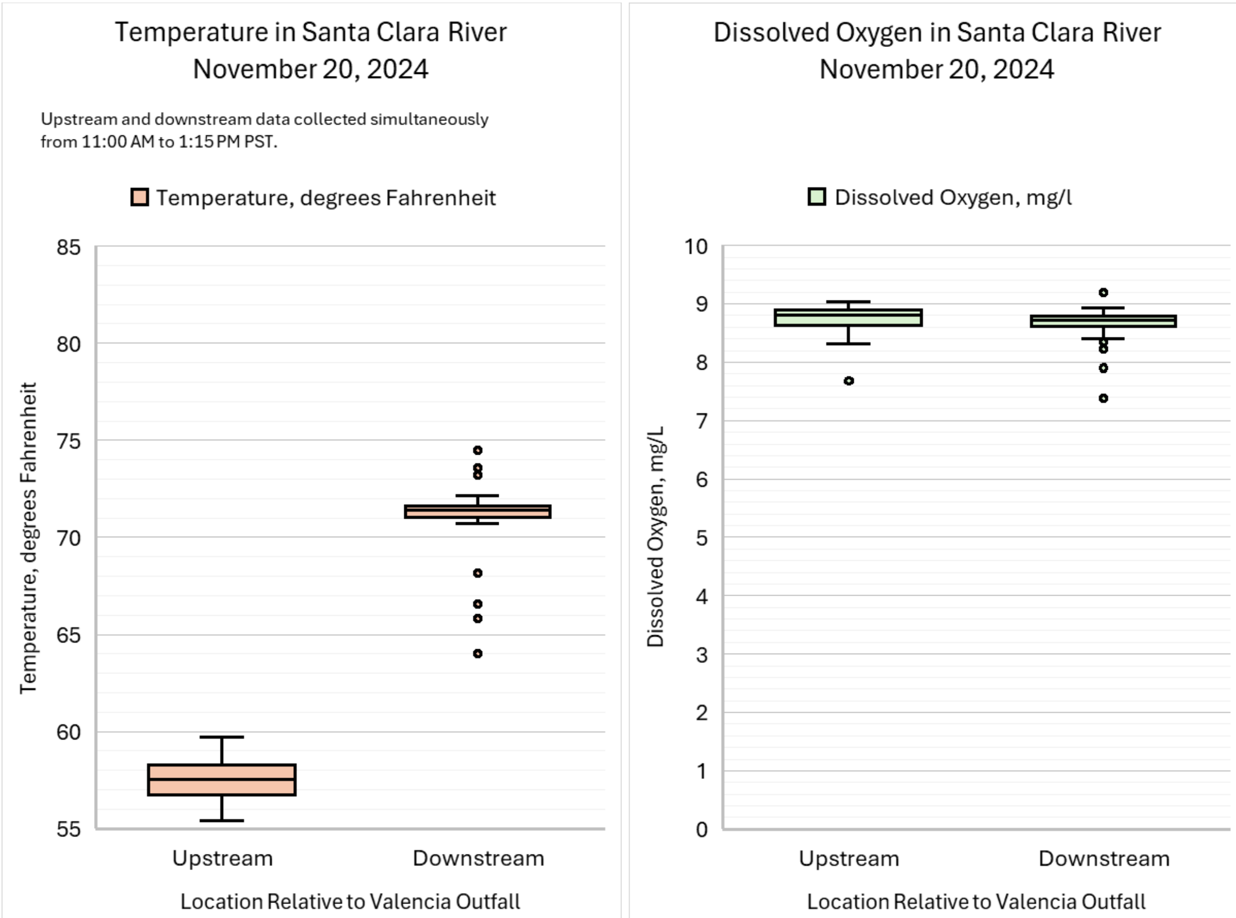


Figure 3-12

Temperatures and Dissolved Oxygen Upstream and Downstream of the Valencia Water Reclamation Plant during the November 20, 2024, Mapping

Substrate type in November 2024 was dominated by gravel upstream (67 percent of points) and by sand downstream (66 percent of points).

Canopy cover again exhibited a contrast between the upstream and downstream reaches, with the upstream reach at mainly less than 25 percent cover (62 percent of points) and 25 to 50 percent cover (33 percent of points) while the downstream reach was more in the range of less than 25 percent cover (84 percent of points).

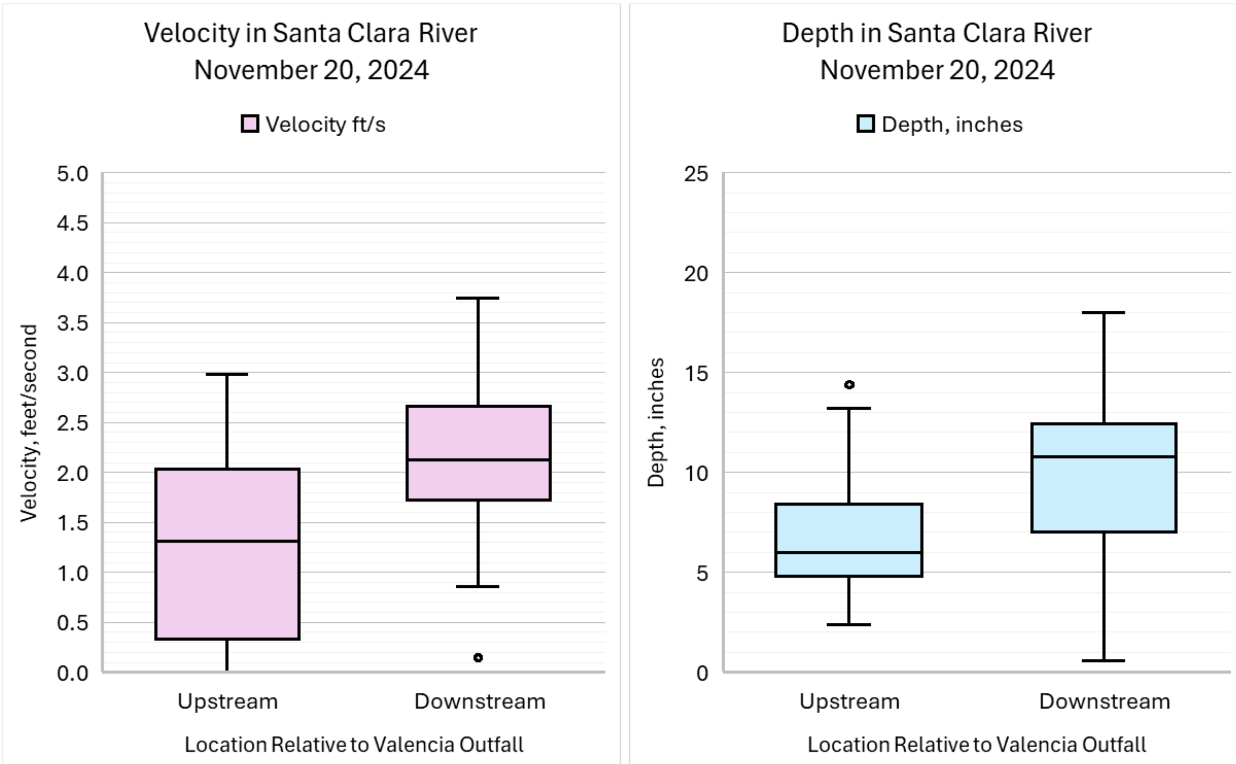


Figure 3-13
Velocities and Depths Upstream and Downstream of the Valencia Water Reclamation Plant during the November 20, 2024, Mapping

3.6.5 February 2025 Mapping

On February 12, 2025, temperature and DO levels were recorded simultaneously at both reaches between 10:30 a.m. and 1:15 p.m., with upstream flows of 18.2 ft/sec and downstream flows of 33.9 ft/sec. In the upstream reach, the 25th-, 50th-, and 75th-percentile temperatures were narrowly clustered around 59°F, while in the downstream reach, temperatures were clustered around 68.5°F (**Figure 3-14**). Temperatures mixed quickly downstream of the Valencia WRP, with about 1°F of difference across the first cross section (100 feet downstream of the discharge point) and less in subsequent cross sections. DO levels were also tightly clustered, but with a slight reduction downstream of the Valencia WRP: upstream, between 8.7 and 8.8 mg/l with a median of 8.8 mg/l; and downstream, 8.2 to 8.4 mg/l with a median of 8.3 mg/l.

Velocity and depth (**Figure 3-15**) were lower in the upstream reach and higher in the downstream reach because of discharge from the Valencia WRP. The 25th and 75th percentiles for velocities ranged from 1.2 to 2.4 ft/sec upstream with a median of 1.9 ft/sec, while downstream velocity percentiles were 1.6 to 2.9 ft/sec with a median of 2.5 ft/sec. Depths ranged from 4 to 7 inches (median of 6 inches) upstream and 9 to 15 inches (median of 12 inches) downstream.

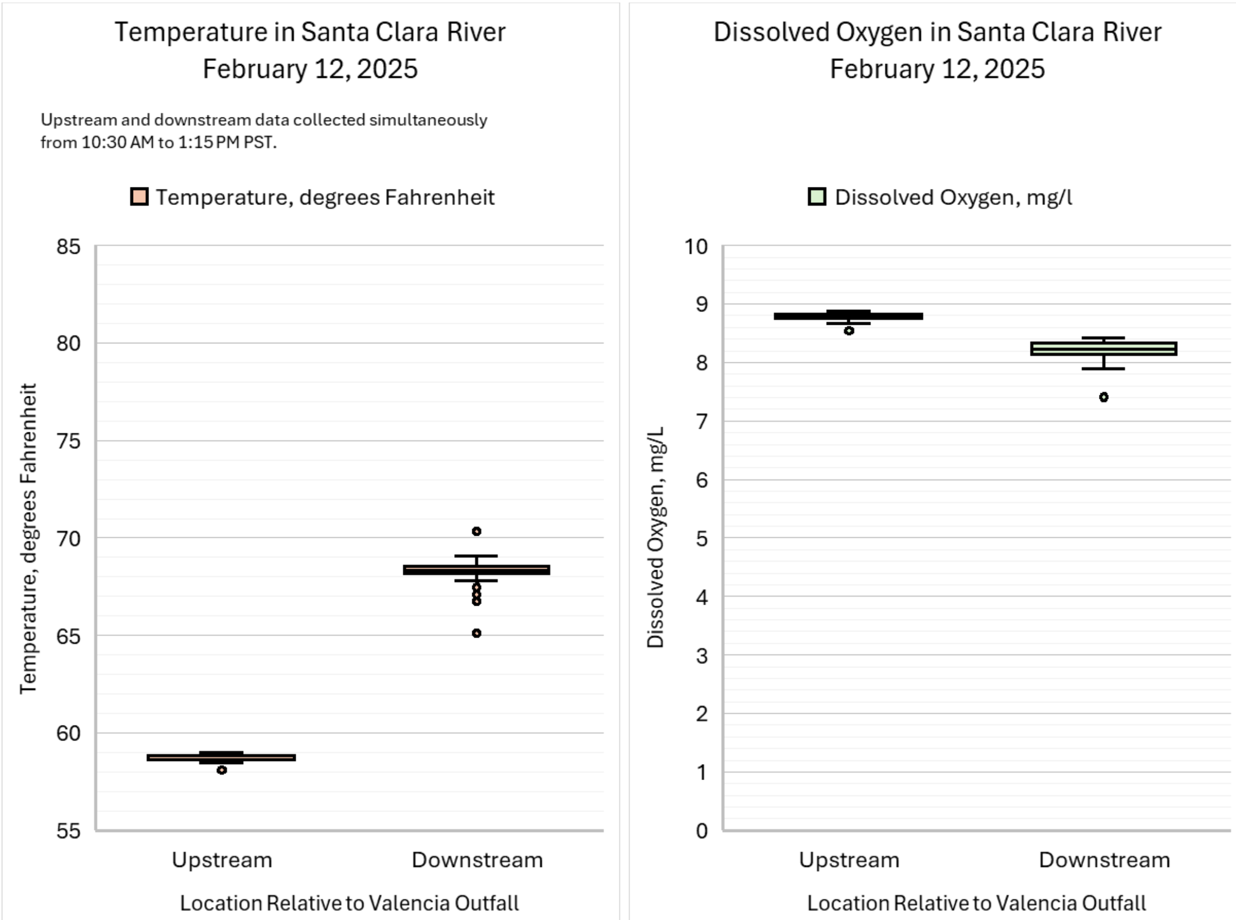


Figure 3-14
Temperatures and Dissolved Oxygen Levels Upstream and Downstream of the Valencia Water Reclamation Plant during the February 12, 2025, Mapping

February 2025 substrate measurements were more typical of conditions on the Santa Clara River during the Study, with 73 percent sand and 21 percent gravel upstream of the Valencia WRP and 92 percent sand to 8 percent gravel downstream.

Upstream reach canopy cover in February 2025 was similar upstream and downstream. The less than 25 percent cover class made up 84 percent of points upstream of the Valencia WRP and 75 percent downstream, with the remainder of points having more cover.

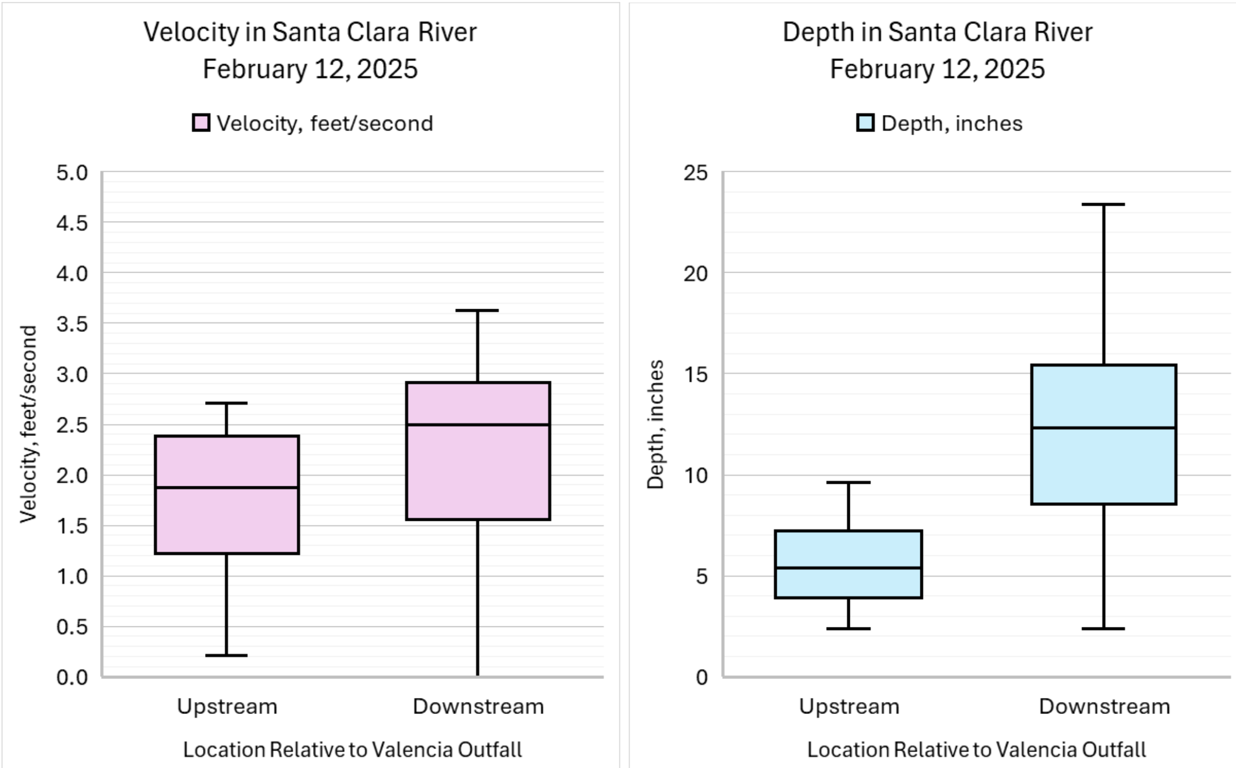


Figure 3-15
Velocities and Depths Upstream and Downstream of the Valencia Water Reclamation Plant during the February 12, 2025, Mapping

3.7 Monitoring and Mapping Discussion

The results of the temperature monitoring and mapping showed several key patterns:

- Over the course of the year, 24-hour-average temperatures varied by 15°F to 20°F between August and February for most locations monitored.
- Over the course of the day, continuously monitored temperatures at sites immediately downstream of the Valencia WRP varied by about 5°F over a 24-hour period. Sites farther from the WRPs varied by about 10°F to 12°F over the course of the day, with highs around 2 p.m. and lows around 7 a.m. The smaller temperature fluctuations near the WRP reflected the more constant temperatures of the effluent, with smaller nighttime drops than at the more distant sites.
- The average daily temperature for a given day typically occurred around 10 a.m. for the reach immediately downstream of the Valencia WRP. This is the time of day when grab samples are most likely to be representative of average temperature.
- Spatially, temperatures immediately downstream of the Valencia WRP were about 8°F to 10°F warmer than immediately upstream in the summer and about 12°F to 14°F warmer in the winter.
- About half the water temperature increase from the Valencia WRP was lost by the Castaic Creek confluence (2.5 miles downstream of the WRP), and most of the remaining warmth was lost by Newhall Orchards (10 miles downstream).

- Although the most common situation is for water to cool downstream of the Valencia WRP, on very hot summer days some warming can occur downstream of the WRP, presumably as a result of solar and thermal heat loading.
- There were 3 days when river temperatures were greater than 80°F upstream of the Valencia WRP during the 2-year Study, in July of 2024 based on the 15-minute resolution continuous water temperature monitoring.
- Temperatures just downstream of the Valencia WRP was greater than 80°F more than 100 times during the summer and fall of 2024 and more than 75 times during the summer and fall of 2025 based on the continuous monitoring. Temperatures over 80°F began in June and occurred almost daily between July and the middle of September in both 2024 and 2025. Peak temperatures were around 82°F to 83°F during the warmest periods of July and August of both summers, while nighttime temperatures dropped to about 75°F.

Intensive temperature mapping supported the conclusions of the monitoring described above and revealed the following additional information:

- There were no large areas of colder than average water (thermal refugia) within the first mile of river downstream of the Valencia WRP. Some small patches of colder water were found along the west (left) bank and in isolated side channels, but these locations often had very low DO levels and thus were less suitable for aquatic organisms. These patches of colder water are likely associated with local groundwater upwelling.
- Warm effluent from the Valencia WRP can take a long distance to mix with cooler upstream water because of the wide, shallow, and braided nature of the receiving channel downstream of the discharge point. There was a zone of poor lateral mixing (up to 10°F of temperature difference between river left and river right) that ranged from 300 to 700 feet long, depending on the time of year and upstream flow rates. This has implications for measurement at the RD NPDES measuring location, which is within the mixing zone. For continuous measurements, it would be desirable to locate the temperature sensor in the middle of the channel if practical; however, challenges exist in maintaining continuous sensors in the Santa Clara River, given its geomorphic dynamism.

DO levels have previously been measured in the Study Area via grab samples, which are susceptible to missing periods of low DO levels during the night. This Study collected additional daytime grab samples during the intensive mapping efforts and installed continuous monitors for several 24-hour periods to capture nighttime conditions, with the following results:

- Point measurements of DO were all in the range considered suitable for most aquatic life in a river with a WARM beneficial use classification (i.e., over 5 mg/l[10]) (EPA 2021; Basin Plan), except for isolated pockets of groundwater upwelling. Daytime DO levels were typically in the range of 8–9 mg/l upstream of the Valencia WRP and 7–8 mg/l downstream.

[10] The U.S. Environmental Protection Agency's criteria for the protection of aquatic life is 5.0 mg/l for early life stages and 3.0 mg/l for other life stages (1 day minimum measured as instantaneous concentration) (EPA 2021). Unarmored threespine stickleback (UTS) have a moderate tolerance to oxygen reduction. Based on work by Feldmeth and Baskin (1976) that found UTS required additional energy and exhibited reduced activity, reproduction and somatic growth at DO levels below 2.0 mg/l, Mulder (2017) suggested 2.0 mg/l as the lower limit of habitat suitability for DO.

- Continuous 24-hour monitoring of DO levels found that the lowest values occurred at night or early in the morning, but still remained above 5 mg/l. The lowest nighttime values recorded were around 6 mg/l downstream of the Valencia WRP, about 1 mg/l below the high values for the same day.
- Most of the DO values found below 6 mg/l were during the reconnaissance when the field team specifically searched for areas of cold water and found potential groundwater upwelling areas that also had low DO levels, typically along the banks of the river.

Velocity and depth were similar upstream and downstream of the Valencia WRP, but with higher velocities and deeper conditions downstream because of the greater discharge. Velocities were around 0.5 to 1.0 ft/sec faster and depths 3–5 inches deeper in the downstream reach.

Hydraulic conditions also affect fish distribution and therefore mediate exposure to elevated water temperatures. Measured velocities and depths were compared to habitat suitability criteria previously applied on the Santa Clara River for unarmored threespine stickleback (UTS) and Santa Ana sucker (e.g., Mulder 2017; ESA 2024): Velocities upstream of the Valencia WRP more frequently fall within the most suitable range for UTS (approximately 0.1 to 1 ft/sec; Mulder 2017), whereas velocities downstream are more likely to fall within or above this range. Depths both upstream and downstream of the Valencia WRP mostly lie within the suitable range for UTS (approximately 0.25 to 1.25 feet; Mulder 2017). In contrast, habitat suitability for Santa Ana sucker is greatest at velocities of 1–5 ft/sec and depths exceeding 1 foot (Mulder 2017). Upstream of the Valencia WRP, velocities and depths are generally below optimal conditions, while conditions downstream more often lie with the most suitable range. This suggests that flow velocity is a potentially limiting factor on UTS habitat suitability in this reach, independent of water temperature. As a result, reducing or eliminating flows below the Valencia WRP would likely improve conditions for UTS but degrade habitat suitability for Santa Ana sucker, regardless of any associated temperature effects. Moreover, because UTS are unlikely to occupy downstream areas where velocities are excessive, they would also be unlikely to experience elevated temperatures in those reaches.

Substrate was highly variable both spatially and temporally. Generally, the channel was dominated by either sand or fine gravel, with occasional exposure of cobbles. The channel bed and banks in the Study Area are highly mobile and vary widely between sampling events: Bedload transport of sand was commonly observed in the downstream reach at flows around 20 cfs, and one site experienced 200 feet of lateral bank migration in a 6-week period with no large flow events.

Canopy cover also varied widely between locations and times. Both reaches experienced a large erosive event in winter 2024 that dramatically changed the river and exposed the channel. The downstream reach took longer to recover and was still mostly in the 0–25 percent cover class after 18 months.

Overall, the results confirm previous measurements of elevated temperatures downstream of the Valencia WRP and their gradual dissipation with greater distance, but they also highlight the variability of the Santa Clara River with respect to temperature and other physical habitat attributes. Conditions in the river can vary greatly over a few feet and a few hours, as well as seasonally. Comparing attributed physical habitat with fish habitat suitability criteria, habitat suitability likely varies greatly over space and time, as substrate, velocity, depth, canopy cover, and temperature vary.

CHAPTER 4
Temperature Modeling

4.1 Background and Purpose

The purpose of this Study element was to model existing conditions and potential management scenarios to identify the following information:

- Temperature variations along the Santa Clara River in response to different flow levels and weather conditions.
- The frequency with which river temperatures would be greater than 80 degrees Fahrenheit (°F) under different flow and weather conditions.
- The effectiveness of different possible management scenarios (e.g., cooling or reducing the volume of WRP effluent) in meeting the potential 80°F and Δ5°F[11] temperature thresholds in different year types.

4.2 Prior Studies

The following temperature modeling studies were previously conducted on the Santa Clara River:

- The U.S. Geological Survey used measured and modeled temperatures in and below the Santa Clara River as a tracer to understand surface water–groundwater exchanges (Constantz et al. 2002). This study provided data on temperatures and exchange rates across groundwater and the river, but it was confined to a small location and time.
- As part of a project for LACSD in 2017, Environmental Science Associates (ESA) performed initial temperature modeling to assess the effects of a potential reduction in discharge from the Valencia WRP. The one-dimensional temperature model was developed in-house (i.e., was not a commercially or publicly available model).
- In 2019, ESA performed additional simulations using the same in-house model to assess treated wastewater discharges from a potential Newhall WRP.

4.3 Model Description and Setup

At the request of the Technical Advisory Committee, all studies described in this Study report were carried out using a publicly available temperature model, CE-QUAL-W2. As described on the Portland State University Water Quality Research Group's CE-QUAL-W2 support page, "CE-QUAL-W2 is a water quality and hydrodynamic model in 2D (longitudinal-vertical) for rivers, estuaries, lakes, reservoirs

[11] The "Δ5°F limit," as used in this Study report, refers to the specification in the *Water Quality Control Plan for the Los Angeles Region* that the receiving water temperature shall not be altered by more than 5°F above the natural temperature.

and river basin systems. W2 models basic eutrophication processes such as temperature-nutrient-algae-dissolved oxygen-organic matter and sediment relationships" (Portland State University 2025). The model, created by the U.S. Army Corps of Engineers in 1986, is now hosted and updated by the Department of Civil and Environmental Engineering at Portland State University with support from the U.S. Army Corps of Engineers and others.

Figure 4-1 presents a conceptual graphic of the processes represented in the model of the Santa Clara River and key locations assessed. The location of the model is shown in **Figure 4-2**.

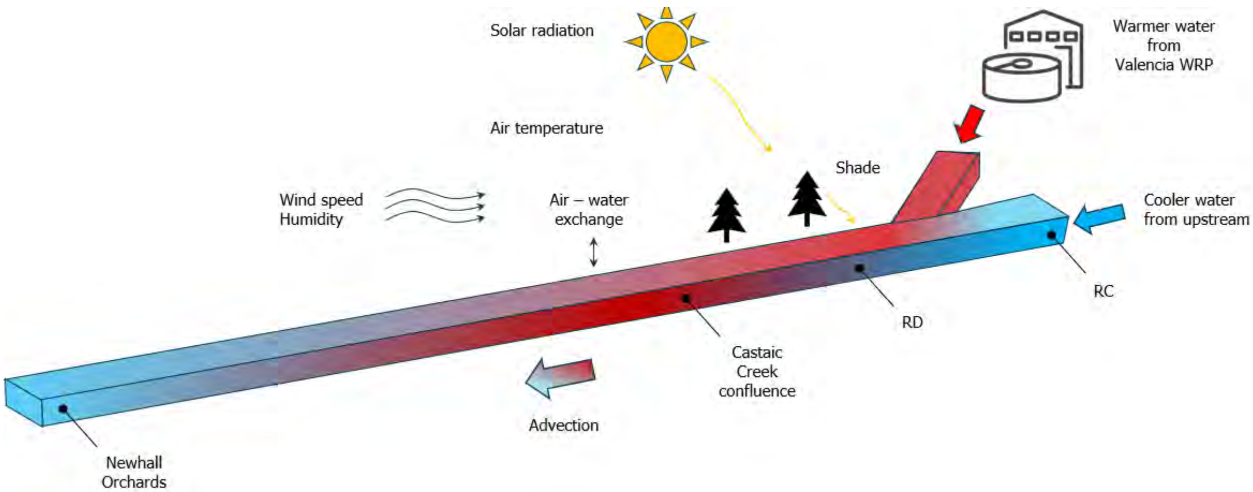
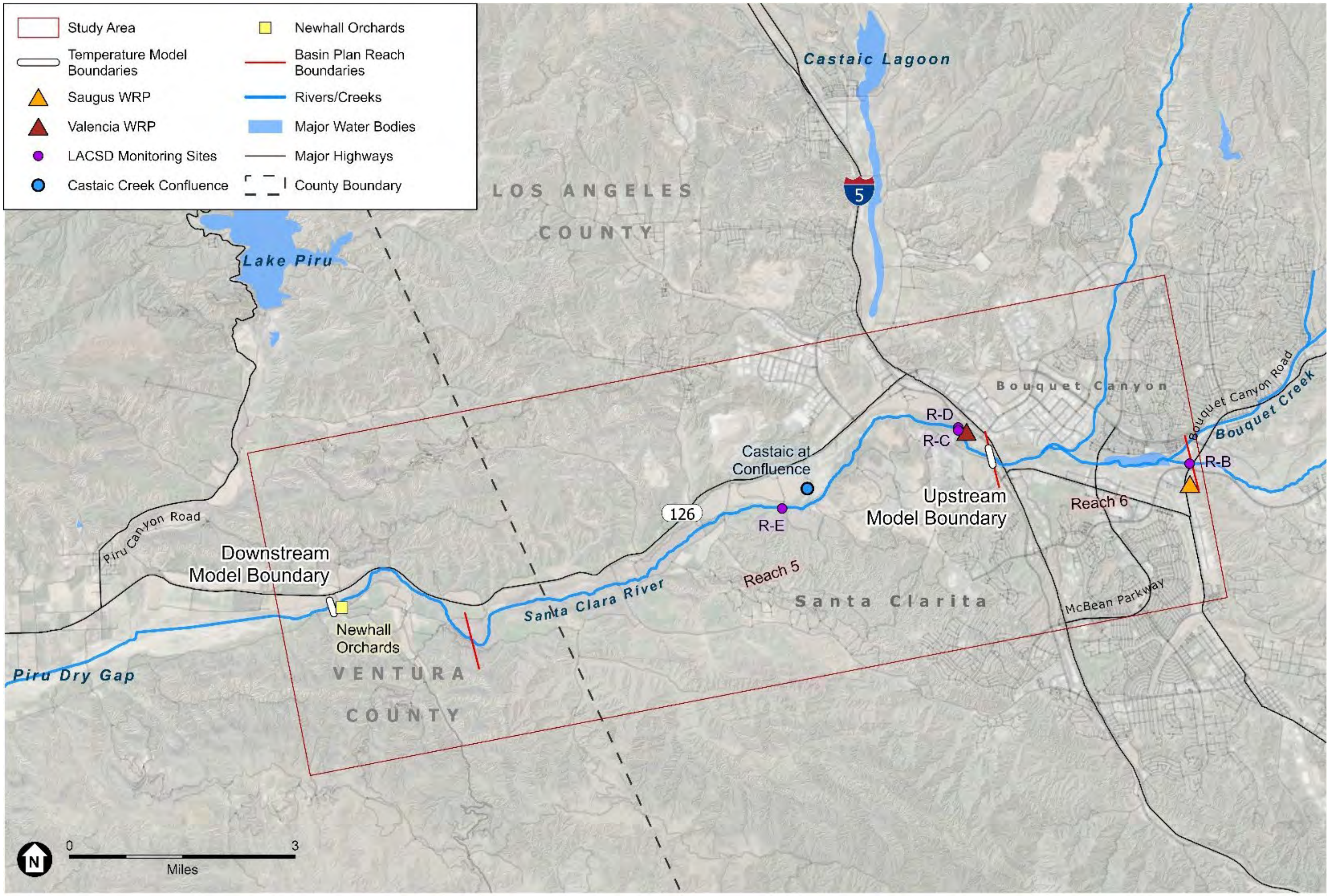


Figure 4-1
Processes Represented in the CE-QUAL-W2 Water Temperature Model of the Santa Clara River

The model's upstream boundary was the Valencia RSW-001U (RC) monitoring location a few hundred feet upstream of the Valencia WRP, while the downstream boundary was Newhall Orchards, located 3.4 miles west of the Ventura County line. The CE-QUAL-W2 model has modules that can be used to simulate a variety of water quality parameters; however, the current Study employed only the hydraulic module to estimate advection and flow width and depth, and the temperature module to simulate heat dispersion and heat and energy transfers between the river and the atmosphere (e.g., radiation absorption and emissions, evaporative cooling, and conduction). **Table 4-1** shows the model's input parameters.

The daily river-flow time series at the RC measurement point was assembled from monthly flow measurements made by LACSD using interpolation between measurements. This time series captures prevailing baseflow conditions (flows between rainfall-runoff events) but omits high-flow events (e.g., individual high-rainfall-runoff events), which are typically not measured by LACSD because of safety considerations.

Channel cross sections for the hydraulic module were cut from a bathymetric surface of the Santa Clara River developed by ESA for the Santa Clarita Valley Water Agency, through the use of a green (water-penetrating) light detection and ranging (LiDAR) laser that was flown on July 14, 2022.



SOURCE: Esri, 2023; ESA, 2023

Figure 4-2

Extent of the Santa Clara River Temperature Model

TABLE 4-1
DATA SOURCES FOR THE SANTA CLARA RIVER TEMPERATURE MODEL

Parameter	Location	Frequency	Source
River flow	Upstream of the Valencia WRP	Daily	Time series interpolated/extrapolated from bimonthly LACSD measurements
WRP outflow rate	Valencia WRP	Hourly	LACSD data
Water temperature	Upstream of the Valencia WRP (RC), Valencia WRP	15 minutes	LACSD data and data from the current Study
Meteorology (air temperature, solar radiation, wind speed, dew point)	Santa Clarita	Hourly	CIMIS Station #204 (Santa Clarita)
Channel depths and widths	Santa Clara River	NA	Cross sections cut from a bathymetric surface developed by ESA for the Santa Clarita Valley Water Agency

NOTES: CIMIS = California Irrigation Management Information System; ESA = Environmental Science Associates; LACSD = Los Angeles County Sanitation Districts; NA = not applicable; Study = Santa Clara River Waterbody Temperature Study; WRP = Water Reclamation Plant

SOURCE: Data compiled by Environmental Science Associates in 2025

The model generates output every tenth of a day (2.4 hours). In the analysis below, data are presented for both daily averages (mean of each 24-hour period) and instantaneous results from the 10 daily timesteps of approximately 2 hours.

4.4 Model Assumptions and Limitations

Several assumptions were made regarding the use of the CE-QUAL-W2 model as applied to the Santa Clara River for this Study. Those assumptions and associated limitations are described below.

- **The model's extent was limited to the mainstem river.** The model represented the mainstem of the Santa Clara River but did not include Castaic Creek and other tributaries that add water and may dilute the effect of discharges from the Valencia WRP. During the summer and in drought periods, the tributaries are often dry, so this simplification of the system had a minimal effect on predicted temperatures; however, the tributaries can contribute flow during the winter and spring. Castaic Creek is periodically used for water transfers from Castaic Lake to the Metropolitan Water District of Southern California and other downstream users, although these transfers normally cease by the end of May. As described below in Section 4.5, *Model Calibration and Sensitivity Analysis*, when water is released from Castaic Lake at rates and temperatures measured from spring of 2024, the released water lowers the temperature in the Santa Clara River by about 2°F to 3°F immediately below the Castaic Creek confluence.
- **Peak flows were not simulated.** The discharge module was parameterized using LACSD's monthly flow measurements for the periods simulated (described below), which omit peak-flow events. During a peak flow (i.e., after a rainfall-runoff event in the watershed), runoff greatly dilutes the effects of the Valencia and Saugus WRP discharges. However, peak flows are rare during the summer and early fall when water temperatures are highest, so the model was relatively unaffected by this limitation during these critical periods.

- **Surface water–groundwater exchanges were not included.** The CE-QUAL-W2 model omits surface water–groundwater exchanges. LACSD flow measurements made over the last 20 years show that the reach between the Valencia RSW-002D (RD) measurement location (immediately downstream of the Valencia WRP) and the Valencia RSW-003D (RE) measurement location (approximately 4 miles downstream) is a gaining reach in most months of most years, with cooler groundwater upwelling into the river and likely providing some dilution and attenuation of Valencia WRP discharges. During some summer months and longer periods during droughts, the river shifts from gaining to losing conditions, with river water percolating to groundwater.

Considered together, these assumptions mean that the temperature model is likely to have progressively overestimated the effect of the Valencia WRP on river temperature with increasing distance downstream, especially during the winter and spring when tributary flows and groundwater upwelling are greatest. The modeling results are likely more accurate for the summer and for drought conditions when inflows are minimal.

The following additional assumptions and limitations apply to the application of the CE-QUAL-W2 model to the Santa Clara River:

- **Channel morphology and shade were assumed to be constant.** The channel was represented by the LiDAR surface flown in July 2022, while a single value for canopy cover was used for all simulations. Both channel morphology and canopy cover have changed from 2022 through the subsequent course of the Study, as the river has evolved and vegetation has recolonized previously eroded bars. Given the dynamic nature of the Santa Clara River, such changes will likely continue over time as the channel experiences large “resetting” events. These resetting events are expected to erode vegetated channel bars and result in bare braided channels that are laterally dynamic, followed by vegetation colonization that progressively blocks smaller secondary channels and pinches flow down to a smaller number of narrower but deeper threads.
- **The model could not accurately simulate flows below 3 cubic feet per second (cfs).** The model was run across a range of baseflows between about 0.4 cfs and 20 cfs, representing different combinations of upstream flows and Valencia WRP discharges. The Study team noticed that at very low flows (below 3 cfs), the hydraulic module became numerically unstable; this required that the channel cross sections be artificially constrained to produce stable results. Even with these adjustments to the hydraulic module, the temperature module produced estimated diurnal temperature swings that were greater than field observations in similar conditions (e.g., at RC). Based on these observations, the model should not be used to assess scenarios in which the flow rate is less than 3 cfs.

4.5 Model Calibration and Sensitivity Analysis

A calibration was performed on the baseline model that represented existing conditions (based on 2024 data). The CE-QUAL-W2 model was calibrated by comparing the modeled baseline temperatures at four points along the length of the Santa Clara River to the closest points at which ESA had collected continuous data. Calibration was achieved by varying the canopy cover, which is the main model input that was not directly measured.

Data were compared on hourly and daily time frames. Correlation plots were developed to compare the daily modeled and measured data (**Figure 4-3**). The results were as follows:

- Upstream of the Valencia WRP, the model closely matched measured temperatures (R2 = 1.0), as would be expected so close to the model's upstream boundary.
- Directly downstream of (0.14 mile below) the WRP, the correlation remained high (R2 = 0.98), with no specific pattern of the model underestimating or overestimating temperatures compared to observed values.
- At the Castaic Creek confluence (2.5 miles below the Valencia WRP), the correlation dropped slightly (R2 = 0.9), with the model tending to overestimate temperature slightly compared to observed values. This may be because the model did not include upwelling of cool groundwater between the Valencia WRP and the Castaic Creek confluence.
- By Newhall Orchards (10 miles below the WRP), the correlation remained relatively consistent with the values seen at the Castaic Creek confluence (R2 = 0.91); however, noticeably more variability between modeled and observed temperatures occurred at Newhall Orchards than farther upstream, with the model both underpredicting and overpredicting values compared to observed conditions. Overall, the model was still relatively reliable at this location, but observers should be cautious when considering the highest and lowest temperature outputs from the model.

Comparing instantaneous data (2.4-hour model timesteps) with corresponding measurements from the temperature sensors, the model was generally within 1°F to 2°F of observed conditions between the Valencia WRP and Castaic Creek confluence, but overestimated the highest instantaneous temperatures at Newhall Orchards by as much as 5°F. The CE-QUAL-W2 model is considered reflective of existing conditions on-site in the Santa Clara River, particularly at locations near the Valencia WRP. The pattern shown was expected because the model did not consider any additional inputs to the system such as groundwater or small tributaries flowing into the river, which would have had a buffering effect on temperatures compared to modeled conditions.

Sensitivity analysis runs were conducted to evaluate the effect of shade and wind shielding on the modeling results, and to inform the evaluation of potential nature-based management strategies such as vegetation management (discussed later in this chapter). The highest and most consistent correlation was found when shade was kept at a constant value of 50 percent along the length of the river. Wind shielding was found to have minimal effects on the resulting temperature.

ESA also conducted a sensitivity analysis to evaluate the effect of Castaic Creek on temperatures in the Santa Clara River. Available data for Castaic Creek were sparse; therefore, assumptions were made about the anticipated flow rate and temperature of the water entering from the creek. Including Castaic Creek in the modeling results dropped temperatures by 1°F to 2°F downstream; however, because this temperature change was relatively small and the hydrologic parameters for Castaic Creek were uncertain, ESA decided not to include the creek in the final model results. Additionally, Castaic Creek typically does not flow during the summer and early fall, when water temperatures in the Santa Clara River are highest.

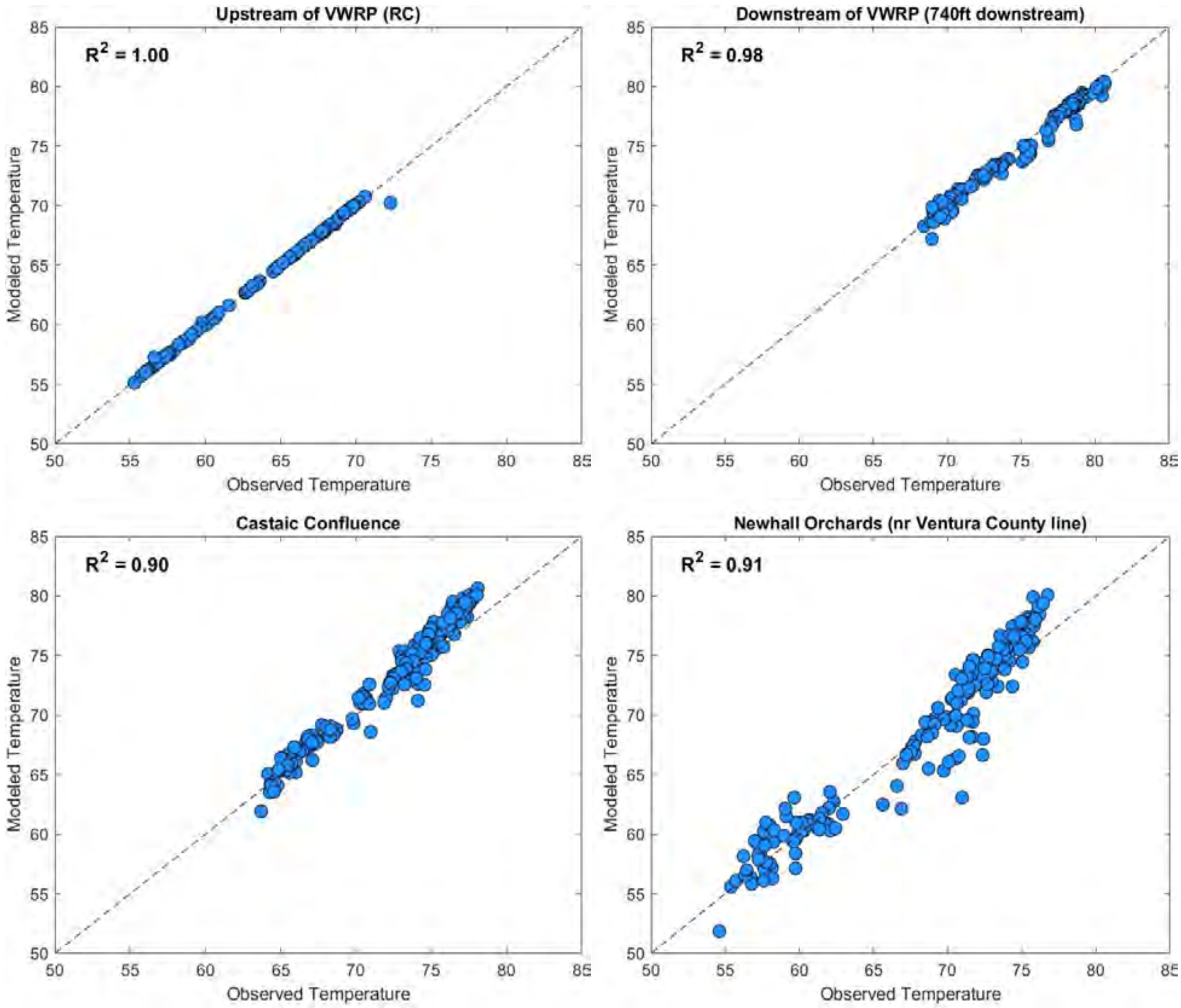


Figure 4-3
Correlation between Modeled and Observed Mean Daily Temperatures at Four Locations in the Study Area, June–December 2024

4.6 Modeling of Potential Management Scenarios

As part of an associated study, LACSD is evaluating different ways to reduce water temperatures downstream of the Valencia WRP by modifying WRP flows and operations. For the Study discussed in this report, initial modeling was performed to show how sensitive river temperatures would be to potential management actions in a range of background conditions (i.e., different upstream flow conditions and ambient air temperatures).

The temperature model was set up and run with eight different scenarios (**Table 4-2**). Existing conditions and three hypothetical flow management scenarios were simulated over two time periods: June–December of both 2022 and 2024.

TABLE 4-2
TEMPERATURE MODELING BACKGROUND CONDITIONS AND SCENARIOS

	June–December 2022	June–December 2024
Background Conditions		
Average air temperature	69°F	67°F
Average flow upstream of the Valencia WRP	0.4 cfs (5th-percentile flow)	5 cfs (68th-percentile flow)
Average flow from the Valencia WRP	19 cfs	22 cfs
Scenarios		
Existing conditions	✓	✓
50% Valencia WRP effluent reduction	✓	✓
80°F effluent temperature cap	✓	✓
100% Valencia WRP effluent reduction	*	✓

NOTES: °F = degrees Fahrenheit; cfs = cubic feet per second; WRP = Water Reclamation Plant

* A 100% effluent reduction was numerically unstable because of low flow: This scenario was run with flows below the Valencia WRP fixed at 3 cfs.

SOURCE: Data compiled by Environmental Science Associates in 2025

The scenarios tested were as follows:

- The *existing-conditions scenario* used the measured flow rate and temperature time series upstream of the Valencia WRP (at the RC location) and the time series of effluent from the Valencia WRP, with meteorological data from the nearby California Irrigation Management Information System station. This scenario assumed no additional flows from groundwater upwelling or tributaries, so it was a simplification of actual existing conditions that likely slightly overestimated water temperatures with increasing distance downstream of the Valencia WRP (e.g., by 1°F to 2°F based on the model correlation). However, the existing-conditions scenario was run to provide a baseline for comparison with the management scenarios.
- The *50 percent Valencia WRP effluent reduction scenario* was designed to assess a scenario in which half the WRP discharge could be beneficially reused (e.g., treated and reused or percolated to groundwater) while the remaining half would be discharged to the river to maintain instream flows. This scenario was modeled by taking the measured Valencia WRP effluent flow rate and temperature time series, then halving flows while leaving temperatures at the observed values.
- The *80°F effluent temperature cap scenario* assumed the addition of a cooling system to the Valencia WRP treatment process to prevent effluent discharges from exceeding 80°F. This scenario was modeled by taking the time series for Valencia WRP effluent and capping all temperatures exceeding 80°F at 80°F, while leaving all records of lower temperatures at their measured levels.
- The *100 percent Valencia WRP effluent reduction scenario* took the upstream flow rate and temperatures for the RC location and routed them along the entire length of the Santa Clara River to the Ventura County line, assuming that all flows from the Valencia WRP could be beneficially reused and not discharged to the river.

The testing of these scenarios used a combination of temperature data collected by LACSD and data collected for this Study from June through December in 2022 and 2024. Hourly flows were taken from the extrapolated time series based on monthly discharge measurements at RC, with modifications for the flow rate in 2022 as described below. The June–December period was modeled because the Study team had deployed temperature loggers in the river during these periods and thus could capture a range of conditions that included both the hottest water temperatures and nearly the coolest temperatures of each year. The years 2022 and 2024 were initially chosen because they represented the widest range of upstream water flow rates within the Study period.

In 2022, the flow at RC (upstream of the Valencia WRP) was typically about 0.4 cfs between June and December, representing the 5th-percentile flow over the last 20 years (i.e., 95 percent of flows were larger). In 2024, upstream flows were 5 cfs, the 68th-percentile flow for the last 20 years. These flows provided initial bookends for assessing the effectiveness of different management scenarios under higher and lower than average flow conditions.

When the model was run using data from the 2022 period, it became apparent that the hydraulic model was numerically unstable for the 100 percent Valencia WRP effluent reduction scenario because of the low flows (0.4 cfs) relative to the wide braided river cross sections downstream of the WRP. This issue was partially solved by constraining some cross sections to force flows into a single low-flow channel (simulating what would likely happen naturally with the sedimentation of side channels).

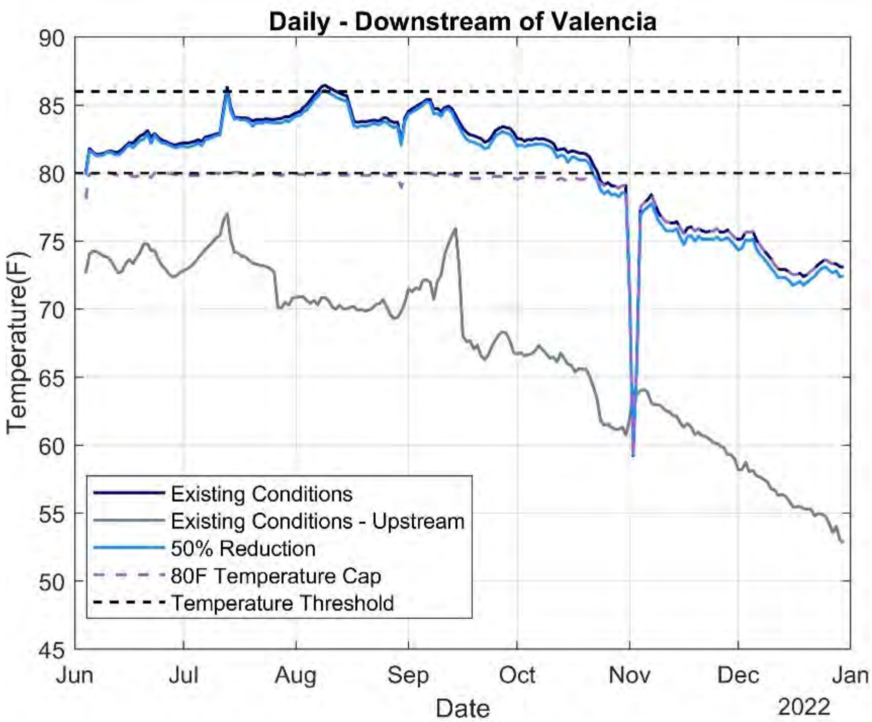
In addition to the hydraulic issue, the hourly temperature output for the 100 percent Valencia WRP effluent reduction scenario varied more widely than what was observed for nearby monitoring locations under similar flows at RC, suggesting that it was not accurate when modeling such low flows. For this reason, the Study team increased RC flows from 0.4 cfs to 3 cfs at 1 cfs increments for the 100 percent Valencia WRP effluent reduction scenario while continuing to use the extrapolated RC temperature time series. At 3 cfs, the hydraulic module was numerically stable without requiring manipulations of cross sections, and the predicted temperatures downstream of the Valencia WRP more closely resembled analogous temperatures at RC for the 100 percent Valencia WRP effluent reduction scenario. A flow of 3 cfs upstream of the WRP is approximately a median flow. Although this work-around means that a direct comparison between management scenarios cannot be made for the 2022 100 percent Valencia WRP effluent reduction scenario, it does provide an approximate analysis of the scenario.

4.7 Temperature Model Results

The results of the temperature modeling conducted for existing conditions and the management scenarios under both 2022 and 2024 conditions are discussed below.

4.7.1 Results under 2022 Conditions

Figure 4-4 and **Figure 4-5** show modeling results for 24-hour-average temperatures in June–December for all 2022 scenarios, except the 100 percent Valencia WRP effluent reduction. Figure 4-4 shows the results for a point a few hundred feet downstream of the Valencia WRP and at the Castaic Creek confluence while Figure 4-5 shows the results at Newhall Orchards. Note that the water temperature dropped sharply in November 2022, after a period when the WRP ceased discharge to accommodate maintenance activities.



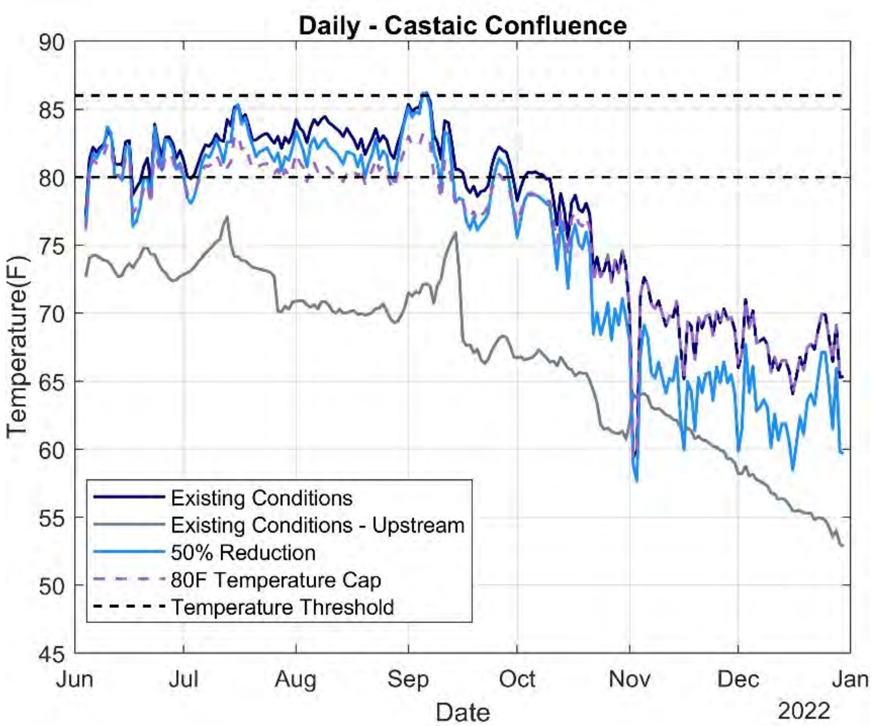


Figure 4-4

Modeled 24-Hour-Average Water Temperatures Immediately Downstream of the Valencia WRP and at the Castaic Creek Confluence, 2022 – All Scenarios Except 100 Percent Valencia WRP Effluent Reduction

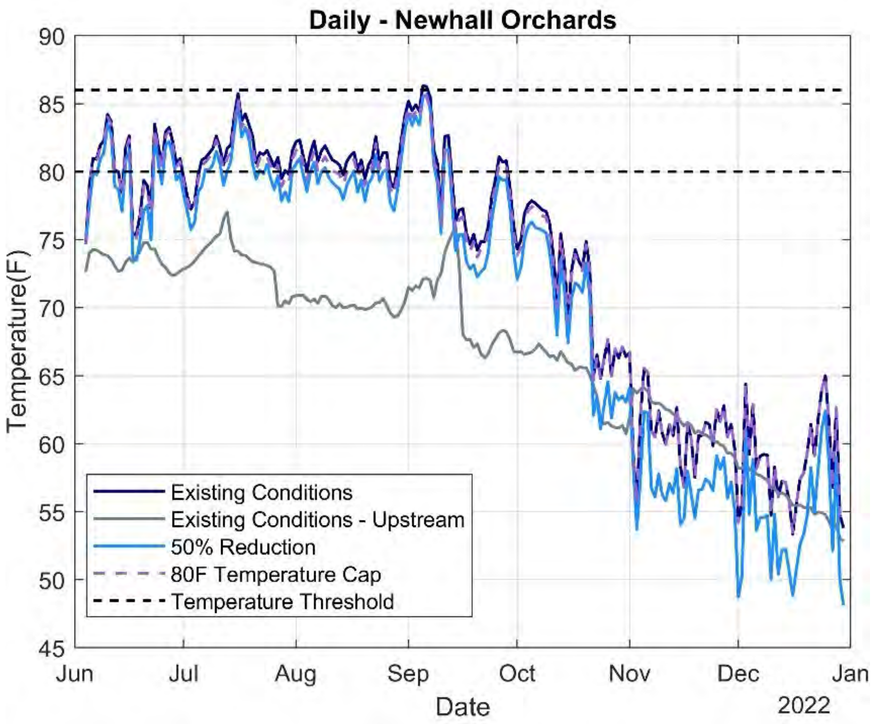


Figure 4-5
Modeled 24-Hour-Average Water Temperatures at Newhall Orchards, 2022 – All Scenarios Except 100 Percent Valencia WRP Effluent Reduction

Figure 4-6 and **Figure 4-7** show output for the 100 percent Valencia WRP effluent reduction scenario with flows fixed at 3 cfs. Similar to Figures 4-4 and 4-5, these figures show the results for a point a few hundred feet downstream of the Valencia WRP and for the Castaic Creek confluence and Newhall Orchards. **Figure 4-8** shows the mean temperature in September (the warmest month for water temperatures modeled in this simulation) along the profile of the Santa Clara River between the Valencia WRP and Newhall Orchards.

The existing-conditions scenario results are described first below, followed by the respective management scenarios and modeled continuous input for both September 2022 (warm period) and December 2022 (cool period).

4.7.1.1 Existing-Conditions Scenario—2022

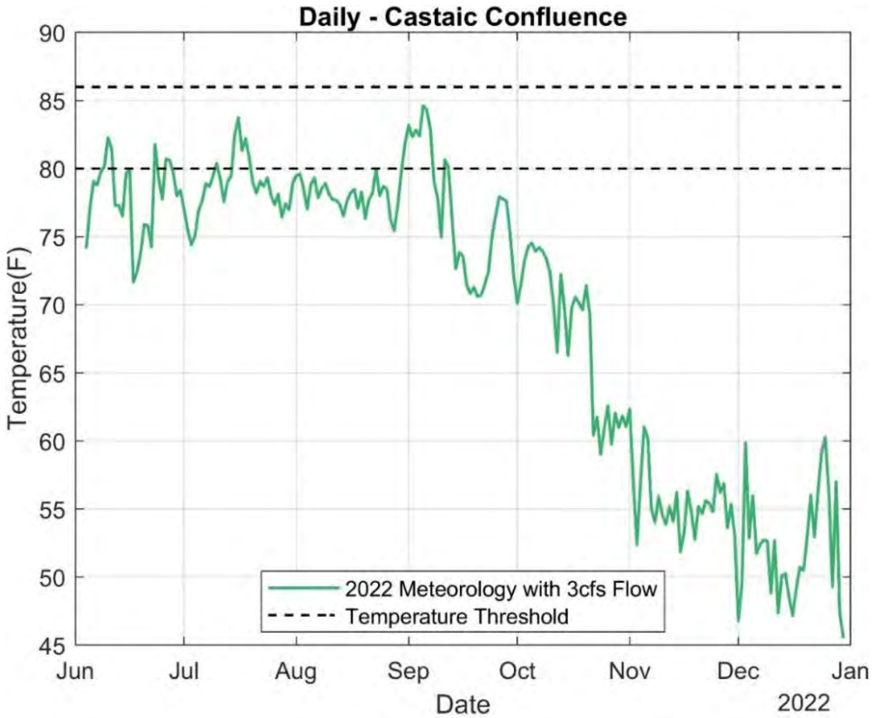
Under existing conditions, modeled daily-average water temperatures upstream of the Valencia WRP peaked around 73°F in June and July before falling to 53°F in December. Immediately downstream of the WRP, modeled temperatures rose from around 83°F in June to a peak of around 86°F in August before declining to 72°F in December. Thus, temperatures were 8°F to 15°F warmer downstream of the Valencia WRP for most of the modeled period.

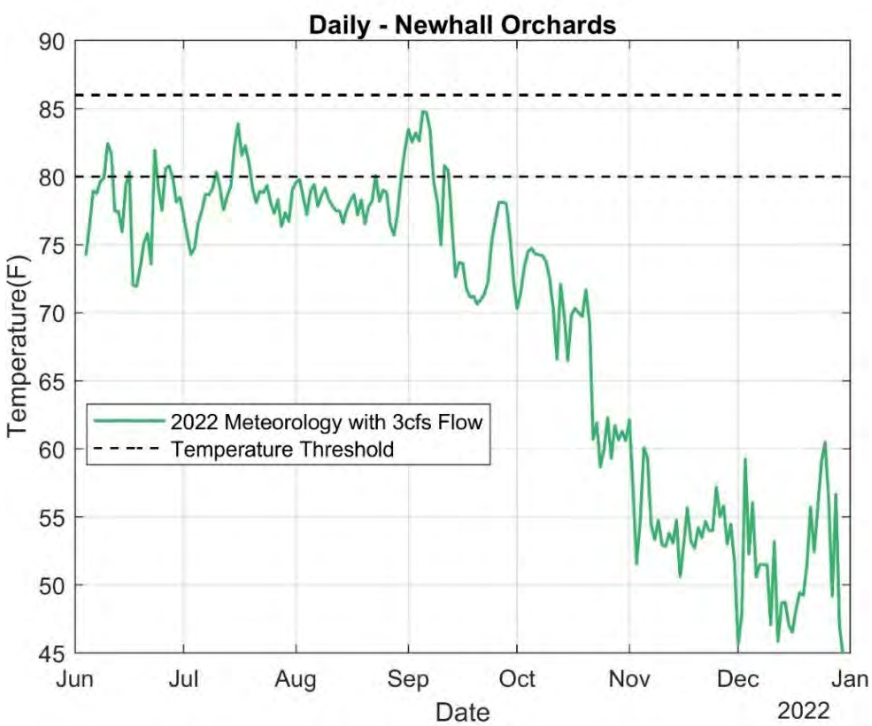
NOTE: Under this scenario, flow was fixed at 3 cfs to accomplish model stability.

Figure 4-6
Modeled 24-Hour-Average Water Temperatures Immediately Downstream of the Valencia WRP, 2022 – 100 Percent Valencia WRP Effluent Reduction Scenario Only

Modeled daily-average temperatures below the Valencia WRP were greater than 80°F for 139 days of the period, only dropping below that level in November and December. Temperatures mostly cooled by around 1°F to 2°F by the Castaic Creek confluence during the warmer months and dropped by around 6°F once air temperatures cooled in October. However, there were periods of a few days when the modeled temperature rose between the Valencia WRP and the Castaic Creek confluence because of high air temperatures and solar loading. A similar pattern was seen at Newhall Orchards, with temperatures falling by a further 1°F to 2°F below those at the Castaic Creek confluence in the summer/early fall and by 6°F to 8°F from November onward. Reviewing model output at smaller time increments of 2.4 hours (one-tenth of a day), river temperatures were greater than 80°F on 146 days.

Viewing the temperature profile along the river (Figure 4-8) for September 2022, water temperatures rose slightly downstream of the Valencia WRP for a distance of about 4 miles in response to high air temperatures and solar input, before falling slightly between that point and Newhall Orchards 10 miles downstream of the Valencia WRP.





NOTE: Under this scenario, flow was fixed at 3 cfs to accomplish model stability.

Figure 4-7

Modeled 24-Hour-Average Water Temperatures at the Castaic Creek Confluence and Newhall Orchards, 2022 – 100 Percent Valencia WRP Effluent Reduction Scenario Only

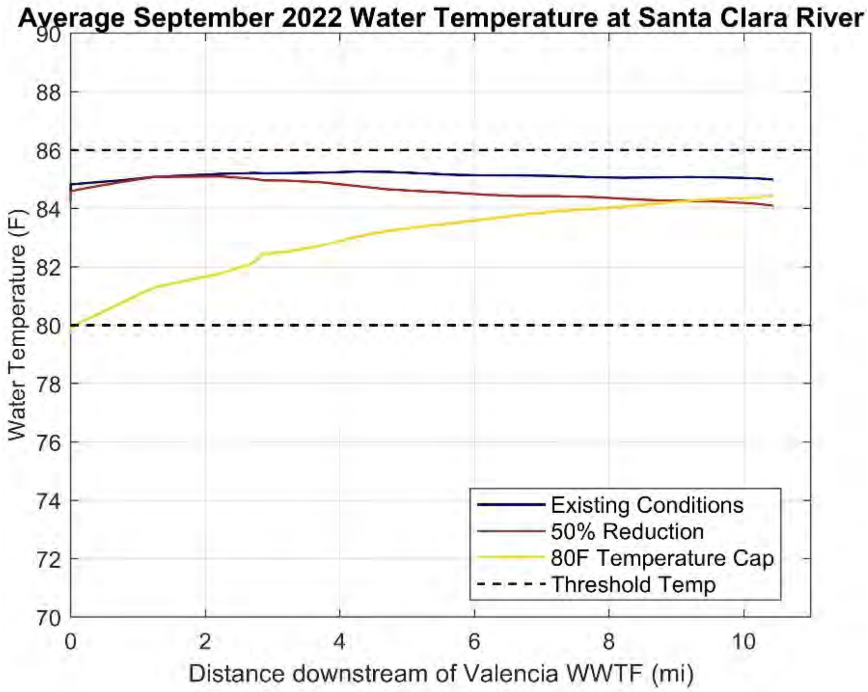


Figure 4-8
Modeled Average Water Temperature in September along the Santa Clara River

4.7.1.2 50 Percent Valencia WRP Effluent Reduction Scenario—2022

The 50 percent effluent reduction under this scenario had a very small effect on average river temperatures downstream because the upstream contribution of 0.4 cfs was still small relative to the 10 cfs project flow from the Valencia WRP. Overall, temperature trends downstream of the WRP were very similar to existing conditions during the summer and early fall (about 1°F cooler or smaller difference). Reviewing model output at smaller time increments of 2.4 hours (one-tenth of a day), the river temperatures were greater than 80°F on 152 days, slightly more than existing conditions. A slightly larger temperature reduction was seen with increasing distance downstream, with a 2°F to 3°F temperature reduction between the Valencia WRP and the Castaic Creek confluence in the summer and a further 1°F to 2°F fall by Newhall Orchards. This scenario was more effective in lowering temperatures during the fall and winter, potentially because the cooler ambient air temperatures had more of a cooling effect on the smaller volume of water. By November, modeled water temperatures at Newhall Orchards were similar to or lower than those upstream of the Valencia WRP. Overall, however, this scenario did not help meet a potential 80°F limit, as the mean daily temperature at RD was greater than that limit for 138 days, almost identical to existing conditions. Reviewing the 2.4 hourly model output, simulated temperatures were greater than 80°F on 152 occasions. Similarly, the difference between upstream and downstream river temperatures were greater than the Δ5°F limit throughout the modeled period.

Viewing the temperature profile along the river for September 2022, water temperatures rose slightly downstream of the Valencia WRP for 2 miles downstream (close to Castaic Creek confluence) in response to high air temperatures and solar input, before falling by about 1°F below the existing conditions temperature between Castaic Creek and Newhall Orchards.

4.7.1.3 80°F Effluent Temperature Cap Scenario—2022

This scenario was much more effective at reducing 80°F excursions than the 50 percent Valencia WRP effluent reduction on a mean daily basis, but the mean daily river temperature was still higher than the threshold at RD on 51 days. In summer, this scenario mostly kept average river temperatures close to 80°F; however, during periods of high ambient air temperatures, the river warmed up downstream of the Valencia WRP to the Castaic Creek confluence and rose beyond the 80°F limit. During the fall when WRP discharges fell below 80°F under existing conditions, the temperature distribution matched existing conditions, as would be expected. By November 2022, temperatures at Newhall Orchards matched temperatures upstream of the Valencia WRP. Reviewing model output at smaller time increments of 2.4 hours, river temperatures were greater than the 80°F limit on 141 days, similar to existing conditions.

Viewing the temperature profile along the river for September 2022, water temperatures started out much lower than existing conditions immediately downstream of the Valencia WRP and then rose from around 80°F to 84°F by Newhall Orchards, about 10 miles downstream. By Newhall Orchards, the river temperature had come close to equilibrating with the existing conditions temperature.

4.7.1.4 100 Percent Valencia WRP Effluent Reduction Scenario—2022

River temperatures in this scenario (with flows set to 3 cfs to accomplish model stability) closely mirrored those upstream of the Valencia WRP, with no excursions above 80°F immediately downstream of the WRP using the 24-hour-average temperature, and one excursion using instantaneous output. However, by the Castaic Creek confluence, the modeled water temperatures had risen above the 80°F limit several times during the summer and early fall as a result of solar and thermal loading downstream of the Valencia WRP. Had the actual upstream flow of 0.4 cfs been simulated, this warming would likely have been even higher than modeled because of the lower thermal mass and inertia. A similar pattern was seen at Newhall Orchards, with temperatures exceeding 80°F on several days during the summer and early fall.

In the fall as air temperatures fell and solar radiation was reduced, water temperatures dropped and temperatures across the Study reach converged into a narrower band, within about 8°F of each other.

4.7.1.5 Modeled Continuous Output—September 2022

Figure 4-9 shows 1 week of modeled output including all 10 timesteps per day just downstream of the Valencia WRP and at the Castaic Creek confluence for September 2022, one of the warmest water periods simulated. Key points from this output include the following:

- River temperatures were above 80°F throughout the week detailed in the figure (September 1–7, 2022). This was part of a period of 146 days where modeled temperatures were above 80°F for at least one 2.4-hour timestep.
- River temperatures were about 10°F higher downstream of the Valencia WRP than upstream during the hottest part of the day and about 15°F higher at night.
- Diurnal temperature fluctuations were lower downstream of the Valencia WRP than upstream, given the more constant temperature of the effluent and the greater flow volume.
- Note that for the Castaic Creek confluence, the temperature model tended to overestimate temperatures over about 75°F; the results should be viewed with caution.

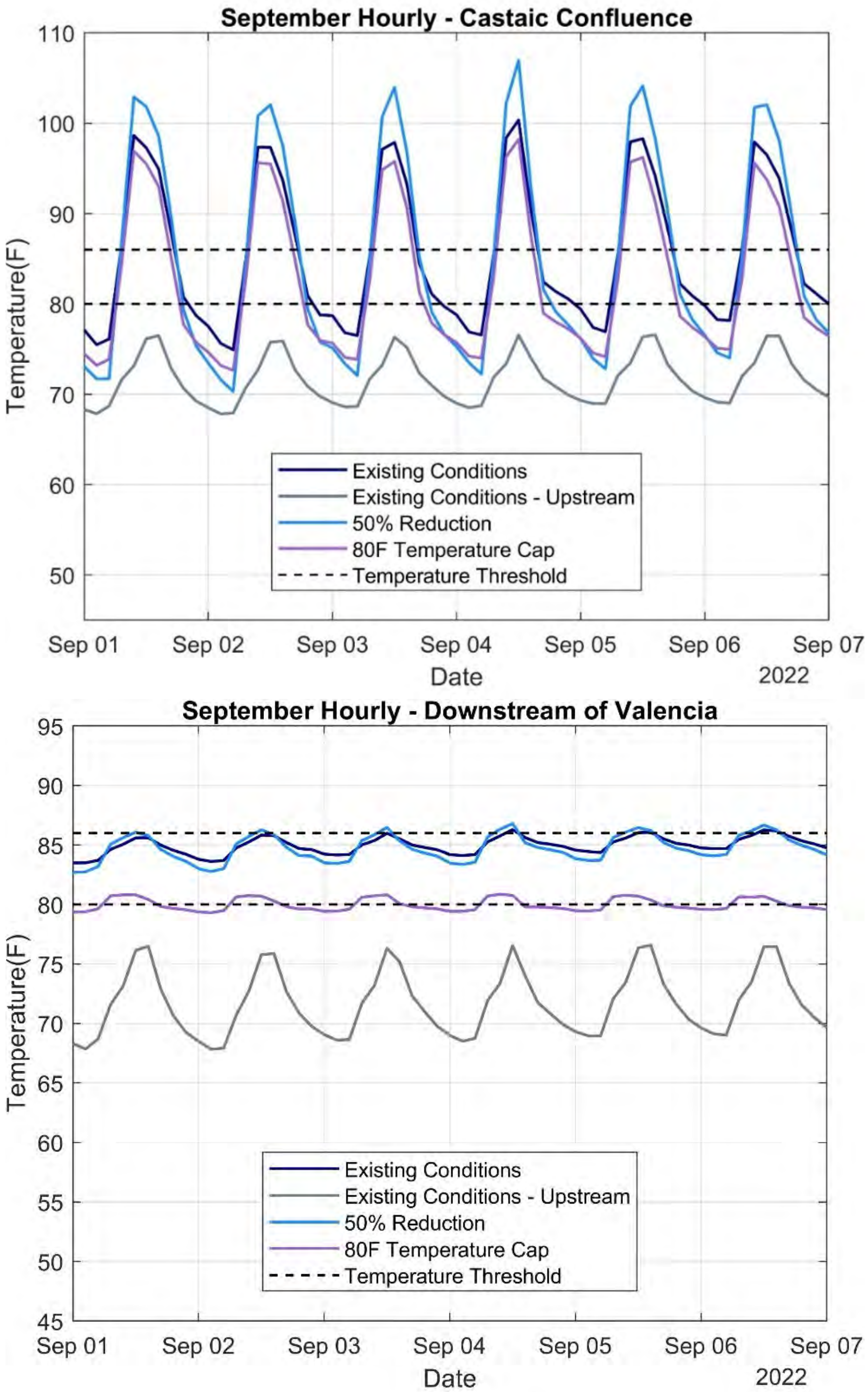


Figure 4-9

Modeled Continuous Water Temperatures Just Below the Valencia WRP and at the Castaic Creek Confluence, September 2022 – All Scenarios Except 100 Percent Valencia WRP Effluent Reduction

- Reducing WRP effluent by 50 percent had little effect on mean temperature because the remaining effluent volume was still much higher than the upstream flow rate (roughly 10 cfs of effluent to 0.4 cfs of upstream flow).
- Although average temperature was similar for existing conditions and the 50 percent Valencia WRP effluent reduction scenario, diurnal variability was higher in the reduced-flow scenario. Daytime peak temperatures were slightly higher in the reduced-flow scenario while nighttime lows were lower. This is because although the WRP effluent mostly warms the receiving water, it also increases its thermal mass and inertia to external temperature exchanges. Reducing the volume of water downstream of the Valencia WRP during periods of high air temperatures and solar radiation can create some situations in which the lesser volume of cooler water heats up more than a larger volume of warmer water.

4.7.1.6 Modeled Continuous Output—December 2022

Figure 4-10 shows corresponding output for December 2022, during one of the weeks with the coolest simulated water temperatures. Key findings include the following:

- Temperatures were below the 80°F limit throughout the week detailed in the figure (December 7–14, 2022).
- Temperatures were around 15°F higher downstream of the Valencia WRP than upstream during the hottest part of the day and around 17°F to 18°F higher at night.
- All scenarios had much less diurnal variability than during the summer/early fall because of the lower thermal loading from solar radiation and air temperature during the daytime.
- There was no difference between existing conditions and the 80°F effluent temperature cap scenario because the temperature of the effluent was below this threshold.

4.7.2 Results under 2024 Conditions

Modeling results for 24-hour-average temperatures in June–December for all 2024 scenarios are shown in **Figure 4-11** and **Figure 4-12** and summarized in **Table 4-3**.

4.7.2.1 Existing-Conditions Scenario—2024

Under existing conditions, modeled daily-average water temperatures upstream of the Valencia WRP peaked around 72°F in July and August before falling to 57°F in December. Immediately downstream of the Valencia WRP, modeled temperatures rose from around 78°F in June to a peak of around 81°F in August before declining to 70°F in December. Thus, temperatures were 8°F to 13°F warmer downstream of the Valencia WRP for most of the modeled period.

Temperatures below the Valencia WRP were above 80°F for 13 days in July and August using the daily-average temperature. Temperatures mostly cooled by around 1°F to 2°F by the Castaic Creek confluence during the warmer months and dropped by around 4°F once air temperatures cooled in October. A similar pattern was seen at Newhall Orchards, with temperatures falling by a further 1°F to 2°F below those at the Castaic Creek confluence in the summer/early fall and by 4°F to 5°F from November onward. Reviewing model output at smaller time increments of 2.4 hours (one-tenth of a day), river temperatures were above 80°F on 84 days.

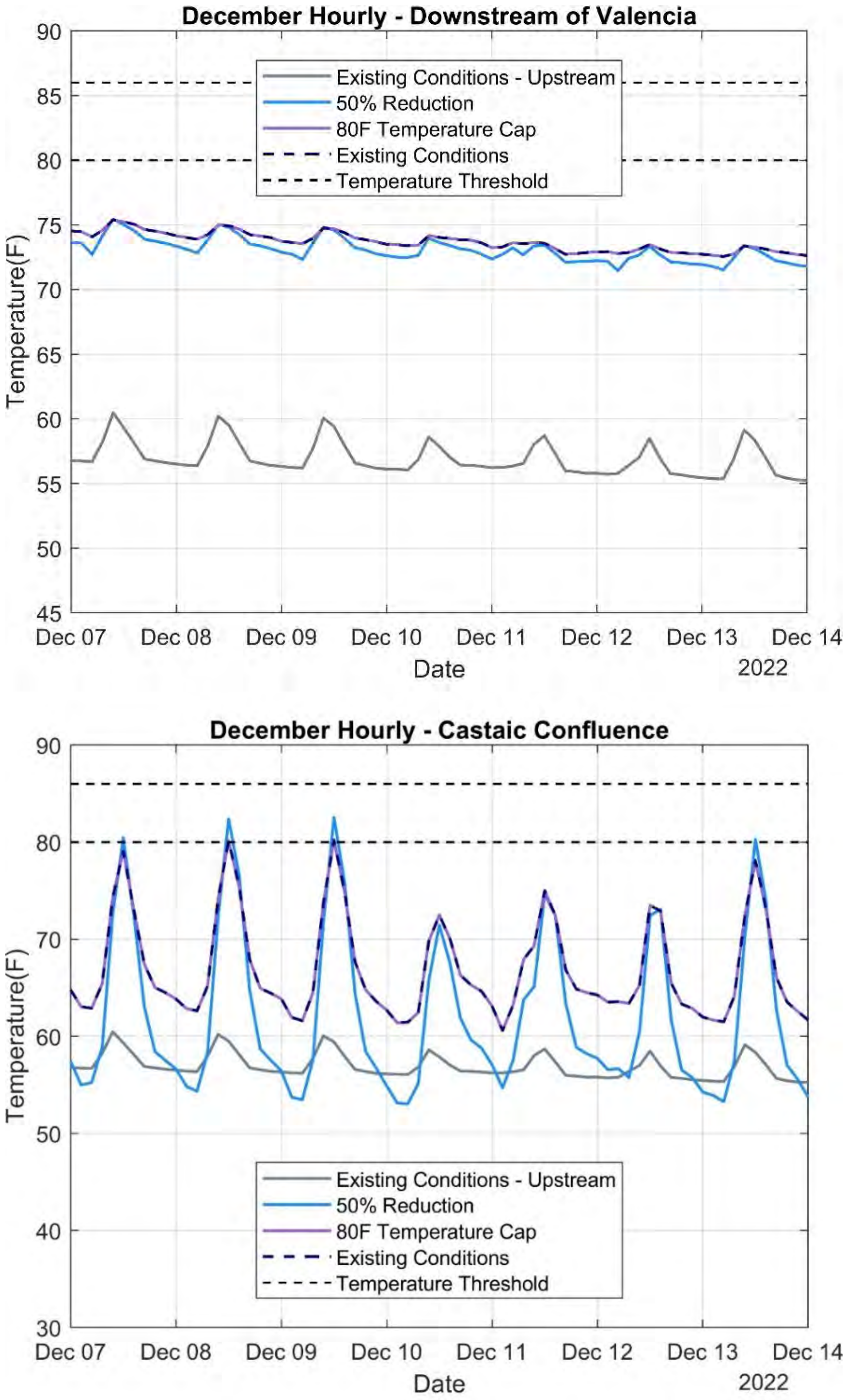
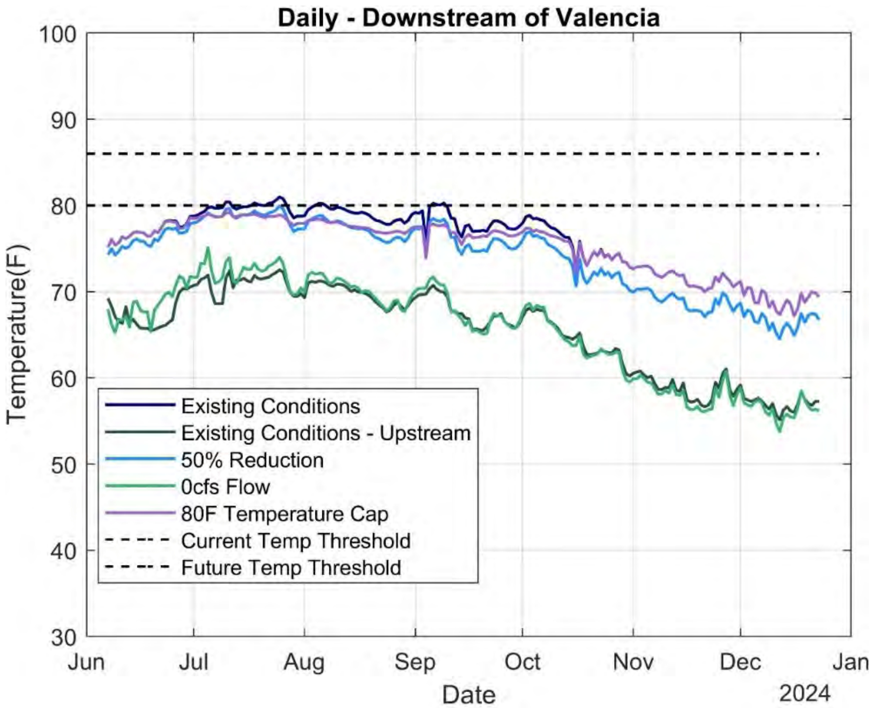


Figure 4-10

Modeled Continuous Water Temperatures Just Below the Valencia WRP and at the Castaic Creek Confluence, December 2022 – All Scenarios Except 100 Percent Valencia WRP Effluent Reduction



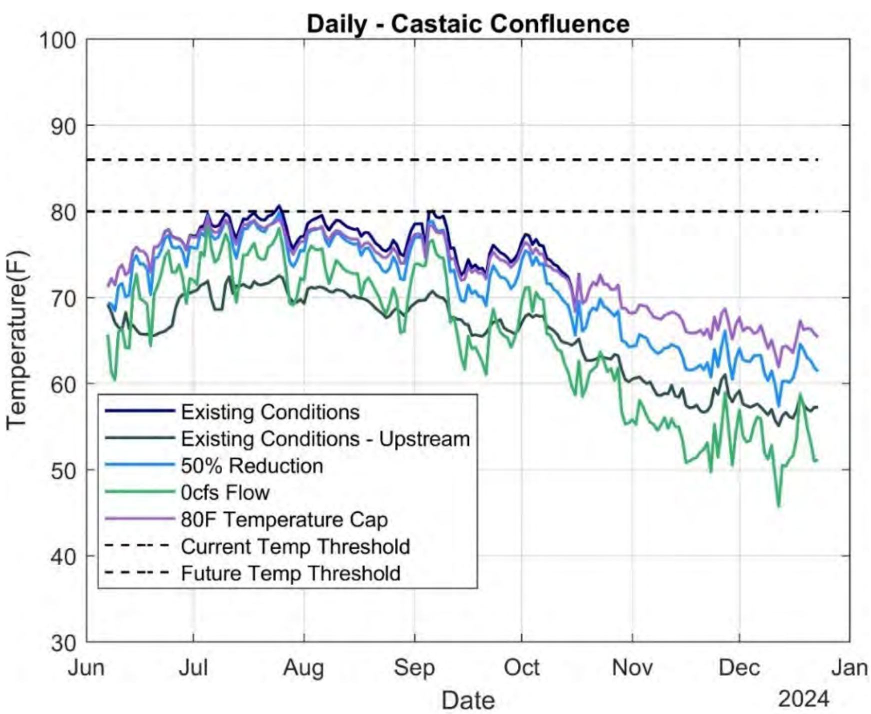


Figure 4-11

Modeled 24-Hour-Average Water Temperatures Immediately Downstream of the Valencia WRP and at the Castaic Creek Confluence, 2024

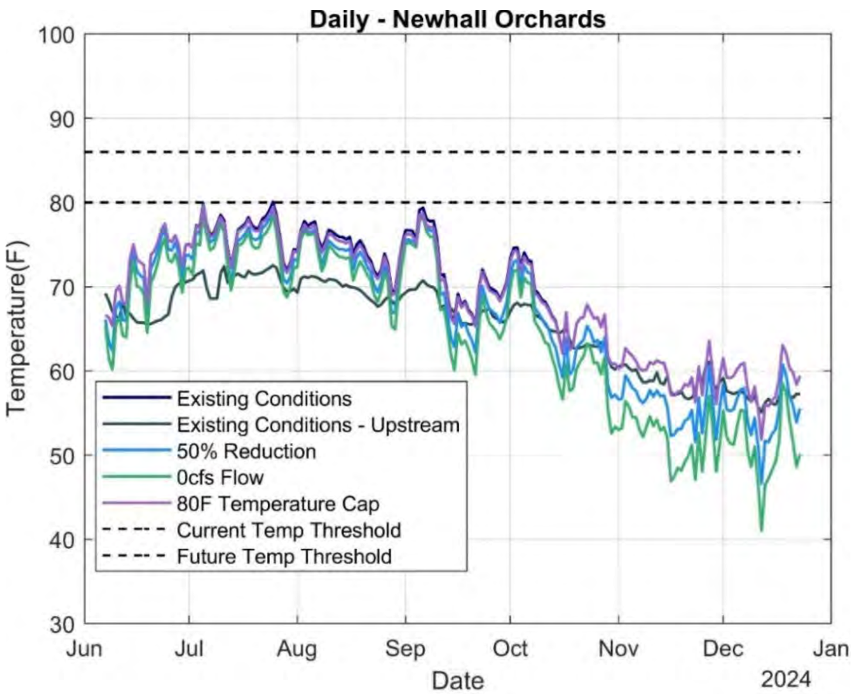


Figure 4-12
Modeled 24-Hour-Average Water Temperatures at Newhall Orchards, 2024

TABLE 4-3
RESULTS OF TEMPERATURE SCENARIO MODELING

	June–December 2022	June–December 2024
Background Conditions		
Average air temperature	69°F	67°F
Average flow upstream of the Valencia WRP	0.4 cfs (5th-percentile flow)	5 cfs (68th-percentile flow)
Average flow from the Valencia WRP	19 cfs	22 cfs
Scenarios		
Existing conditions	80°F exceeded on 139 days (daily mean), and 146 days (2.4 hourly data) Δ5°F limit exceeded throughout simulation	80°F exceeded on 13 days (daily mean), and 84 days (2.4 hourly data) Δ5°F limit exceeded throughout simulation
50% Valencia WRP effluent reduction	80°F exceeded on 138 days (daily mean), and 152 days (2.4 hourly data) Δ5°F limit exceeded throughout simulation	80°F exceeded on 0 days (daily mean), and 65 days (2.4 hourly data) Δ5°F limit exceeded throughout simulation
80°F effluent temperature cap	80°F exceeded on 51 days (daily mean), and 141 days (2.4 hourly data) Δ5°F limit exceeded throughout simulation	80°F exceeded on 0 days (daily mean), and 32 days (2.4 hourly data) Δ5°F limit exceeded throughout simulation
100% Valencia WRP effluent reduction	80°F exceeded on *0 days (daily mean), and 1 days (2.4 hourly data) No exceedances of the Δ5°F limit/NA	80°F exceeded on 0 days (daily mean), and 38 days (2.4 hourly data) No exceedances of the Δ5°F limit/NA

NOTES: Δ5°F limit = specification in the *Water Quality Control Plan for the Los Angeles Region* that the receiving water temperature shall not be altered by more than 5 degrees Fahrenheit above the natural temperature; °F = degrees Fahrenheit; cfs = cubic feet per second; NA = not applicable; WRP = Water Reclamation Plant

* A 100% effluent reduction in 2022 was numerically unstable because of low flow. This scenario was run with flows fixed at 3 cfs.

SOURCE: Data compiled by Environmental Science Associates in 2025

4.7.2.2 50 Percent Valencia WRP Effluent Reduction Scenario—2024

Although the 50 percent effluent reduction under this scenario lowered mean daily river temperatures by only about 1°F compared with existing conditions and downstream river temperatures were still around 10°F higher than at RC, the reduction in WRP effluent volume kept river temperatures below the proposed 80°F regulatory temperature limit during the period modeled using mean daily temperature output. Using model output at smaller time increments of 2.4 hours, temperatures were greater than 80°F on 65 days.

The difference between upstream and downstream temperatures was greater than Δ5°F throughout the modeled period. The summertime reductions in temperature downstream were similar to existing conditions, with about a 1°F to 2°F reduction between the Valencia WRP and the Castaic Creek confluence and a further 1°F to 2°F drop by Newhall Orchards. In the fall, the river lost more temperature with distance downstream, with 3°F to 4°F of cooling by the Castaic Creek confluence and a further 6°F to 7°F by Newhall Orchards, bringing temperatures at Newhall Orchards below those upstream of the Valencia WRP from late October to the end of December.

4.7.2.3 80°F Effluent Temperature Cap Scenario—2024

Like the 50 percent Valencia WRP effluent reduction scenario in 2024, this scenario met the 80°F limit at RD throughout the simulation using daily-average temperature but did not meet the Δ5°F limit. In the summer, this scenario kept river temperatures close to a daily average of 80°F, declining to around 70°F in December. By November, daily-average temperatures at Newhall Orchards matched temperatures upstream of the Valencia WRP. Reviewing model output at smaller time increments of 2.4 hours, temperatures were greater than 80°F on 32 days.

4.7.2.4 100 Percent Valencia WRP Effluent Reduction Scenario—2024

Under this scenario, the daily mean water temperature downstream of the Valencia WRP was consistently below 80°F. Unlike in the modified 2022 scenario, the river never warmed up enough to exceed 80°F downstream of the Valencia WRP, presumably because of the greater volume and thermal mass of water from upstream of the WRP. In the fall as air temperatures and solar radiation declined, the average water temperatures dropped and temperatures across the Study reach converged into a band with a spread of about 8°F. However, reviewing model output at smaller time increments of 2.4 hours, the daily maximum temperature was greater than 80°F on 38 days.

4.7.2.5 Modeled Continuous Output—July 2024

Figure 4-13 shows 1 week of modeled continuous output just downstream of the Valencia WRP and at the Castaic Creek confluence for July 2024, one of the warmest water periods simulated. Key points from this output include the following:

- Existing-conditions temperatures were greater than 80°F during the day but were below at night.
- Temperatures were about 10°F higher downstream of the Valencia WRP than upstream during the hottest part of the day and were higher by a similar amount at night.

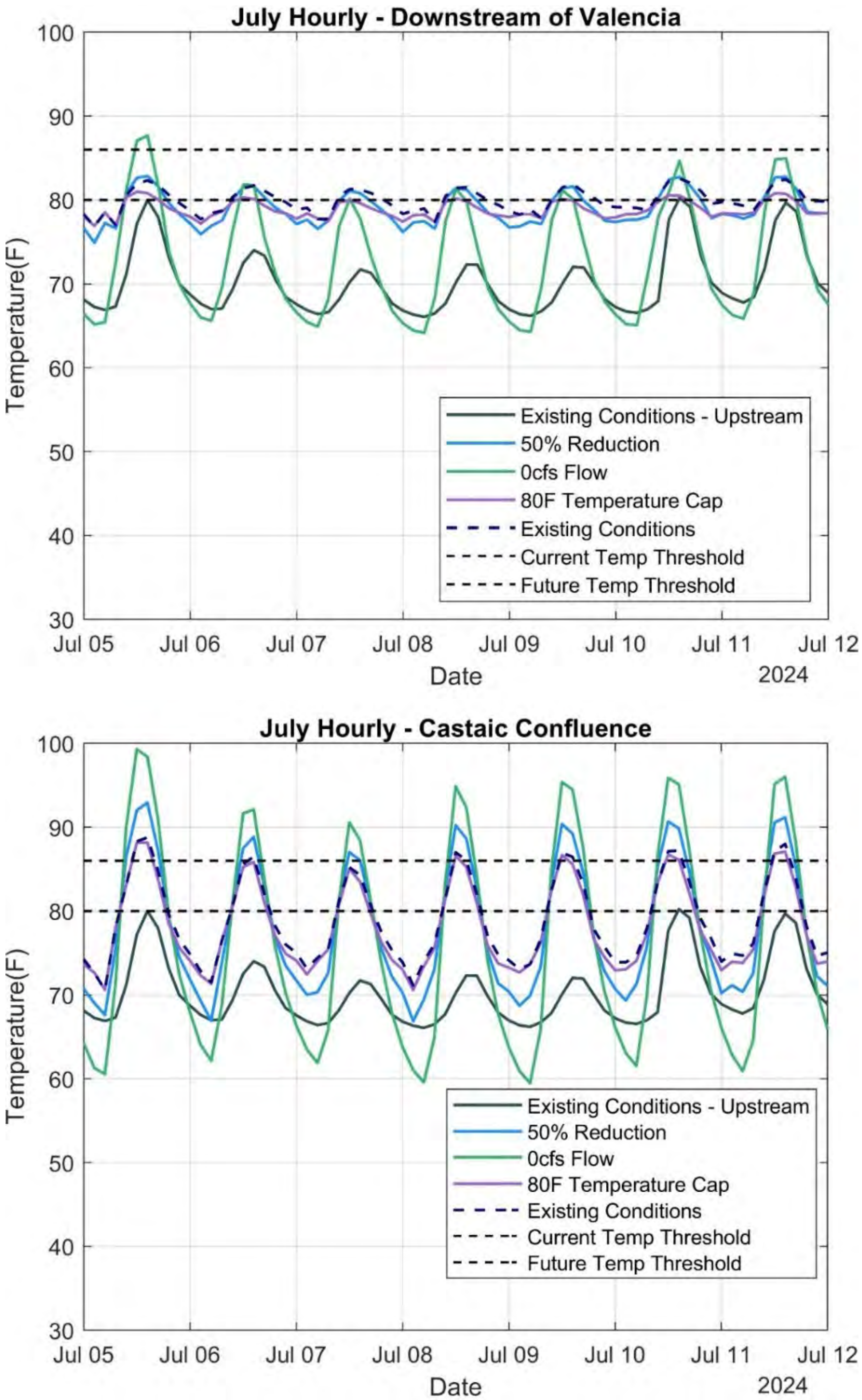


Figure 4-13

Modeled Continuous Water Temperature Just Below the Valencia WRP and at the Castaic Creek Confluence, July 2024

- Diurnal temperature fluctuations were lower downstream of the Valencia WRP than upstream, given the more constant temperature of the effluent.
- Reducing WRP effluent by 50 percent had little effect on mean temperature because the remaining effluent volume was still much higher than the upstream flow rate (roughly 10 cfs of effluent to 0.4 cfs of upstream flow).
- Although average temperature was similar for existing conditions and the 50 percent Valencia WRP effluent reduction scenario, diurnal variability was slightly higher in the reduced-flow scenario. Daytime peak temperatures were around 1°F higher in the reduced-flow scenario, while nighttime lows were 1°F to 2°F lower. This is due to the shallower depths and lower thermal inertia for the 50 percent flow reduction, which allows more rapid equilibration between the water temperature in the river and the air temperature.
- Eliminating effluent completely greatly reduced nighttime temperatures (by 10°F to 14°F compared to existing conditions) but on some days resulted in slightly higher daytime peak temperatures (1°F to 2°F).

4.7.2.6 Modeled Continuous Output—December 2024

Figure 4-14 shows corresponding output for December 2024, during one of the weeks with the coolest water temperatures simulated. Key findings include the following:

- Temperatures were below the 80°F limit throughout the December week detailed in the figure (December 10–17, 2024).
- Temperatures were around 12°F to 13°F higher downstream of the Valencia WRP than upstream during the hottest part of the day and around 10°F to 12°F higher at night.
- All scenarios had much less diurnal variability than during the summer/early fall because of the lower thermal loading from solar radiation and air temperature during the daytime.
- There was no difference between existing conditions and the 80°F effluent temperature cap scenario because the temperature of the effluent was below this threshold.

4.8 Sensitivity of Water Temperature to Riparian Shade

LACSD is considering the potential for nature-based solutions to manage water temperature in the Santa Clara River. To support this work, ESA performed six runs to test the sensitivity of water temperature to shade. The model was run with the same 2022 and 2024 time series as described above for existing conditions (50 percent shade), then was re-run with the shade parameter set for 0 percent and 100 percent shade to provide bookend simulations of the widest possible range of effects. The results are shown in **Figure 4-15** and described below.

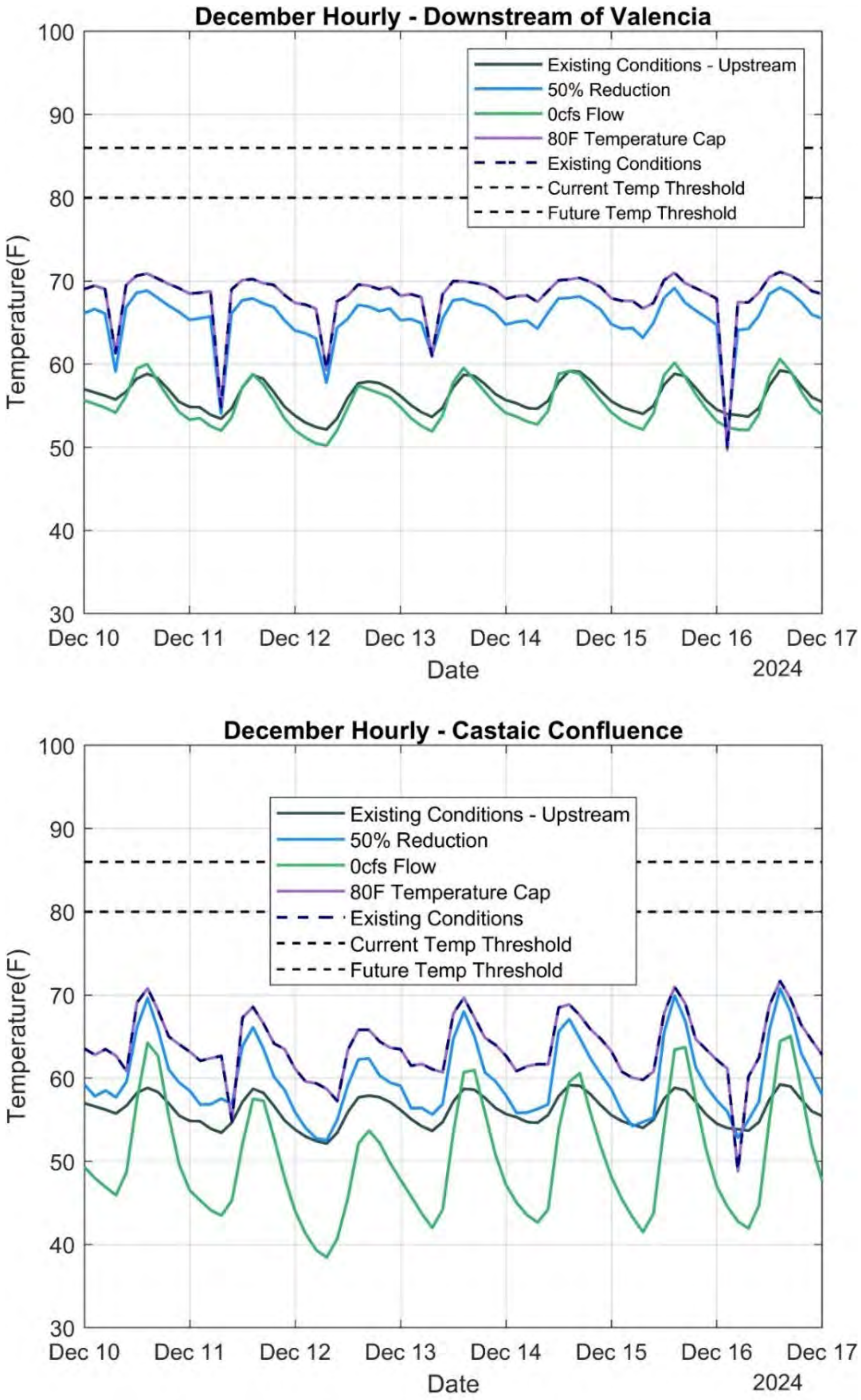


Figure 4-14

Modeled Continuous Water Temperature Just Below the Valencia WRP and at the Castaic Creek Confluence, December 2024

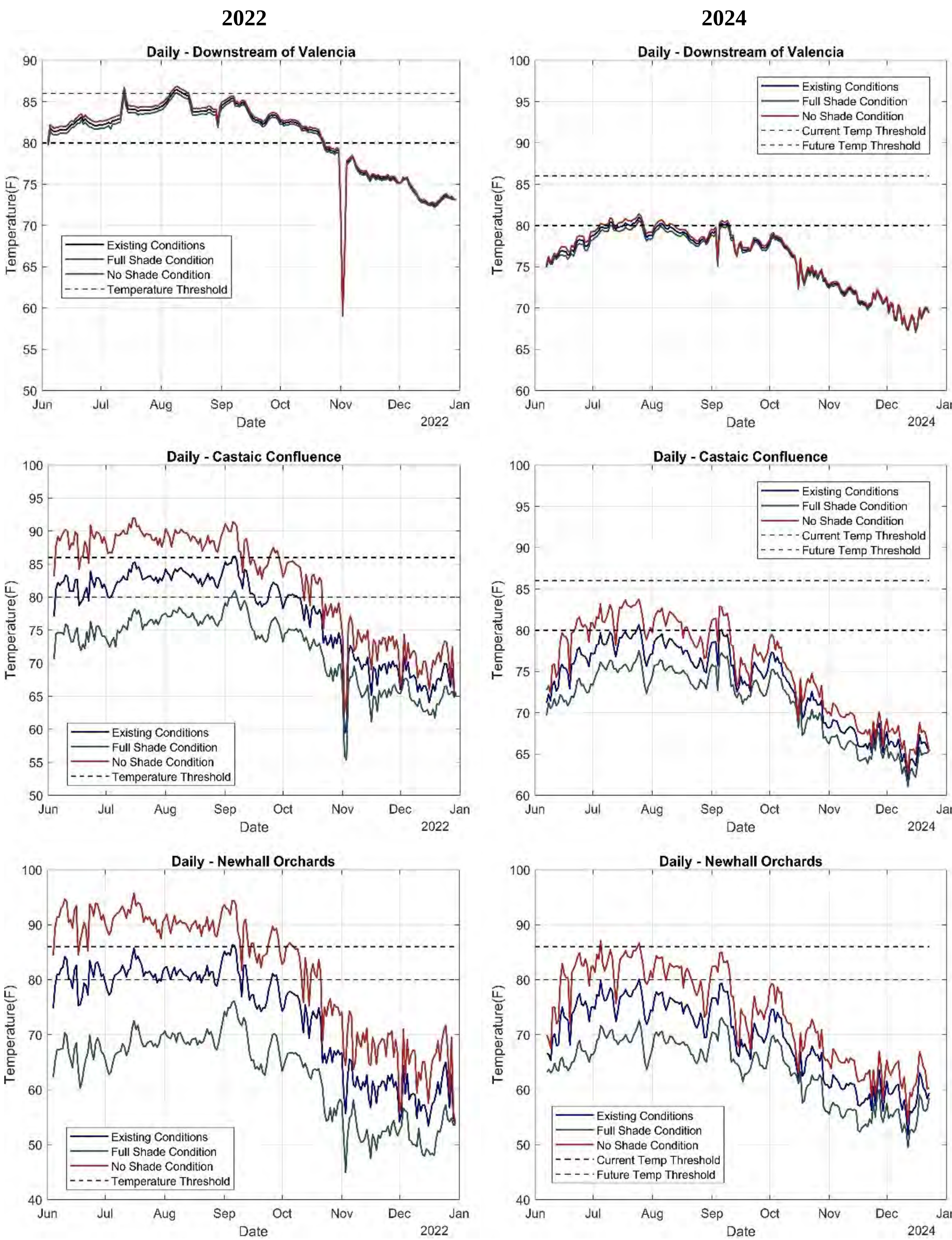


Figure 4-15

Daily Mean Temperatures Modeled with Full Shade (100 Percent), Existing Conditions (50 Percent Shade), and No Shade (0 Percent), 2022 and 2024

For both 2022 and 2024, the model showed a water temperature difference of less than 1°F between the shade scenarios immediately downstream of the Valencia WRP, as would be expected given the short distance of exposure to solar radiation. The model showed a greater effect by the Castaic Creek confluence, with a difference of about 14°F between the 0 percent and 100 percent shade simulations during the summer, diminishing to about 7°F of difference in the winter. By Newhall Orchards, the effect of shading was even more pronounced, with a difference of almost 25°F between the 0 percent and 100 percent shade simulations in the summer and about a 16°F difference in the winter. Comparing this with the existing-conditions runs assuming 50 percent shade (approximately the existing cover), the potential exists to cool the river in the summer by up to 7°F at the Castaic Creek confluence and around 12°F by Newhall Orchards through shading, although there are some practical limitations to this. These limitations include the challenge of accomplishing 100 percent canopy cover on such a large river channel, and the fact that the river experiences a geomorphic “resetting event” in which the canopy is completely eroded from the main channel area approximately every decade. However, these results highlight the importance of riparian canopy cover as an additional natural factor that influences river temperature in the Study Area.

A temperature profile for the Study Area in September 2022 (one of the periods of highest water temperature) is shown in **Figure 4-16**. The profile illustrates how the effect of shade on water temperature increases with increasing distance along the river.

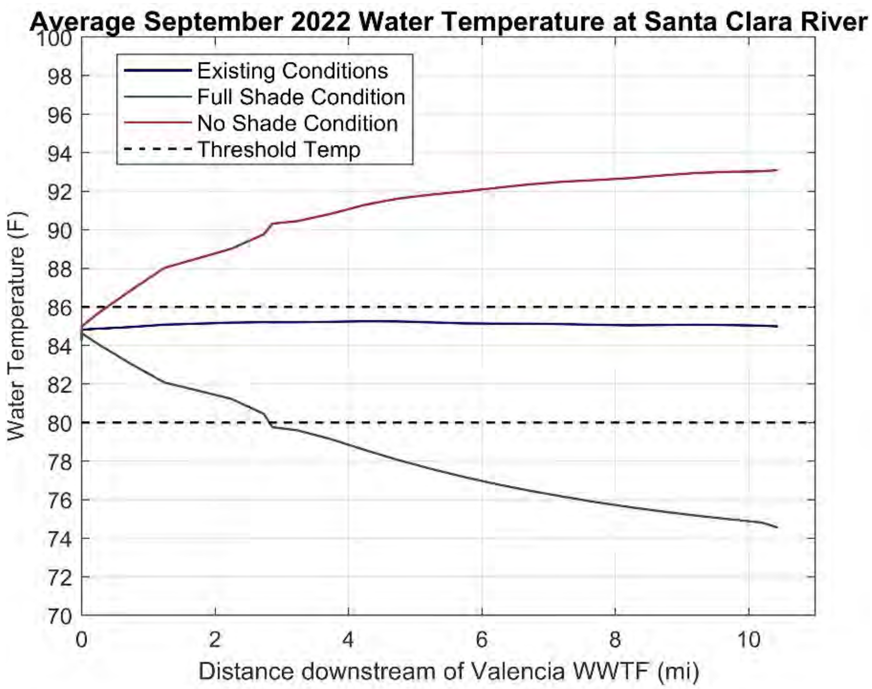


Figure 4-16

Temperature Profile Along Santa Clara River Showing Mean September 2022 Temperatures Modeled with Full Shade (100 Percent), Existing Conditions (50 Percent Shade), and No Shade (0 Percent)

4.9 Summary of Temperature Modeling Results

The results of the temperature modeling in the Study reach can be summarized as follows:

- Under existing conditions, the average daily temperature is likely to be higher than the proposed 80°F temperature threshold for several days to weeks each summer, even at higher than average upstream flow rates that provide some dilution benefit. For 2.4 hourly model output, the frequency of exceeding 80°F is higher, in the order of 80 to 150 days per year for some part of the day.
- The difference between upstream and downstream temperatures was greater than the Δ5°F limit throughout the modeled period from June to December of both years simulated.
- Reducing discharges from the Valencia WRP to 50 percent of their existing level was completely effective in keeping the river below 80°F using daily mean temperature in the wetter than average year modeled (2024). However, the reduction had almost no effect with an upstream river flow of 0.4 cfs (2022) because of the greater volume of effluent relative to background flow. Using 2.4 hourly model output, the scenario resulted in approximately 65 to 150 instances of temperatures greater than 80°F per year. This scenario did not meet the Δ5°F limit for either year.
- Capping Valencia WRP discharge to not exceed 80°F was also effective in preventing temperatures from being higher than 80°F in the wetter than average year, but not in the low-flow year because the river gained temperature downstream of the WRP RD monitoring location. However, this scenario was more effective at reducing the instances where temperatures were greater than 80°F than halving WRP discharge. This scenario did not meet the Δ5°F limit for either year simulated. It still resulted in approximately 140 excursions of the 80°F limit when assessed using 2.4 hourly model output data.
- Completely eliminating the Valencia WRP discharge was the only management scenario that met the proposed regulations in the vicinity of the WRP in both years simulated, although in the modified 2022 scenario the water temperature still was greater than 80°F farther downstream of the RD monitoring location on some occasions because of ambient warming from natural processes.
- Canopy shade has an increasingly large effect on water temperature with increasing length of the channel shaded. It could potentially reduce summer water temperatures by 7°F if all of the channel between the Valencia WRP and the Castaic Creek confluence (2.5 miles) were shaded to 100 percent from its existing level. However, the river’s natural dynamism means that the riparian corridor is eroded out roughly every decade or so, setting cover to almost zero until vegetation reestablishes and shades the river again.

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CHAPTER 5
Aquatic Biological Resources

5.1 Background and Purpose

Aquatic-dependent taxa are species that are fully or partially dependent on water for a significant portion of their lives or key life stages. These include fish, amphibians, and certain aquatic reptiles, as well as benthic macroinvertebrates (BMI) and algae that serve as food resources and are indicators of stream health (Rehn et al. 2015). Broadly applying a temperature criterion of 80°F for WARM beneficial uses across the entire Los Angeles Region is not appropriate because thermal tolerances can vary across species, populations, and life stages. Similarly, the scientific basis for broadly applying the Δ5°F limit, without consideration of season, species, absolute temperature, or specific waterbody conditions, remains unclear. Information is needed on the variety of aquatic-dependent taxa in the Santa Clara River and their thermal sensitivities.

The purpose of this Study element is to:

- Characterize the aquatic-dependent taxa that are present, were historically present, or could be present in the Study Area, given the current habitat conditions.
- Determine the relationships between waterbody temperature and support of aquatic life in the Santa Clara River.

5.2 Thermal Physiology Framework and Metrics

Fish are ectothermic (often called "cold-blooded"), meaning that their body temperature closely matches the surrounding water. Consequently, water temperature directly influences their activity and functions such as growth, metabolism, or development (Brett 1971). The effects of temperature on organisms and ecosystems can be explored through two paradigms: fundamental thermal physiology and ecological thermal physiology (Zillig et al. 2021; Zillig 2024).

Fundamental thermal physiology focuses on intrinsic physiological traits and abiotic factors that define a species' "thermal window," which is the range of temperatures within which an organism can survive and function. This thermal window is bounded by upper and lower temperature limits, beyond which physiological stress or mortality occurs (Pörtner and Farrell 2008; Pörtner and Knust 2007; Volkoff and Rønnestad 2020). Organisms can acclimate within limits, shifting their thermal windows in response to environmental conditions. Measurements typically include optimal or preferred temperatures (where growth and reproduction occur), suboptimal temperatures (where survival is possible but performance declines), and critical temperatures (tolerance thresholds beyond which survival is impossible).

Several metrics capture complementary aspects of an organism’s response and together provide a holistic view of thermal adaptation and vulnerability:

- **Tolerance**
  - *Critical Thermal Maximum (CT_{MAX})* is a measure of the *acute* upper thermal tolerance of a fish (Beitinger and Lutterschmidt 2011). This trait is influenced by the fish’s thermal history, including acclimation temperatures (temperature exposures over days to weeks) and diurnal fluctuations.
  - *Upper Incipient Lethal Temperature (UILT)* is a measure of *chronic* thermal tolerance. UILT experiments identify the relationship between thermal exposure and time-limited thermal tolerance, such as the warmest temperature at which some proportion of fish will survive indefinitely or the amount of time a fish can tolerate a chronic thermal exposure (i.e., resist temperatures that ultimately lead to death).
- **Metabolism**
  - *Resting Metabolic Rate (RMR)* is the metabolic rate associated with minimal activity and maintaining organismal homeostasis. It approaches the lower boundary of the metabolic activity necessary to sustain organism functioning (Chabot et al. 2016).
  - *Maximum Metabolic Rate (MMR)* is the aerobic metabolic exertion of an organism exercising to its maximum.
  - *Absolute Aerobic Scope (AAS)* is the difference between the RMR and MMR, which quantifies an organism’s aerobic energy budget for functions beyond homeostasis (e.g., digestion, migration, reproduction; Farrell 2016).
  - *Factorial Aerobic Scope (FAS)* is the quotient of the resting and maximum metabolic rates. This measurement can help to identify thermal regions where an organism’s metabolic capacity is not sufficient (Farrell 2016; Halsey et al. 2018).
- **Preference:** A fish’s preferred temperature is estimated from its behaviorally selected temperatures over time (Beitinger and Fitzpatrick 1979).

Ecological thermal physiology focuses on the intersection of physiological responses with ecological processes. Predation, competition, and disease often vary with temperature, influencing fitness beyond individual tolerance (McInturf et al. 2022). Species with narrow thermal windows may be disadvantaged compared to non-native species with broader tolerances (Pörtner and Knust 2007). Warmer conditions increase predators’ metabolism and feeding rates (Reese and Harvey 2002), while prey face increased metabolic demands and fatigue during escape (McInturf et al. 2022). Invasive species that have greater thermal flexibility can outcompete or prey upon native species constrained by narrower ranges (Correia 2003; Velema et al. 2012; McInturf et al. 2022).

Water temperature can influence primary productivity but is usually not the main controlling factor. Moderate warming can increase overall river metabolic activity and may increase algal production where light, nutrients, and stable flow conditions are sufficient (Aristi et al. 2015; Zhang and Chadwick 2022). However, across rivers—including California Mediterranean climate streams—primary productivity is more strongly controlled by light availability, nutrient supply, riparian shading, and flow disturbance than by temperature alone, and apparent temperature effects are often confounded by land use and elevation (Frazier 2017; Bernhardt et al. 2022). In addition, wastewater discharges alter multiple factors simultaneously, making temperature only effects difficult to isolate (Aristi et al. 2015; Zhang and Chadwick 2022). Finally, warming can alter food web interactions, with short term increases in periphyton sometimes followed by declines as grazing invertebrates become more active and increase consumption rates (Kazanjian et al. 2018; Beck et al. 2019).

5.3 Approach and Information Sources

The approach included all of the following:

- Review of existing reports, databases, and scientific literature to document the occurrence and distribution of aquatic-dependent taxa in the Study Area (Appendix B, *Aquatic Taxa Literature Review*). No new fish surveys were conducted as part of this Study because scientific collection activities are constrained by the presence of unarmored threespine stickleback (UTS), a fully protected species.
- Review of available literature on the temperature requirements and tolerances of aquatic taxa (Appendix C, *Thermal Tolerance Literature Review*).
- Qualitative assessment of the potential effects of increased water temperatures on ecological interactions such as predation and competition (Appendix C).
- Selection of target taxa for assessing the impacts of waterbody temperature on the WARM beneficial use based on presence, protected status, thermal sensitivity, and/or ecological function.
- Analysis of bioassessment data to assess the effects of WRP discharge on BMI communities, including a review of historical data and additional BMI sampling where feasible (Section 5.7, *Summary of Aquatic Biota Review*).

The following information sources were reviewed for the Study:

- Existing aquatic resources survey data for the Santa Clara River.
- Survey data specific to UTS and Santa Ana sucker (SAS).
- The California Department of Fish and Wildlife’s California Natural Diversity Database.
- The U.S. Fish and Wildlife Service’s Information for Planning and Consultation.
- The District’s annual bioassessment reports of benthic communities.
- Consultation with regional experts and resource agencies.
- Scientific literature and databases for thermal tolerance data.

5.4 Santa Clara River Aquatic Taxa

5.4.1 Fishes

Thirteen fish species have been documented historically (surveys 1989–2015) or recently (surveys 2016–2023) and are potentially present in the Study Area (Figure 1-2, **Table 5-1**). These include three fish species native to Southern California: UTS (*Gasterosteus aculeatus williamsoni)*, SAS (*Catostomus santaanae*), and arroyo chub (*Gila orcuttii*). UTS is native to the Santa Clara River. Arroyo chub is native to the Los Angeles Basin but not to the Santa Clara River watershed. SAS is native to the Los Angeles Basin and three populations (not including the Santa Clara River) federally listed as threatened, while the Santa Clara River population is considered one of the few remaining potentially viable populations.

TABLE 5-1
FISH SPECIES OCCURRENCE IN THE STUDY AREA

Common Name	Scientific Name	Status[a]	Occurrence Period[b,c]		Distribution[b]		
			Historic (1989–2015)	Current (2016–2023)	Reach 6	Reach 5	Santa Clara River Watershed
Native to the Santa Clara River							
Unarmored threespine stickleback	*Gasterosteus aculeatus williamsoni*	FE, SE, FP	Common	Rare	X	X	X
Native to Southern California							
Santa Ana sucker[d]	*Catostomus santaanae*	FT[e]	Common	Common	X	X	X
Arroyo chub	*Gila orcuttii*	SSC	Common	Common	X	X	X
Non-native to Southern California							
Convict cichlid	*Archocentrus nigrofasciatus*		Rare	Common	X		
Goldfish	*Carassius auratus*		Rare	Rare/Absent		X	
Prickly sculpin	*Cottus asper*		Common	Common	X	X	
Common carp	*Cyprinus carpio*		Rare	Common		X	
Mosquitofish	*Gambusia affinis*		Common	Common	X	X	X
Black bullhead	*Ictalurus melas*		Rare	Rare		X	
Green sunfish	*Lepomis cyanellus*		Rare	Rare		X	X
Largemouth bass	*Micropterus salmoides*		Common	Common		X	X
Fathead minnow	*Pimephales promelas*		Rare	Rare			X
Sailfin molly	*Poecilia latipinna*		Rare	Rare/Absent		X	

NOTES:

a. FE = federally listed as endangered, FT = federally listed as threatened, SE = state-listed as endangered, FP = State Fully Protected, SSC = State Species of Special Concern
b. Sources by location:
- *Reach 6:* CDFW 2021, 2022; Compliance Biology 2010; Hovore et al. 2008; Dellith, pers. comm. 2023; USFWS 2021
- *Reach 5/6:* Haglund and Baskin 1995, 2000; Impact Sciences 2003a
- *Reach 5:* Aquatic Consulting Services 2002a, 2002b, 2002c; CDFW 2015; Cardno 2015a; Dudek 2010; ENTRIX 2006a, 2006b, 2010; Impact Sciences 2003b, 2003c, 2010; USFWS 1980, 1985; Pareti, pers. comm. 2023
- *Watershed:* Bell 1978; Swift et al. 1993

c. Occurrence (absent, rare or common) is qualitatively based on the relative frequency of times a species was mentioned among the historic surveys reviewed for the Aquatic Taxa Literature Review (Appendix B).
d. Recent genetic analysis found that there is some support for Santa Ana sucker being native to the Santa Clara River, but results were ambiguous.
e. Federally listed with respect to occurrence in the Los Angeles Basin. Not listed with respect to occurrence in the Santa Clara River.

SOURCE: Data compiled by Environmental Science Associates in 2024 (Appendix B)

Ten non-native fish species occur in the Study Area (Table 5-1). These species generally tolerate and often prefer warm water temperatures, which may give them an advantage over native species in warmer reaches of the Study Area. Except for mosquitofish, which are widespread, many of the non-native species are more common downstream of the Valencia WRP and very common immediately downstream of the Saugus WRP.

Life history information is provided below for UTS and SAS, with further details on all species provided in Appendix B. Thermal tolerances of UTS, SAS, and other fishes are described below in Section 5.5.1, *Fundamental Thermal Physiology*.

5.4.1.1 Unarmored Threespine Stickleback

Taxonomy and Status

The unarmored threespine stickleback (referred to herein as "UTS") (*Gasterosteus aculeatus williamsoni*) is both federally listed and state-listed as endangered and is a State of California Fully Protected Species. UTS is a subspecies of the threespine stickleback (*G. aculeatus*), a species complex distributed across the Northern Hemisphere in marine, anadromous, and freshwater populations (Wootton 1984). Threespine stickleback are characterized by three dorsal spines, pelvic spines, and lateral bony plates ("armor") along the sides (Moyle 2002) (**Figure 5-1**).

The threespine stickleback[12] is well-known for evolving different body armor types, including fully plated (marine and anadromous), partially armored (brackish or freshwater), low-plated (freshwater), and the rare unarmored form found only in fresh water (Moyle 2002; Richmond et al. 2015; Turba et al. 2022). In Southern California, stickleback tend to have more plates where they co-occur with predatory trout or garter snakes (Moyle 2002).

Genetic studies in the Santa Clara River show a clear population structure (Richmond et al. 2015). In the lower Santa Clara River below the Piru Dry Gap, all stickleback are low-plated forms.[13] Unarmored forms are found only above the Piru Dry Gap, with three main population clusters: (1) San Francisquito Canyon, Valencia, and Newhall; (2) Soledad Canyon east of the Santa Clarita Gap; and (3) upper Bouquet Creek. In Bouquet Creek, mixing and hybridization has occurred between resident UTS and low-plated individuals from downstream, likely as a result of trout stocking (Richmond et al. 2015).

For regulatory purposes, agencies including the U.S. Fish and Wildlife Service presume that any stickleback observed in the Study Area are UTS, considering their protected status and the difficulty of distinguishing hybrids or low-plated forms in the field. Agency staff commonly refer to the forms in the Santa Clara River as "partially armored threespine stickleback" (PATS) (low-plated form), "unarmored threespine stickleback" (UTS), and "PATS-UTS hybrids" (hybrid stickleback). PATS and hybrid stickleback do not have protected status. Notably, hybrid stickleback are known to occur upstream of the Study Area in Bouquet Creek (Turba et al. 2022; Richmond et al. 2015).

[12] In this report, the term "threespine stickleback" or simply "stickleback" refers broadly to the threespine stickleback (*Gasterosteus aculeatus*) species complex, and is used when discussing general biological, ecological, or physiological information that applies to the species as a whole, including references to global literature.

[13] The terms "low-plated," "low-plate morph," and "partially armored" are used interchangeably in the literature to describe stickleback with an intermediate number of lateral plates (see Richmond et al. 2015; Turba et al. 2022). This Study report uses "partially armored threespine stickleback" (PATS) for consistency with regulatory and management usage.

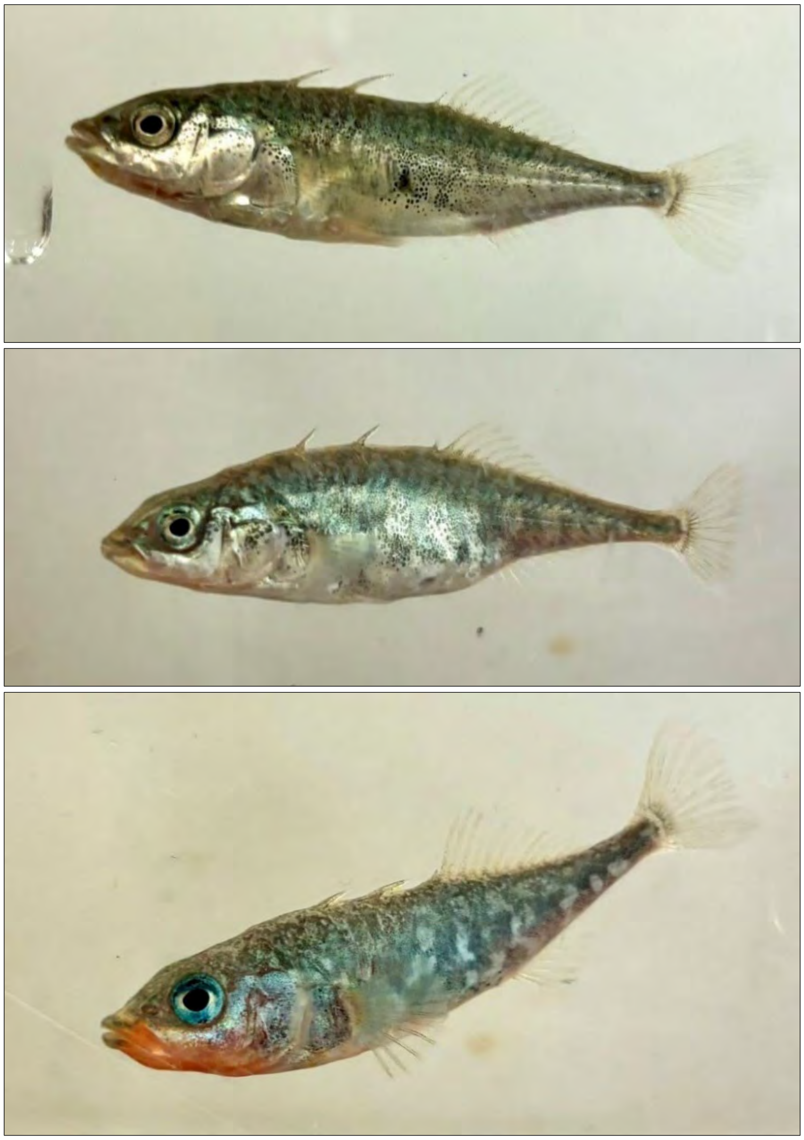


Figure 5-1
Partially Armored Threespine Stickleback Collected from the lower Santa Clara River, April 2024: (Top) Adult, Sex Unknown; (Middle) Gravid Female; (Bottom) Male in Breeding Coloration (Photo credit: Cassidy Cooper UC Davis)

Occurrence in the Study Area

UTS have been consistently recorded in the Study Area from San Martinez Grande Canyon upstream to Bouquet Canyon, with most samples collected between Castaic Creek and Interstate 5. They appear most abundant upstream of the Valencia WRP to around Interstate 5. Historical California Natural Diversity Database records (1994–2007) document UTS from State Route 118 east to San Francisquito Creek.

Recent data are limited. Pre-2016 data suggest that UTS were locally abundant in some years. The California Department of Fish and Wildlife (CDFW 2015) regularly observed UTS between Interstate 5 and the Valencia WRP outfall, but not downstream of the outfall. From late 2011 to 2014—California's driest period on record—much of the Santa Clara River between the Valencia WRP and the Saugus WRP was dry or at exceptionally low flows (CDFW 2021, 2022; Hovey 2014). In 2014, a UTS-occupied section dried out, prompting a rescue (Hovey 2014). That same year, a snorkel survey conducted from Salt Canyon to the Castaic confluence, approximately 1.5 miles downstream of the Valencia WRP, found no UTS (Cardno 2015a). Surveys conducted near the Iron Horse Bridge (just downstream of Interstate 5) detected UTS in June and November 2021 when flows were present (CDFW 2021), but not in 2022. In 2021 near Interstate 5, only one individual was recorded (USFWS 2021; Dellith, pers. comm. 2023; Pareti, pers. comm. 2023; CDFW 2023).

UTS distribution appears strongly influenced by hydrologic variability, which ranges from minimal drought flows to extreme floods that scour channels and streamside vegetation. Lack of perennial flow upstream of the Saugus WRP and downstream of the Saugus WRP outfall to Bouquet Canyon likely precludes the presence of UTS. The species has not been detected in the Saugus WRP outfall channel. Downstream of this channel, UTS have been observed from Bouquet Canyon to the Valencia WRP, with distribution varying by surface flow. UTS have not been detected downstream of the Valencia WRP in recent surveys. Current populations in the Study Area may be greatly reduced as a result of recent drought conditions.

On June 10, 2025, during BMI sampling conducted by Environmental Science Associates (ESA) (Mulder, pers. comm. 2025), stickleback were documented in Reach 6 (see Figure 1-2), as discussed below in Section 5.6.3.2, *2025 Benthic Macroinvertebrate Results*. It is unclear whether these fish were UTS, PATS, or hybrid stickleback because this area is near the confluence with Bouquet Creek. One adult in the Saugus WRP outfall channel and one juvenile just upstream of the Bouquet Canyon Road Bridge were inadvertently captured and released unharmed (water temperature 71.1 degrees Fahrenheit [°F] at time of capture). At another site downstream of the Saugus WRP near Bridgeport Park, approximately 10–15 stickleback were visually observed (water temperature 80.4°F at time of observation).

Life History and Habitat Requirements

Adult UTS can be found in all areas of a stream, often gathering in areas of slower moving water (USFWS 1985). In small artificial pools, UTS tend to be concentrated at the upstream end of the pool, where the water is flowing in. No adults have been found living permanently in pools isolated from the main channel (USFWS 1985). **Table 5-2** describes the physical habitat needs of each UTS life stage.

TABLE 5-2
LIFE STAGE HABITAT REQUIREMENTS OF UNARMORED THREESPINE STICKLEBACK

Life Stage	Habitat Requirements	References
Spawning	Slowly flowing, well-vegetated backwaters or streamside margins.	USFWS 1985
Fry Development	Shallow edges of the stream in areas of dense vegetation, which may serve as a velocity break.	USFWS 1985
Juvenile and Adult Rearing	Slow-moving reaches or quiet-water microhabitats in streams and rivers, well-vegetated backwaters, or streamside margins. In places where water is moving rapidly, adults tend to be found behind obstructions or at the edge of the stream, especially under the edge of algal mats.	USFWS 1985, 2009 Bell 1978

SOURCE: Data compiled by Environmental Science Associates in 2025

Stickleback can reproduce year-round in dry years when a stream is minimally disrupted by storm flows. Activity peaks during the spring (March), continues at lower levels through the summer and fall, and is lowest from October to January (USFWS 1985, 2009). The male builds a small nest of decaying vegetation, attracts females to spawn in the nest, then guards and cares for the eggs until hatching (USFWS 2009).

Dissolved oxygen (DO) levels greater than 2.0 milligrams per liter (mg/l) are sufficient to support UTS (Feldmeth and Baskin 1976; Mulder 2017).

Stickleback are invertivores that predominantly prey on microcrustaceans (copepods, cladocerans, and ostracods), the larvae of midge flies (chironomids), and aquatic nymphs of mayflies, with lesser proportions of oligochaetes, mollusks, and algae (Wootton 1984). Stickleback may also eat stickleback eggs during the breeding season.

5.4.1.2 Santa Ana Sucker

Status and Distribution

The Santa Ana sucker, or SAS (*Catostomus santaanae*), is federally listed as threatened (USFWS 2000). This listed species is currently known to occur in three watersheds: the Santa Ana River, the San Gabriel River, and Big Tujunga Creek of the Los Angeles River. An SAS population also occurs in the Santa Clara River, although that population is not included in the species’ listing as threatened, presumably because it was thought to have been introduced to the Santa Clara River (Greenfield et al. 1970; USFWS 2023). Recent genetic analysis of the various SAS populations was equivocal but may suggest that the Santa Clara River population is native rather than introduced (Richmond et al. 2017). With populations declining in neighboring watersheds, the Santa Clara River population is recognized by biologists as one of the potentially viable populations in Southern California.

Occurrence in the Study Area

SAS have been observed regularly throughout the Study Area, although their presence near and upstream of Interstate 5 is occasional, possibly based on flow conditions. A recent habitat survey in fall/winter 2024 suggested that habitat conditions in the Study Area are not currently suitable for SAS.

Life History and Habitat Requirements

SAS typically inhabit perennial streams with water depths ranging from a few inches to several feet and with currents that vary from slight to swift (Smith 1966). Periodic high-flow events (flood flows) are important because they deliver coarse substrates (such as gravel and cobble) and create complex habitat such as open sandy bars for juveniles and deep, undercut banks and runs for adults (USFWS 2017). **Table 5-3** describes habitat requirements for each SAS life stage. Suitable habitat must contain algae, aquatic emergent vegetation, macroinvertebrates, and riparian vegetation (USFWS 2010). SAS feed by scraping algae, insects, and detritus from gravel and cobble substrate (Greenfield et al. 1970; Haglund et al. 2003). SAS likely avoid continuously turbid conditions but could survive in seasonally turbid conditions (Haglund et al. 2003).

TABLE 5-3
SANTA ANA SUCKER LIFE STAGE HABITAT REQUIREMENTS

Life Stage	Habitat Requirements	References
Spawning	Areas with gravel substrates at a moderate depth, but close to areas of deeper water or aquatic vegetation that serve as refugia.	Haglund et al. 2003
Fry Development	Areas with negligible flow over silty substrate. Fry often “bask” in shallow, sunny areas but then retreat to vegetated areas for protection.	Haglund et al. 2003 Feeney and Swift 2008
Juvenile and Adult Rearing	Well-lit reaches with coarse substrates, where photosynthetic algae (food source) can grow. Adults and juveniles are found over gravel, cobble, or a mixture of gravel or cobble with sand within riffles, runs, and pools. Adults are found in deeper areas than juveniles and prefer runs over pools or riffles.	Haglund et al. 2001, 2003, 2010 Haglund and Baskin 2003, 2004 Feeney and Swift 2008 BonTerra Psomas 2015 Thompson et al. 2010

SOURCE: Data compiled by Environmental Science Associates in 2025

5.4.1.3 Arroyo Chub

Distribution and Occurrence

The arroyo chub (*Gila orcuttii*) was designated a California species of special concern in 1995 in its native range, which includes the Los Angeles, San Gabriel, San Luis Rey, Santa Ana, and Santa Margarita rivers and Malibu and San Juan creeks. This species has been introduced to many river systems in Southern California, including the Santa Clara River. Arroyo chub is common throughout the Study Area and has been cited as the dominant species in this area of the Santa Clara River (ENTRIX 2010).

Life History and Habitat Requirements

Arroyo chubs are typically found in slow-moving sections of cool to warm streams, although they are also found in fairly fast-moving sections of stream with coarse substrate (Moyle 2002). Arroyo chubs have been found in a diversity of habitats including pools with gravel, cobble, and boulder substrates (Feeney and Swift 2008), but they are more often found in pools dominated by sand and silt substrates (Moyle 2002). These fish are adapted to survive the fluctuating conditions present in Southern California streams.

Arroyo chub spawning takes place in pools and edge habitat from February to August, with a peak in June and July. Several males may fertilize the eggs of one female. Fertilized eggs stick to plants or bottom substrate and hatch in about 4 days. Fry stay on the substrate for a few days, then rise to the surface and stay among plants or other cover for 3–4 months (Moyle 2002).

5.4.2 Herpetofauna

Five amphibian species native to the Santa Clara River and two non-native amphibian species have been observed historically or currently or are potentially present in the Study Area (**Table 5-4**). Two native aquatic-dependent reptile species have also been recorded from the Study Area. Turtles and snakes are expected to be more tolerant to warm water temperatures than most fish species, because of their harder impermeable skin, use of terrestrial and aquatic habitats, and ability to move out of the river during thermally stressful events.

TABLE 5-4
OCCURRENCE OF AMPHIBIAN AND REPTILE SPECIES IN THE STUDY AREA

Common Name	Scientific Name	Status[a]	Historically[b] Present	Currently[c] Present
Native				
Amphibians				
Western toad	*Anaxyrus boreas*		Common	Common
Arroyo toad	*Anaxyrus californicus*	FE, SSC	Unknown	Rare/Absent
Baja California chorus frog	*Pseudacris hypochondriaca*		Common	Common
California treefrog	*Pseudacris cadaverina*		Rare	Rare
Western spadefoot toad	*Spea hammondii*	SSC	Rare	Rare/Absent
Aquatic-Dependent Reptiles				
Southwestern pond turtle	*Actinemys pallida*	SSC	Common	Common
Two-striped garter snake	*Thamnophis hammondii*	SSC	Rare	Rare
Non-Native				
American bullfrog	*Lithobates catesbeianus*		Rare	Common
African clawed frog	*Xenopus laevis*		Rare	Common

NOTES:

a. FE = federally listed as endangered; SSC = State Species of Special Concern
b. Based on survey data 1989–2015.
c. Based on survey data 2016–2023.

SOURCES: Aquatic Consulting Services 2002a, 2002b, 2002c; Bell 1978; Cardno 2015a, 2015b; CDFW 2015; Compliance Biology 2004; Dudek 2010; ENTRIX 2006a, 2006b, 2010; Haglund 1989; Haglund and Baskin 1995, 2000; Hovore et al. 2008; Impact Sciences 2001; SMEA 1994, 2005.

5.4.3 Invertebrates

Benthic macroinvertebrates, or BMI, play a critical role in stream ecosystems by supporting higher trophic levels such as fish and contributing to nutrient cycling and organic matter breakdown (Covich et al. 1999). In addition, stream assessments often use BMI as biological indicators of water quality (Rehn et al. 2015). Benthic macroinvertebrates are discussed in detail below in Section 5.6, *Benthic Macroinvertebrate Assessment* and in Appendix B.

Red swamp crayfish (*Procambarus clarkii*) have been captured or observed regularly in the Study Area (Cardno 2015a; ENTRIX 2006a, 2006b). Red swamp crayfish were introduced to the Santa Clara River and are native to the Gulf coastal plain from the Florida panhandle to Mexico.

5.5 Thermal Physiology Review

5.5.1 Fundamental Thermal Physiology

5.5.1.1 Fishes

The *Thermal Tolerance Literature Review* (Appendix C) shows the results from an examination of peer-reviewed publications and reports of thermal tolerances of aquatic taxa in the Santa Clara River. **Table 5-5** summarizes thermal preference ranges and tolerances, as compiled from the literature.

TABLE 5-5
FISH THERMAL PREFERENCES AND TOLERANCES

Species	Optimum or Preferred °F[a]	Maximum °F[b]	Source
Native to the Santa Clara River			
Unarmored threespine stickleback	<73.4–75.2°F	86.9–94.3°F	a. Moyle 2002 b. Feldmeth and Baskin 1976 (CT_{MAX} acclimated at 46.4°F and 72.9°F)
Native to Southern California			
Santa Ana sucker	<71.6°F prefer, 50–82.9°F observed	86–93.2°F	a. Moyle 2002, Swift 2001, Santa Ana Watershed Association 2014; Greenfield et al. 1970 b. Wulff et al. 2023; Russell, pers. comm. 2024
Arroyo chub	50–75.2°F	95°F	a. Moyle 2002 b. Castleberry and Cech 1986 (acclimated at 86°F)
Non-native to Southern California			
Goldfish	80.6–98.6°F	105.8°F	a. Moyle 2002 b. Moyle 2002
Prickly sculpin	46.4–55.4°F	86°F	a. Moyle 2002 b. Moyle 2002
Common carp	59–73.4°F	87.8–96.8°F	a. Moyle 2002 b. Moyle 2002
Mosquitofish	77–86°F	95–103.1°F	a. Nevada Department of Environmental Protection 2016 b. Carveth et al. 2006 (103.1°F CT_{MAX} acclimated at 77°F); Nevada Department of Environmental Protection 2016 (95°F acute tolerance)
Black bullhead	68–91.4°F	100.6°F	a. Moyle 2002 (based on brown bullhead) b. Smale and Rabeni 1995
Green sunfish	78.8–86°F	99.3°F	a. Moyle 2002 b. Carveth et al. 2006 (CT_{MAX} acclimated at 77°F)
Largemouth bass	77–89.6°F	95–100°F	a. Moyle 2002 b. Davis et al. 2019 (103.1°F CT_{MAX} acclimated at 60.8°F); Carveth et al. 2006 (103.1°F CT_{MAX} acclimated at 77°F)
Fathead minnow	71.6–73.4°F	97°F	a. Moyle 2002 b. Carveth et al. 2006 (CT_{MAX} acclimated at 77°F)

NOTES: CT_{MAX} = critical thermal maximum; °F = degrees Fahrenheit

a. Reference for preferred or optimum temperature.
b. Reference for maximum tolerance (with degrees Celsius converted to Fahrenheit).

SOURCE: Data compiled by Environmental Science Associates in 2025

Unarmored Threespine Stickleback

Past research on UTS thermal physiology is limited to a single study. Feldmeth and Baskin (1976) found that UTS had an acute upper lethal temperature (CT_{MAX})[14] of about 87°F when acclimated at 46°F, and 94.3°F when acclimated at 72.9°F. These results indicate that UTS can increase their thermal tolerance

14 "CT_{MAX}" was defined by Feldmeth and Baskin (1976) as the temperature at which fish were observed to stop passing water through their gills.

with acclimation. Feldmeth and Baskin (1976) describe 72.9°F as the warmest summer temperatures typically experienced in the Santa Clara River.

Studies of threespine stickleback from more northerly regions indicate that egg development is inhibited at 77°F and above (Wootton 1976). Additionally, elevated water temperatures can alter parental care and reduce reproductive success. For example, increasing water temperature by 10.8°F above ambient conditions (from 60.8 to 62.6°F) led to increased egg-fanning effort by males, resulting in higher rates of incubation failure and mortality (Hopkins et al. 2011).

Santa Ana Sucker

SAS prefer temperatures less than 71.6°F, according to the species summary in Moyle (2002). In the Santa Clara River, SAS have been documented in waters between 50°F and 79°F (Greenfield et al. 1970). However, surveys in the Santa Ana River have documented SAS occupying habitat with temperatures ranging from 59°F to 82°F (Swift 2001) and 68.4°F to 82.9°F (Santa Ana Watershed Association 2014). Recent surveys on the Santa Ana River found adults occupying habitat in the upper 80s to low 90s °F, but failed to detect SAS as water temperatures approached 95°F (Wulff et al. 2023; Russell, pers. comm. 2024).[15] Although a lethal limit for water temperature is unknown, water temperatures much above 86°F likely limit distribution and movement of this species (Swift 2001). No information on the thermal capacity of embryo and larval SAS is available.

Arroyo Chub

Arroyo chub are adapted to survive warm, hypoxic conditions in summer and high flows and turbidity levels in winter. In laboratory studies, arroyo chub from Big Tujunga Creek (approximately 20 miles from the Santa Clara River) were fully acclimated and held at 86°F for 5-8 weeks (Castleberry and Cech 1986). Growth temperatures for the species are 50–75°F (Moyle 2002). The early life stages of arroyo chub remain unstudied. Nevertheless, the extended spawning season, which includes peak spawning in June and July, suggests that this species' fundamental thermal physiology is not a limiting factor for existing in the Santa Clara River.

Non-native Fishes

The non-native species that make up the majority of the Santa Clara River fish community exhibit broad thermal tolerances and often survive higher temperatures than UTS (Table 5-5). Small invertebrate-eating (invertivorous) fishes, which may compete with native fishes for food or directly predate on young life stages, exhibit greater acute thermal tolerance than UTS, ranging from 97°F for fathead minnow (Carveth et al. 2006) to greater than 104°F for mosquitofish (Carveth et al. 2006) and goldfish (Moyle 2002). Several predatory fish in the Study Area are considered warm water species, and all exhibit CT_{MAX} higher than that for UTS: largemouth bass, 95–100°F (Davis et al. 2019; Carveth et al. 2006); green sunfish, 95°F to 102.2°F (Nikel et al. 2021); and black bullhead catfish, 100.6°F (Smale and Rabeni 1995). These species may also exhibit interpopulation variation in thermal physiology, but these data were collected

[15] The Riverside-Corona Resource Conservation District manages the Santa Ana Sucker Conservation and Research Program in cooperation with the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife. The program's studies evaluate SAS tolerance to different levels of water pollution and the species' life history and longevity, both in captivity and in the wild.

from more northern populations; thus, it is likely that Santa Clara River populations would exhibit at least equal, if not greater thermal capacity.

5.5.1.2 Herpetofauna

Amphibian species in the Study Area use aquatic habitat for breeding, and thus their interaction with water temperature presumably would be limited to spawning, embryo incubation, and larval rearing. Larval development is accelerated in warmer water temperatures. For example, the arroyo toad (*Anaxyrus californicus*) would be exposed to water temperatures during the spawning period (April–July), embryo incubation, and larval rearing (70–90 days after egg fertilization [Jennings and Hayes 1994]). No literature was found on the thermal tolerance of arroyo toad embryos and larvae or the impact of temperature on the development of these young life stages. However, juvenile toads, which are terrestrial but associated with the damp substrates near the stream, select habitats with temperatures 89.6°F to 95°F and avoid landscapes with temperatures warmer than 107.6°F (Jennings and Hayes 1994). Extended droughts have been theorized to lead to population declines among arroyo toad because habitat for spawning would be limited (Hitchcock et al. 2022).

Western pond turtles (*Actinemys pallida)* are highly dependent on aquatic habitat for feeding and rearing but lay their eggs in upland habitat; they prefer water temperatures up to 104°F. Two-striped garter snakes (*Thamnophis hammondii)* use upland areas, riparian areas, and aquatic habitat for foraging and are likely tolerant of warm water, although specific temperature preferences are unknown.

5.5.1.3 Crayfish

Red swamp crayfish prefer water temperatures from 70°F to 86°F but can adapt to colder temperatures (Peruzza et al. 2015). Red swamp crayfish exhibited CT_{MAX} values exceeding 102°F after 2 weeks of acclimation at 75°F, 81°F, and 86°F (Logarbo and Bonvillain 2020).

5.5.2 Ecological Thermal Physiology

This Study included a qualitative assessment of the potential effects of increased water temperatures on ecological factors such as interspecific interactions (predation and competition). Direct assessments of predation rates, competitive outcomes, and disease susceptibility at varying temperatures require time-intensive, multi-species trials (see McInturf et al. 2022 for example). A practical alternative is a qualitative comparison of species based on thermal tolerances, diet, and DO requirements. The question of whether DO levels are sufficient to support UTS (>2.0 mg/l; Feldmeth and Baskin 1976; Mulder 2017) was resolved through diurnal DO monitoring, which documented DO levels at no less than 5.9 mg/l even during the night in the summer (Section 3.4.3, *Diurnal Dissolved Oxygen Trends*).

The aquatic assemblage in the Santa Clara River is dominated by non-native species (Tables 5-1 and 5-4). **Table 5-6** summarizes the occurrence and diet of aquatic species documented in the Study Area. Most fish species feed on invertebrates or are omnivorous (feeding on algae, plant material, detritus, invertebrates). Stickleback predominantly prey on invertebrates such as copepods and chironomids (Wootton 1984). Omnivores include arroyo chub, fathead minnow, carp, and goldfish. Mosquitofish, carp, fathead minnow, and convict cichlid may compete for habitat or food resources or consume eggs (Moyle 2002). Santa Ana sucker predominantly feed on algae and detritus that they scrape from rocks and other surfaces. The Santa Clara River also has large non-native predatory fishes including largemouth bass, green sunfish, and black bullhead catfish, which can prey on small fish species such as UTS and early life stages of other fishes. Diets frequently change as individuals grow and their capacity to capture prey increases. Smaller fish or younger life stages may eat algae or zooplankton, then shift to larger prey such as benthic invertebrates, insect larvae, and/or fish.

TABLE 5-6
OCCURRENCE AND DIET OF SANTA CLARA RIVER AQUATIC SPECIES

Species	Occurrence[a]	Diet and Foraging Behavior	References
Fish Native to Santa Clara River			
Unarmored threespine stickleback (*Gasterosteus aculeatus williamsoni*)	Rare	Benthic invertebrates (crustaceans, larval insects); occasional cannibalism of eggs by males.	Wootton 1984
Fish Native to Southern California			
Santa Ana sucker (*Catostomus santaanae*)	Common	Algae (especially diatoms) from rocks; detritus; may also eat insects.	Moyle 2002
Arroyo chub (*Gila orcuttii*)[b]	Common	Omnivorous. Algae, insects, and small crustaceans.	Moyle 2002
Non-native Fish			
Convict cichlid (*Archocentrus nigrofasciatus*)	Common	Worms, crustaceans, insects (dipteran larvae), fish, and plant matter.	USFWS 2025
Goldfish (*Carassius auratus*)	Rare	Algae and organic detritus, sometimes zooplankton and aquatic macrophytes. Young eat zooplankton and aquatic insects.	Moyle 2002; Bonham and Siriwardena 2010
Prickly sculpin (*Cottus asper*)	Common	Benthic invertebrates, aquatic insects, mollusks. Adults may also eat small fish and frogs.	Moyle 2002
Common carp (*Cyprinus carpio*)	Common	Omnivorous. Aquatic insect larvae, small mollusks, crustaceans, worms, some plant/algae material. Young eat algae and zooplankton.	Moyle 2002
Mosquitofish (*Gambusia affinis*)	Common	Opportunistic feeder of mosquito larvae, algae, zooplankton, terrestrial insects, plus algae and diatoms if food is scarce. Cannibalism possible when mosquitofish densities are high.	Moyle 2002; USFWS 2017
Black bullhead (*Ictalurus melas*)	Rare	Aquatic insects, crustaceans, mollusks, dead fish, slow live fish.	Moyle 2002
Green sunfish (*Lepomis cyanellus*)	Rare	Young feed on invertebrates and small fish. Adults switch to large aquatic and terrestrial insects, crayfish, and other fish.	Moyle 2002; Allen 2019
Largemouth bass (*Micropterus salmoides*)	Common	Young feed on crustaceans and rotifers, then insects and fish fry. Adults feed on fish, crayfish, tadpoles, and frogs. Pursuit and ambush predator.	Moyle 2002; USFWS 2019
Fathead minnow (*Pimephales promelas*)	Rare	Opportunistic benthic feeder. Filamentous algae, diatoms, small invertebrates (crustaceans, chironomids), and loose organic matter.	Moyle 2002; Wakefield 2012
Sailfin molly (*Poecilia latipinna*)	Rare	Detritus and algae, sometimes invertebrates.	Moyle 2002

Species	Occurrence[a]	Diet and Foraging Behavior	References
Non-native Herpetofauna			
American bullfrog (*Lithobates catesbeianus*)	Common	Generalist predator of invertebrates, amphibians (tadpoles and adults), fish, and terrestrial vertebrates. Cannibalism.	Jordon 2024
African clawed frog (*Xenopus laevis*)	Common	Omnivorous. Benthic aquatic invertebrates, as well as frogs (tadpoles and adults), fish (including unarmored threespine stickleback), and terrestrial invertebrates. Cannibalism.	Tinsley and McCoid 1996; Lafferty and Page 1997; Stratton and Somma 2024
Non-native Invertebrate			
Red swamp crayfish (*Procambarus clarkii*)	Common	Omnivorous. Juveniles consume more invertebrates and adults consume more detritus and plants. Cannibalism.	Correia 2003

NOTES:

a. Occurrence based on review of reported surveys conducted 1980–2023. Ratings may not be an accurate assessment of current occurrence or abundance.
b. Arroyo chub are native to Southern California in general but are not native to the Santa Clara River watershed.

SOURCE: Data compiled by Environmental Science Associates in 2025

The aquatic life stages (tadpoles) of most amphibians are herbivorous, while adults usually feed on invertebrates. However, two non-native amphibians, American bullfrog and African clawed frog, are well-known predators on small fish (Lafferty and Page 1997; Moyle 2002). Bullfrogs are generalist predators that consume various prey including insects, other amphibians (they may cannibalize tadpoles and adults at high bullfrog densities), fish, crayfish, worms, and even small mammals and birds (Jordon 2024). African clawed frogs are voracious generalist predators and scavengers that mainly consume aquatic invertebrates, as well as aquatic vertebrates (fish, tadpoles, and other frogs), terrestrial invertebrates, and terrestrial vertebrates (Lillo et al. 2011; Stratton and Somma 2024). African clawed frogs were identified as a predator of rare fish in Southern California (Lafferty and Page 1997), including UTS (Tinsley and McCoid 1996 cited in Lillo et al. 2011; USFWS 2009). These predators will cannibalize their own tadpoles and adults, which allows them to persist in invaded areas with a depleted prey population (McCoid and Fritts 1993).

The two-striped garter snake, a native aquatic snake, preys on fish including threespine stickleback (Bell and Haglund 1978). This species is uncommon in the Study Area.

Non-native invertebrates such as crayfish can also disrupt aquatic ecosystems. Red swamp crayfish feed on plants, tadpoles, snails, fish and amphibian eggs, and insect and newt larvae (Momot 1995; Momot et al. 1978; Stenroth and Nystrőm 2003).

Invasive species often have a competitive edge over native species because of their generalist feeding strategies. This dietary flexibility allows them to adapt to varying environmental conditions and resource availability, giving them a significant advantage over any native species that have more specialized diets (Moyle and Light 1996). Omnivores and detritovores use a food resource that is rarely limited in aquatic systems (Moyle and Light 1996). The ability to utilize diverse food sources enables invasive species to maintain their populations even when specific resources are scarce, thereby increasing their chances of long-term persistence in new environments (Rahel and Olden 2008). Because of the food resource abundance in the Study Area, this relative advantage was not identified as a limiting factor.

Warmer conditions could increase impacts on small native fish from non-native predators and competitors (Rahel and Olden 2008). Increased metabolic demands at higher temperatures require greater food intake or more frequent foraging, increasing exposure to predation. Thermal stress may also reduce escape performance in sensitive species. Given the thermal sensitivity of UTS (Feldmeth and Baskin 1976) and the higher tolerance to warm water temperatures of non-native aquatic species that dominate the Santa Clara River, warmer water temperatures in the Study Area may shift competitive dynamics in favor of thermally tolerant species. However, predation from non-native fishes occurs at all temperatures, and the degree to which UTS are limited by predation is unknown.

5.6 Benthic Macroinvertebrate and Algal Assessment

5.6.1 Background

BMI indices are widely used to assess stream health because they integrate biological responses to multiple stressors over time (Mazor et al. 2016). These communities respond to changes in flow, sediment, temperature, and water quality, making them effective for detecting cumulative impacts rather than single-point measurements. Shifts in community composition can indicate changes in overall habitat conditions, but may not isolate temperature effects since responses can be confounded by other factors (Rehn et al. 2015).

As described earlier in Section 1.2, *Study Area and Environmental Setting*, the Study Area is a dynamic and highly modified system. Such conditions generally limit the diversity and stability of BMI assemblages and are expected to favor more tolerant taxa. Sand substrates provide limited habitat stability, reduced surface area for periphyton growth, and minimal refugia during high-flow events (Allan and Castillo 2007). Periods of intermittent drying, elevated temperatures, and reduced DO levels during low-flow periods can further constrain sensitive taxa such as Ephemeroptera, Plecoptera, and Trichoptera (EPT), which are key biological indicators of water and habitat quality (Rehn et al. 2015). For example, BMI sampling in the Santa Clara River near McBean Parkway in 2005 and 2006 found that most BMI inhabiting that reach were invertebrates that are moderately to highly tolerant of poor environmental conditions and are both feeding and habitat generalists. (Hovore et al. 2008).

Similarly, algal indices can be used to assess stream health, with a focus on nutrient loads, sediment, and water quality (Theroux et al. 2020). Like BMI, algal communities integrate environmental conditions over time and can be used to detect cumulative impacts affecting primary producers. However, as noted earlier (Section 5.2), shifts in algal community composition also reflect multiple environmental factors such as light availability, flow stability and disturbance, and nutrients (Frazier 2017; Bernhardt et al. 2022), limiting their ability to isolate temperature effects (Aristsi et al. 2015; Zhang and Chadwick 2022). Predictive algal indices have shown mixed performance in practice (Theroux et al. 2020), and limited algal data for the Santa Clara River constrain quantitative analysis. Nonetheless, because algal communities respond to temperature fluctuations (Zhang et al. 2018), qualitative analysis of species presence can still offer information on relative habitat conditions upstream and downstream of the WRP outfalls. Diatoms, which tend to be better adapted to cooler water (Lurling et al. 2013), may provide insight into potential thermal effects.

As part of the National Pollutant Discharge Elimination System (NPDES) monitoring requirements for the Valencia WRP, Saugus WRP, and the proposed Newhall Ranch WRP, LACSD has conducted BMI and benthic algal bioassessments downstream of the Saugus WRP, upstream and downstream of the Valencia WRP, and at Newhall Ranch approximately 3.3 miles downstream of the Valencia WRP[16]. Sampling near the Valencia WRP ceased after 2015 because the California Department of Fish and Wildlife disallowed sample collection in scientific collection permits issued to the District because of the potential for take of UTS, a fully protected species. In addition, sampling upstream of the Saugus WRP was often not possible due to lack of water.

This Study conducted surveys in June 2025 to compare BMI and algal communities upstream and downstream of the Valencia and Saugus WRPs discharge. This is the first time that sampling has been allowed around the Valencia WRP since 2015. BMI communities were evaluated quantitatively, with a focus on detecting any differences in overall assemblage condition between upstream and downstream sites. Algal communities were assessed qualitatively by examining shifts in the relative contribution of major diatom groups, given the limited availability of algal data and challenges associated with predictive algal indices.

5.6.2 Methods

5.6.2.1 California Stream Condition Index

The California Stream Condition Index (CSCI) is a statewide biological index developed to assess the ecological health of wadable streams based on BMI assemblages (Rehn et al. 2015). It integrates two primary components: the Observed/Expected taxonomic index and the Multimetric Index (MMI). The Observed/Expected index compares the taxa found at a site to those expected under reference (minimally disturbed) conditions, providing a measure of taxonomic completeness and potential biotic impairment. The MMI combines multiple biological metrics—such as functional feeding group diversity, tolerance values, and composition of sensitive taxa—into a single score representing overall biological condition.

The six MMI components of the CSCI score are valuable for identifying compositional differences in the communities. They were therefore selected to explore differences in the communities above and below the Valencia WRP outfall. The six metrics are as follows.

1. **Overall Richness.** Greater richness generally indicates higher habitat diversity and water quality. Lower richness may indicate relative impairment.
2. **Intolerant Taxa Richness.** Streams with high richness of intolerant taxa are typically less affected by pollution and habitat degradation. Lower intolerant taxa richness may indicate relative impairment.
3. **Shredder Taxa Richness.** Shredder taxa break down leaf litter and organic matter. A decline in shredder richness may indicate a lack of riparian leaf input, poor habitat quality, or altered stream energy flow (e.g., increased algae dominance caused by nutrient pollution).
4. **Percent Composition of EPT.** Ephemeroptera (mayflies, “E”), Plecoptera (stoneflies, “P”), and Trichoptera (caddisflies, “T”) are highly sensitive to pollution, temperature fluctuations, and habitat alteration. A high percentage suggests good water quality and minimal disturbance, while a low percentage may indicate pollution, increased temperature, or habitat degradation.

[16] Although the proposed Newhall Ranch WRP location has been sampled historically (NPDES Station Codes NH-RSW-001U and NS-RSW-002D), since no WRP outfall exists currently, it was not included in any of the analyses.

5. **Percent Composition of "Clinger" Taxa.** Clinger taxa rely on stable substrates and are sensitive to sedimentation and habitat disturbance. A high percentage indicates good habitat stability, while a low percentage suggests excessive deposition of fine sediment or flow disturbances.
6. **Percent Composition of Coleoptera Taxa.** Coleopterans (beetles) thrive in a variety of microhabitats. Changes in their abundance can indicate shifts in habitat complexity, water quality, and availability of organic matter.

The CSCI is calibrated such that the mean normalized reference score is 1.0, with lower scores indicating increasing departure from reference condition. The widely accepted threshold for similarity to reference condition is the 10th percentile of the reference distribution (CSCI = 0.79). Sites with CSCI scores above 0.79 are considered supportive of warmwater aquatic life beneficial uses based on BMI assemblages (LACSD 2017). For sites that fall outside CSCI reference conditions due to unmanageable features such as channelization, an upstream–downstream comparison can be used to evaluate the impact of point discharges.

5.6.2.2 Historical Benthic Macroinvertebrate Surveys and Datasets

Previous bioassessments in the Study Area have characterized stream habitat conditions as disturbed and the biological community as "likely altered" according to the CSCI classification (LACSD 2017, 2022) (Appendix B).

For this Study, LACSD provided raw BMI survey data from previous surveys (2004–2024). The historical sampling was conducted at four stations designated for NPDES bioassessment, one upstream and one downstream of each of the Valencia and Saugus WRP outflow channels within the mainstem of the Santa Clara River. (**Table 5-7**).

TABLE 5-7
LOCATIONS OF HISTORICAL AND CURRENT BENTHIC MACROINVERTEBRATE SAMPLING EFFORTS

Bioassessment Reach	NPDES Station	Position Relative to Outflow	Period of Record
Saugus WRP			
Saugus US	RA	Upstream of outflow	2024–2025[a]
Saugus DS	RB	Downstream of outflow	2004–2012, 2016–2022, 2024
Valencia WRP			
Valencia US-1	—	Upstream of outflow, approx. 700 meters upstream of RC	2025
Valencia US-2	RC	Upstream of outflow	2004–2011, 2013–2015, 2025[b]
Valencia DS-1	RD	Downstream of outflow (in 2025, reach straddles outflow channel)	2004–2011, 2013–2015, 2025[b]
Valencia DS-2	—	Downstream of outflow, approx. 400 meters downstream of RD	2025
Valencia DS-3	—	Downstream of outflow, approx. 500 meters downstream of DS-2	2025

NOTES: approx. = approximately; DS = downstream; NPDES = National Pollutant Discharge Elimination System; US = upstream; WRP = Water Reclamation Plant

a. Sampling upstream of the Saugus WRP at SA-RA was not possible in many years due to lack of water in the river channel.
b. Sampling at RC and RD was not permitted 2016–2024.

SOURCE: Data compiled by Environmental Science Associates in 2025

Each reach was broken into 11 transects (A-K). BMI samples were collected starting with the downstream transect and proceeding upstream. Samples were collected at either 25 percent instream of the right bank (R), 50 percent instream of the right bank (C), or 75 percent instream of the right bank (L) at each transect following an R, C, L, R, C, L, etc., pattern starting with the right bank. This alternating pattern was followed along each sampling reach until a single sample was collected at each transect (A–K).

BMI were collected using a 1-foot-wide, 500-micrometer mesh D-frame kick-net. A 1-foot by 1-foot sampling plot, directly in front of the net, was sampled by first checking for heavy organisms such as clams and snails. These organisms were removed from the substrate by hand and placed into the net. Stones larger than a golf ball were carefully picked up and rubbed in front of the net to collect all attached animals. The remaining underlying substrate was sampled by digging through the material to a depth of 4 inches (10 centimeters) and thoroughly manipulating the substrate in each sampling plot with a consistent sampling effort (approximately 1–3 minutes). This procedure was repeated at each of the 11 transects. The resulting 11 samples from a sampled site were composited into a 1-liter jar and preserved in the field using 95 percent ethanol. Larger samples (e.g., samples containing more than 50 percent sediment or 66 percent organic material) were split into additional jars.

Raw BMI data provided by LACSD in tabular Microsoft Excel format were reformatted for compatibility with the R programming language to facilitate the calculation of CSCI metrics. Corresponding CSCI predictor data for each sampling site were also provided by LACSD in a comma-separated value file and incorporated into the analyses.

Because of the limited frequency of sampling at the Saugus upstream station, which was sampled only twice over a 20-year period due to lack of water in most years, the Saugus WRP did not provide sufficient temporal representation for meaningful comparison and was therefore excluded from detailed evaluation. Consequently, this analysis focuses on data collected from the Valencia WRP.

In some years, multiple samples were collected across different months (**Table 5-8**); all such observations were retained to represent seasonal variability. However, samples identified as quality assurance/quality control duplicates (SampleID = “DUP”) were removed from subsequent analyses to maintain data independence.

TABLE 5-8
SAMPLING OCCASIONS WITH DATA FOR BENTHIC MACROINVERTEBRATE SAMPLING AT THE VALENCIA WATER RECLAMATION PLANT

Year	Jan	May	Jun	Jul	Sep	Nov
2004						US/DS
2005			US/DS		US/DS	
2006	DS			US/DS	US/DS	
2007		US/DS				US/DS
2008			US/DS			
2009			US/DS			
2010		US/DS				
2011				US/DS		
2013			US/DS			
2014			US/DS			
2015			US/DS			
2025			US/DS			

NOTES: DS = downstream; US = upstream. Sampling was not permitted 2016–2024.
SOURCE: Data provided by Los Angeles County Sanitation Districts in 2025

5.6.2.3 2025 Benthic Macroinvertebrate Sampling

ESA conducted BMI sampling June 10–11, 2025, near historical NPDES stations (**Figure 5-2**), following established protocols from previous sampling events, with minor modifications to accommodate site-specific conditions.

The standard sampling design was maintained, consisting of one BMI sample collected from the right, center, or left bank at each of the 11 transects within a defined bioassessment reach, composited into a single reach-wide sample.

At the Saugus WRP site, however, sampling on June 10 was curtailed after the incidental capture of one adult and one juvenile threespine stickleback and the observation of approximately 10–15 threespine stickleback individuals[17]. Because this sampling was curtailed, only a single composite BMI sample was collected at the upstream (US) bioassessment reach.

At the Valencia WRP site, changes in river channel morphology altered the hydrologic configuration in such a way that Reach DS-1 (NPDES Station RD) was no longer fully downstream of the effluent confluence. To ensure that sampling would adequately capture the potential influence of the discharge and to characterize the longitudinal extent of possible effects, three new bioassessment reaches were established. One upstream reach, US-1, was located approximately 700 meters upstream of the existing US-2 reach (NPDES Station RC). Two downstream reaches were added, approximately 400 meters and 900 meters downstream of DS-1.

17 Once a threespine stickleback was inadvertently captured, sampling was halted and the California Department of Fish and Wildlife was consulted, as required by the Scientific Collecting Permit for this Study. The Department allowed sampling at other sites with the condition that sampling be discontinued if stickleback were encountered again. These individuals could not be definitively identified in the field as UTS, PATS, or hybrids. Nearby Bouquet Creek has both UTS and hybrid stickleback.

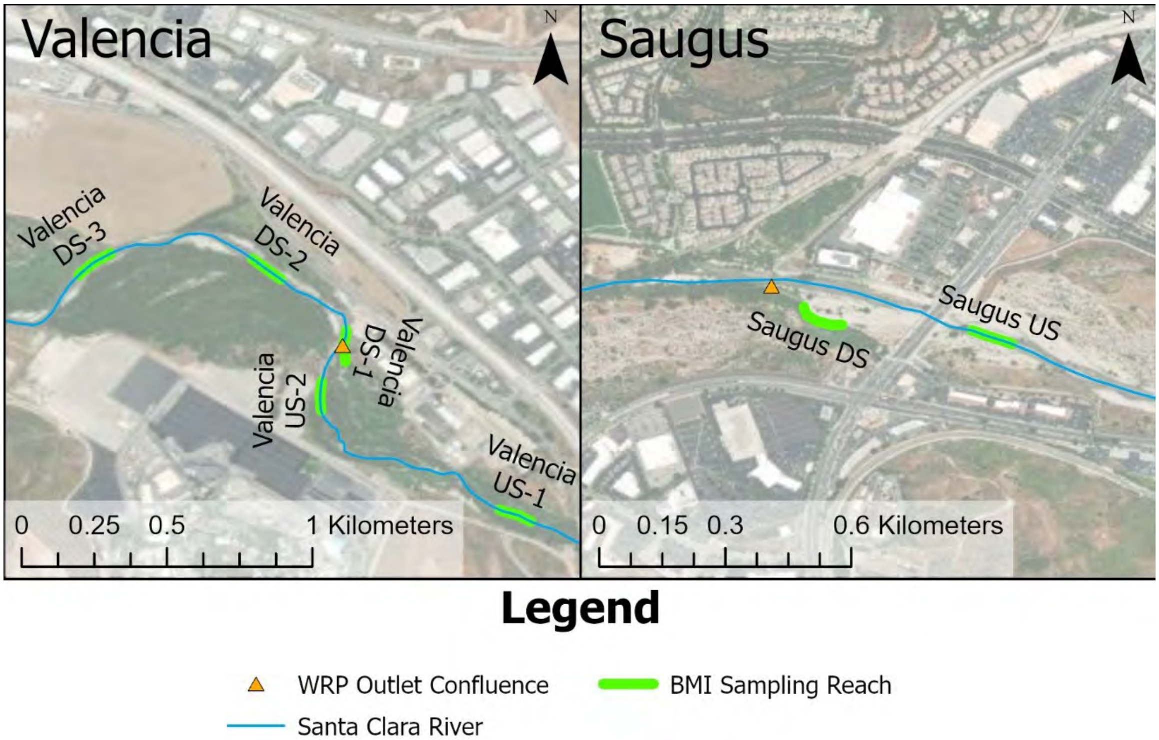


Figure 5-2
June 2025 BMI Sampling Locations Near the Saugus WRP and Valencia WRP

5.6.2.4 Benthic Macroinvertebrate Analysis

Previous surveys have characterized the Santa Clara River as a highly modified system with benthic macroinvertebrate assemblages indicating persistent biological alteration relative to reference conditions. This Study element focused on comparing conditions between the communities upstream and downstream of the Valencia WRP discharge, rather than emphasizing the absolute scores.

To analyze whether the effluent has an impact on the BMI community, comparisons were made using the CSCI MMI scores. Following methods from Rehn et al. (2015), CSCI scores and the component MMI scores ("metric values") were calculated for all Valencia WRP sampling events. These were compared using a permutation test for paired differences of means to evaluate similarity in biological responses between upstream and downstream sampling locations. The permutation test is a nonparametric statistical method that estimates p-values by repeatedly and randomly resampling the observed data to generate a null distribution. In this Study, 10,000 permutations were performed to represent the possible outcomes under the generalized null hypothesis of no difference between paired observations. The p-value was calculated as the proportion of simulated outcomes that were equal to or more extreme than the observed difference (Helsel et al. 2020).

The null hypothesis for this assessment (H_0) states that there is no difference in biological response (e.g., "metric value") between upstream and downstream reaches for the Valencia WRP. Rejection of the null hypothesis indicates a statistically significant difference in mean response, which may reflect an influence of WRP discharge. Failure to reject the null hypothesis suggests no statistically significant difference in biological conditions between upstream and downstream reaches, implying that WRP discharge did not measurably affect BMI community response.

5.6.2.5 2025 Diatom Algal Sampling

Sampling for algae followed Surface Water Ambient Monitoring Program (SWAMP) protocols for collecting stream algae (Stancheva et al. 2015) and was conducted jointly with the sampling for BMI as described above. Algal samples were collected within all five bioassessment reaches at the Valencia WRP. Sampling at the Saugus WRP was curtailed after the incidental capture of a threespine stickleback, as per conditions of the California Department of Fish and Wildlife Scientific Collecting Permit. Therefore, only the results from samples at the Valencia WRP are presented below.

Algae samples were preserved and shipped to Aquatic Biology Associates (ABA) according to their protocols for taxonomic identification. ABA classified diatoms to the lowest possible taxonomic level and then counted individuals and calculated biovolume and density of each taxa. Taxa were subsequently grouped to the genus level for the qualitative analysis. Algal communities were compared qualitatively among the five Valencia WRP reaches and aggregated to compare reaches above (Sites US-1, US-2) against those below (Sites DS-1, DS-2, DS-3) the Valencia WRP.

5.6.3 Results

5.6.3.1 Multiyear Benthic Macroinvertebrate Results

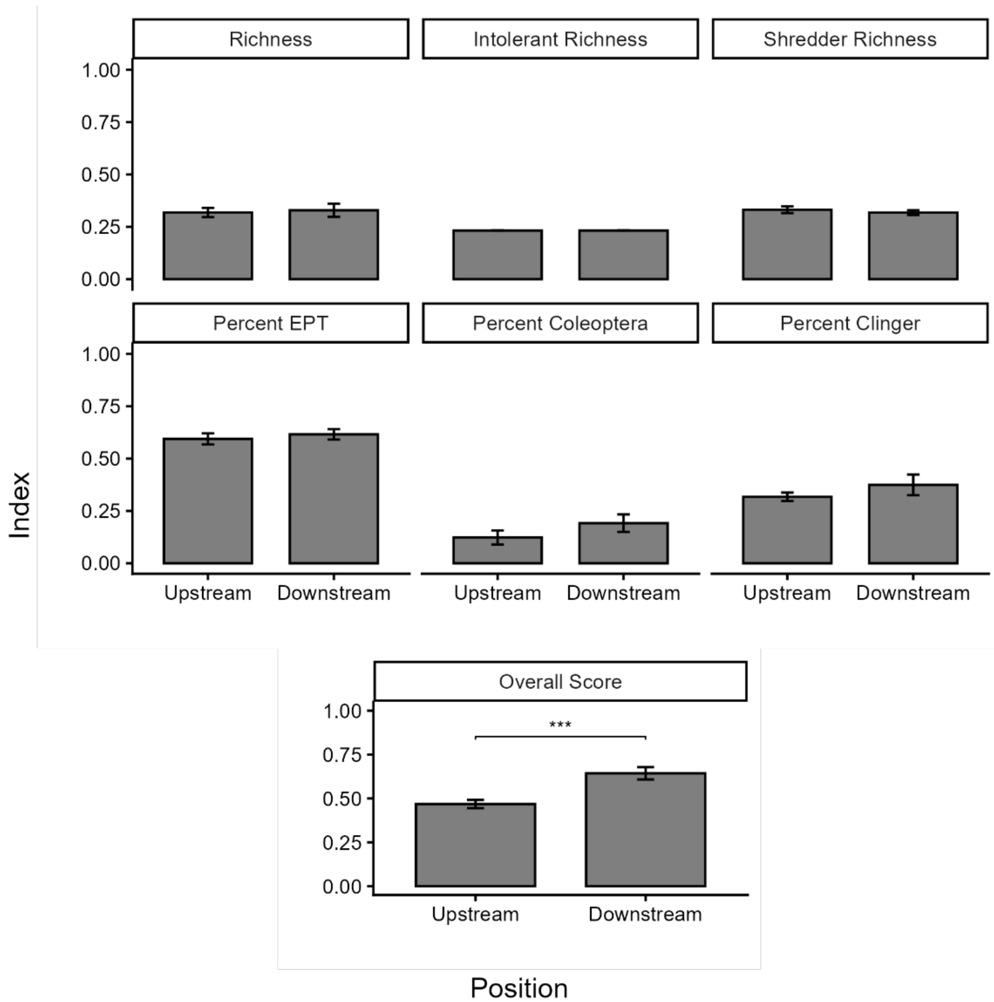
Permutation tests comparing upstream and downstream BMI communities at the Valencia WRP site found a statistically significant difference in the overall CSCI score ($p < 0.001$), with higher average scores downstream (0.63) than upstream (0.46) (**Table 5-9**; **Figure 5-3**). However, evaluation of individual MMI components—richness, intolerant taxa, shredder taxa, EPT composition, clinger taxa, and coleoptera taxa—showed minimal differences that were not statistically significant between sites. This suggests that the difference observed in the overall CSCI scores is not ecologically meaningful. The biological metrics remained similar between upstream and downstream locations, and the composite score does not reflect a substantive shift in community composition or function.

TABLE 5-9
PERMUTATION TEST FOR SIMILARITY RESULTS COMPARING UPSTREAM AND DOWNSTREAM SAMPLES FOR ALL BENTHIC MACROINVERTEBRATE SAMPLES AT THE VALENCIA WATER RECLAMATION PLANT

Metric	Z-Score	P- value	Statistical Significance	Site with Higher Score
Overall CSCI Score	-3.34	<0.001	***	Downstream
Overall Richness	-0.23	0.81	NS	Downstream
Intolerant Richness	0.23	0.82	NS	No Difference
Shredder Richness	1.43	0.51	NS	Upstream
Percent Composition—EPT	-0.64	0.52	NS	Downstream
Percent Composition—Clinger	-1.02	0.31	NS	Downstream
Percent Composition—Coleoptera	-1.16	0.25	NS	Downstream

NOTES: *** = p < 0.001, highly statistically significant; CSCI = California Stream Condition Index; EPT = Ephemeroptera, Plecoptera, and Trichoptera; NS = no statistically significant difference.

SOURCE: Data compiled by Environmental Science Associates in 2025



NOTES: EPT = Ephemeroptera, Plecoptera, and Trichoptera. The graphs present a comparison of upstream vs. downstream index values for the Overall California Stream Condition Index score, and individual Multimetric Index components. Brackets identify statistical significance levels, “***” = p<0.001. Sampling years: 2004–2011, 2013–2015, 2025.

Figure 5-3

Average Benthic Macroinvertebrate Scores Upstream and Downstream of the Valencia WRP

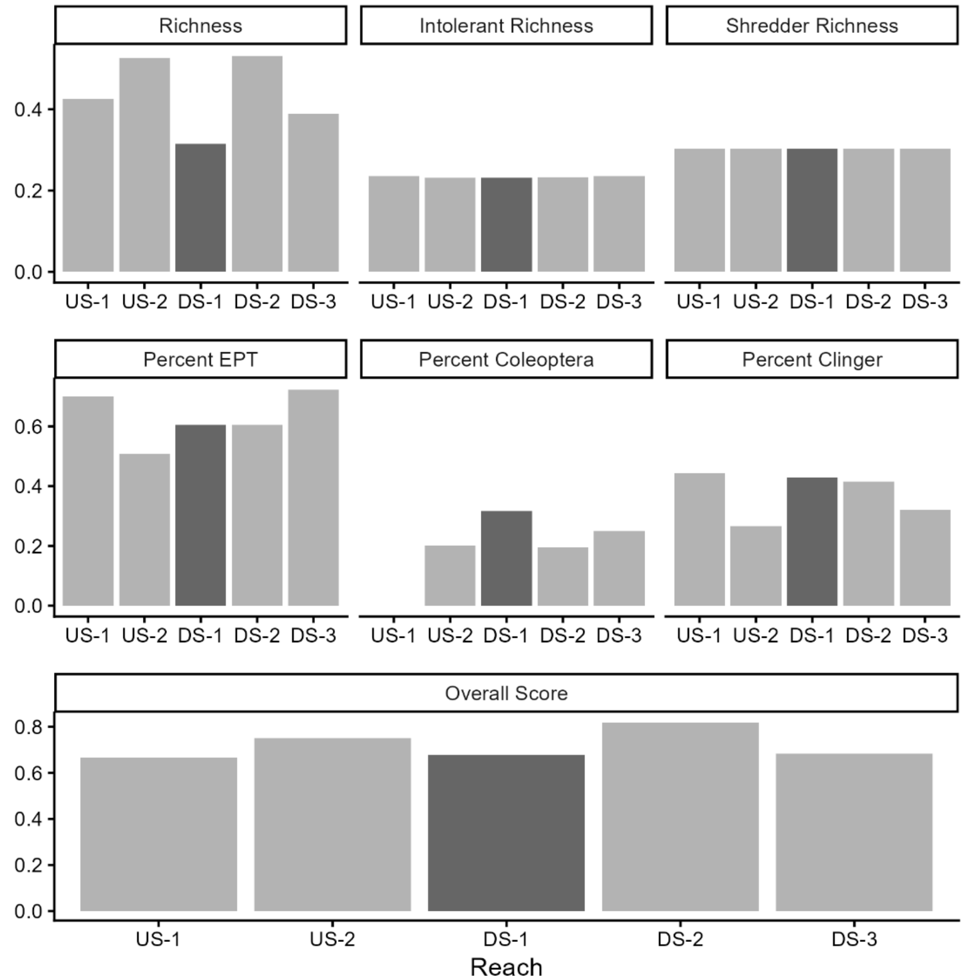
5.6.3.2 2025 Benthic Macroinvertebrate Results

All Valencia WRP samples collected in 2025 were analyzed independently for CSCI and associated MMI metrics. Because only a single sample was available for each of the supplemental 2025 sites (US-1, DS-2, and DS-3), statistical comparisons were not performed. Interpretation was further complicated by the location of Site DS-1, which straddles the effluent outfall and could not be confidently classified as either upstream or downstream of the discharge. Therefore, DS-1 was excluded from all mean calculations.

Graphical evaluation of the MMI indices showed patterns consistent with historical data (**Figure 5-4**). Mean taxonomic richness varied only slightly between upstream (0.48) and downstream (0.46) locations, with no clear longitudinal trend. Intolerant taxa richness and shredder taxa richness were identical across sites. The percent composition of EPT taxa was modestly higher downstream, but this trend was inconsistent and mean values were nearly equivalent (upstream 0.60; downstream 0.66). Mean clinger taxa composition was nearly identical between sites (upstream 0.35; downstream 0.37). The mean

Coleoptera index was higher downstream (0.22) than upstream (0.10), but this likely reflects natural patchiness in the sparse beetle distribution rather than a response to effluent.

Overall, the mean CSCI score was higher downstream (0.75) than upstream (0.71), mirroring the pattern observed in historical data and suggesting similar biological condition trends over time. However, the minimal differences in individual component metrics indicate that the observed variation in the composite score is not ecologically meaningful.



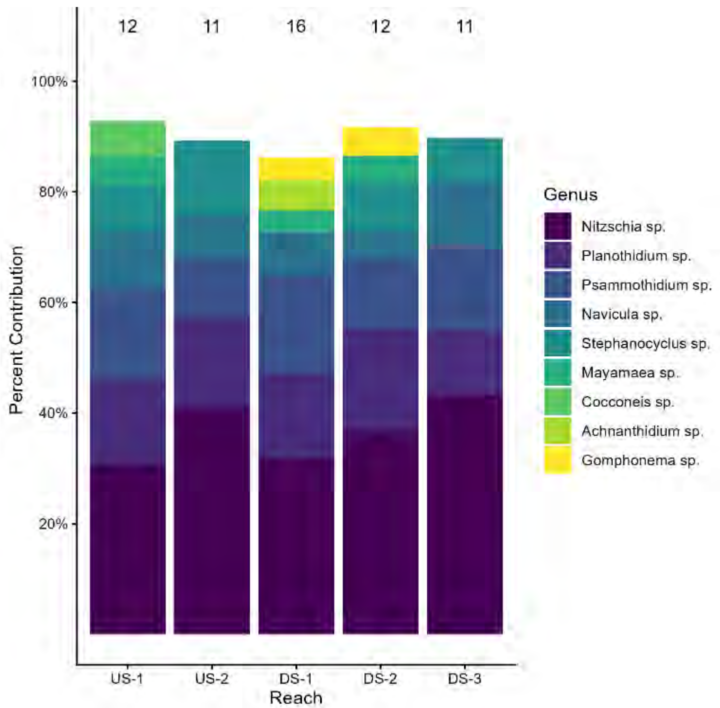
NOTES: DS-# = downstream reach; EPT = Ephemeroptera, Plecoptera, and Trichoptera; US-# = upstream reach. Index values for the six Multimetric Index components and the overall California Stream Condition Index score for the five Valencia reaches sampled in 2025. Reach DS-1 is darkened as the reach straddles the effluent outflow and therefore results cannot be confidently assessed as being “influenced” or “not influenced” by effluent temperatures.

Figure 5-4

2025 Benthic Macroinvertebrate Scores at the Valencia Water Reclamation Plant

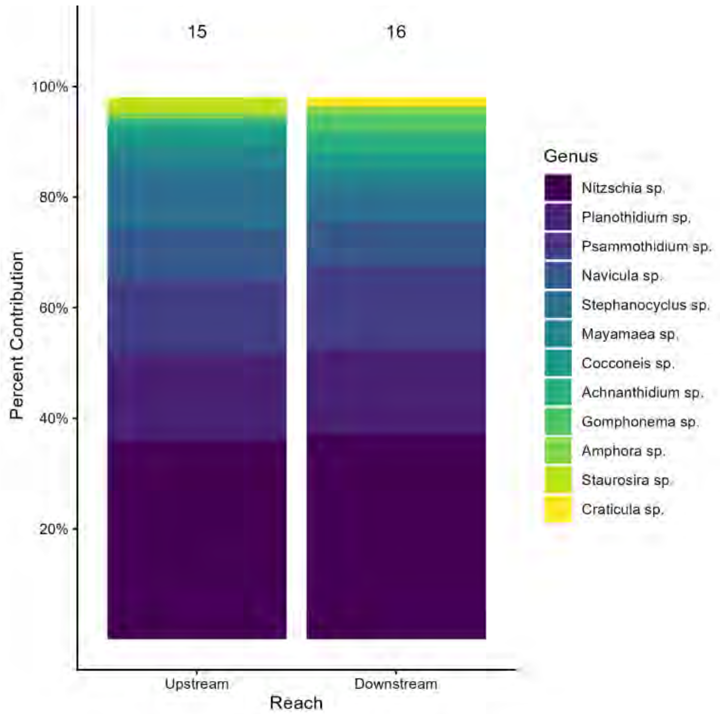
5.6.3.3 2025 Algal Community Results

Algal communities were highly similar across all five sites, with the exception of DS-1, which straddles the effluent outflow (**Figure 5-5**). *Nitzschia* spp. was the most abundant taxon at all sites, followed by *Planothidium* spp., *Psammothidium* spp., *Stephanocyclus* spp., and *Navicula* spp. No meaningful differences in dominant taxa were observed between upstream and downstream locations, although conditions directly adjacent to the outflow may produce localized increases in diversity. When comparing taxa contributions between upstream and downstream sites (**Figure 5-6**), the same overall dominance patterns were evident. Downstream sites generally showed higher relative contributions from less-dominant taxa. *Craticula* spp. occurred only downstream, while *Staurosira* spp. was present only upstream.



NOTES: Diatom taxa richness is provided above each bar. Taxa representing <4% of the population are removed from the graphic to improve comparability.

Figure 5-5
2025 Diatom Taxa Contributions to the Algal Community for Each Reach



NOTES: Diatom taxa richness is provided above each bar. Taxa representing <1% of the population are removed from the graphic to improve comparability.

Figure 5-6
2025 Diatom Taxa Contributions to the Algal Communities Upstream and Downstream of the Valencia WRP Outfall

5.6.4 Discussion

5.6.4.1 Benthic Macroinvertebrate Discussion

Analysis of historical data and 2025 sampling did not reveal evidence that effluent from the Valencia WRP negatively affects BMI community conditions in the Study Area. Mean CSCI scores were slightly higher at downstream sites compared to upstream locations, but individual MMI components showed no statistically significant differences. This consistent pattern across multiple years suggests that effluent discharge does not negatively affect downstream BMI communities.

Potential mechanisms for this pattern include effects of effluent discharge, such as moderating flow variability, sustaining wetted habitat during dry periods, and augmenting baseflow and nutrient inputs that support primary production and invertebrate biomass (Roy et al. 2003; Wenger et al. 2010). However, this Study did not include concurrent measurements of physical habitat or water quality parameters known to influence BMI communities (e.g., substrate composition, channel morphology, canopy cover, temperature, nutrient concentrations), so the specific drivers of observed biological responses cannot be determined.

Finally, although prey availability and energy content were not directly quantified, the abundance of BMI observed during sampling indicates that invertebrate prey resources are available for UTS and other invertivorous fish species in the Study Area.

5.6.4.2 Algal Community Discussion

Qualitative comparison of diatom communities upstream and downstream of the WRP outfall indicates no substantial effect of the Valencia WRP outfall on diatom community composition. The dominant genera occurring at both upstream and downstream sites are generally tolerant of warmer water temperatures (below approximately 77°F) (Zhang et al. 2018, Delgado et al. 2020). Some *Nitzschia* species (spp.) occur in even warmer environments, including hot springs, where they co-occur with *Achnanthidium* spp., indicating both genera may be adapted to warmer environments (Delgado et al. 2020). The limited occurrence of *Achnanthidium* spp. across sites is notable given experimental findings showing *Achnanthidium ambigua* can outcompete other diatoms between approximately 63°F and 90°F (Zhang et al. 2018). Its low abundance in this system suggests that temperature alone is unlikely to be the primary factor structuring the algal community.

As with the BMI analysis, this Study did not include concurrent measurements of environmental factors known to influence algal assemblages, such as light availability, substrate type, flow conditions, nutrient concentrations, or sediment loads. Despite these uncertainties, the high similarity between upstream and downstream diatom communities indicates that large or systematic temperature-related effects from the Valencia WRP outfall are unlikely.

5.7 Summary of Aquatic Biota Review

Historical and recent reports were reviewed to identify aquatic-dependent species documented or potentially present in Reaches 5 and 6 of the Santa Clara River. Species accounts were examined to focus on those with high thermal sensitivity or special status. A targeted review of thermal physiology literature refined species-specific tolerance data, addressing gaps and uncertainties in general life history accounts.

To complement the thermal analysis, BMI data were reviewed as indicators of potential thermal and flow-related impacts. Sampling in June 2025 addressed a data gap since 2016, following earlier collections from 2004–2015 (with the exclusion of 2012)[18]. The analysis emphasized upstream–downstream comparisons rather than absolute CSCI scores to better isolate potential discharge effects, focusing on community composition and metrics were that could signal thermal stress or habitat changes.

Key findings include the following.

- The fish community in the Study Area is dominated by non-native fish species. Of the 13 species documented, only three —UTS, SAS, and arroyo chub —are native to Southern California. Of these, UTS is the only species native to the Santa Clara River watershed. Several species of amphibians and aquatic-dependent reptiles are documented in the Study Area, but these are more tolerant of warm water conditions than most fishes.
- UTS is both federally listed and state-listed as endangered and is the only fish species native to the Study Area. UTS is the most thermally sensitive native aquatic species in the Study Area based on research published prior to this Study. UTS is recommended as the target taxon for evaluating temperature thresholds for aquatic life protection.

[18] With the exclusion of 2012

- The prickly sculpin is a non-native fish species that has a reported thermal tolerance (upper limit 86°F) similar to UTS. This species was documented in numerous surveys both upstream and downstream of the Valencia WRP.
- Research on the thermal physiology of UTS was limited to a single investigation prior to the current Study. Critical Thermal Maximum (CT_{MAX}) trials showed upper acute lethal temperature around 87°F when acclimated at 46°F and 94.3°F when acclimated at 72.9°F (Feldmeth and Baskin 1976). However, the sensitivity of younger life stages (e.g., embryos, larvae, or juveniles) is unknown. A laboratory study of stickleback temperature tolerances and thresholds by life stage was performed to provide more information, as described Chapter 6.
- Sustained warm water conditions may favor thermally tolerant non-native species, and could potentially shift competitive dynamics and increase predation pressure on less-tolerant species like UTS. An 80°F limit approaches the upper tolerance limit for UTS but remains within acceptable ranges for SAS, arroyo chub, and non-native fishes such as mosquitofish, common carp, largemouth bass, green sunfish, and bullhead.
- BMI and algal communities serve as biological indicators of stream health. The Santa Clara River's dynamic channel and variable flows limit BMI community diversity and stability, and observed taxa are mostly tolerant of disturbance. Analysis found no indication that effluent from the Valencia WRP is negatively affecting BMI condition; overall CSCI scores were slightly higher for downstream sites than upstream. Similarly, the diatom communities upstream and downstream of the WRP do not indicate that the effluent is contributing to either the proliferation or degradation of algal communities within the area.

CHAPTER 6
Stickleback Thermal Physiology Study

6.1 Background and Purpose

As described in Chapter 2, *Study Overview*, Section 2.3, one key question addressed by the Study is: "How do differing levels and durations of exposure to higher water temperature affect target taxa?" A literature review on the thermal physiology of aquatic species in the Santa Clara River identified the unarmored threespine stickleback (UTS) as the most thermally sensitive species, having the lowest upper thermal tolerance limit among the native Southern California fishes present (see Section 5.5, *Thermal Physiology Review*). This conclusion, however, was based on a single metric, Critical Thermal Maximum (CT_{MAX}), from one study (Feldmeth and Baskin 1976). Also, it was unclear which UTS life stages would be the most thermally sensitive and therefore most at risk under current and planned management of the Valencia WRP and Saugus WRP.

To address this limitation, the Fish Physiology Laboratory at the University of California, Davis (UC Davis) conducted a thermal physiology study of the closely related partially armored threespine stickleback (PATS). The UC Davis study (referred to herein as the "thermal physiology study") evaluated the fundamental thermal physiology of PATS, across several life stages, as a surrogate for UTS. See **Appendix D** for the full study report.

Objectives of the thermal physiology study were as follows:

- **Objective 1:** Capture and transition wild-caught PATS to laboratory conditions at UC Davis for research on adult fundamental thermal physiology.
- **Objective 2:** Measure the acute (CT_{MAX}) and chronic (Upper Incipient Lethal Temperature [UILT]) thermal tolerances of adult PATS acclimated to a range of temperatures and compare the CT_{MAX} data acquired with the results of prior work on UTS (Feldmeth and Baskin 1976).
- **Objective 3:** Determine the metabolic capacity (resting metabolic rate, maximum metabolic rate, and aerobic scope) of adult PATS across a range of temperatures and build thermal performance curves.
- **Objective 4:** Determine the thermal preference of adult PATS and identify the temperature that they behaviorally select to spend the most time at.
- **Objective 5:** Capture and transition wild-caught adult and juvenile PATS to laboratory conditions at UC Davis for research on cycling temperatures and additional life stages.
- **Objective 6:** Determine the effects of temperature on adult male parental behavior and nest maintenance.

- **Objective 7:** Characterize the effects of a natural thermal cycle on the acute thermal tolerance (CT_{MAX}) and acclimation survival compared to constant temperatures.
- **Objective 8:** Spawn adult PATS to produce embryos for research on early life stages.
- **Objective 9:** Determine temperature effects on incubating embryos, including time to hatch, size at hatch, and limits of survival.

Several metrics capture complementary aspects of tolerance limits, metabolic performance, and preference (defined in Section 5.2, *Thermal Physiology Framework and Metrics*). The thermal physiology study examined the following metrics:

- Tolerance:
  - Critical Thermal Maximum (CTMAX)
  - Upper Incipient Lethal Temperature (UILT)
- Metabolism:
  - Resting metabolic rate (RMR)
  - Maximum metabolic rate (MMR)
  - Absolute aerobic scope
  - Factorial aerobic scope
- Preference
- Embryonic Development

This chapter provides an overview of the experimental design and metrics and summarizes the findings. The full experimental methods, including statistical approaches for analysis, and detailed results are provided in Appendix D.

6.2 Methods

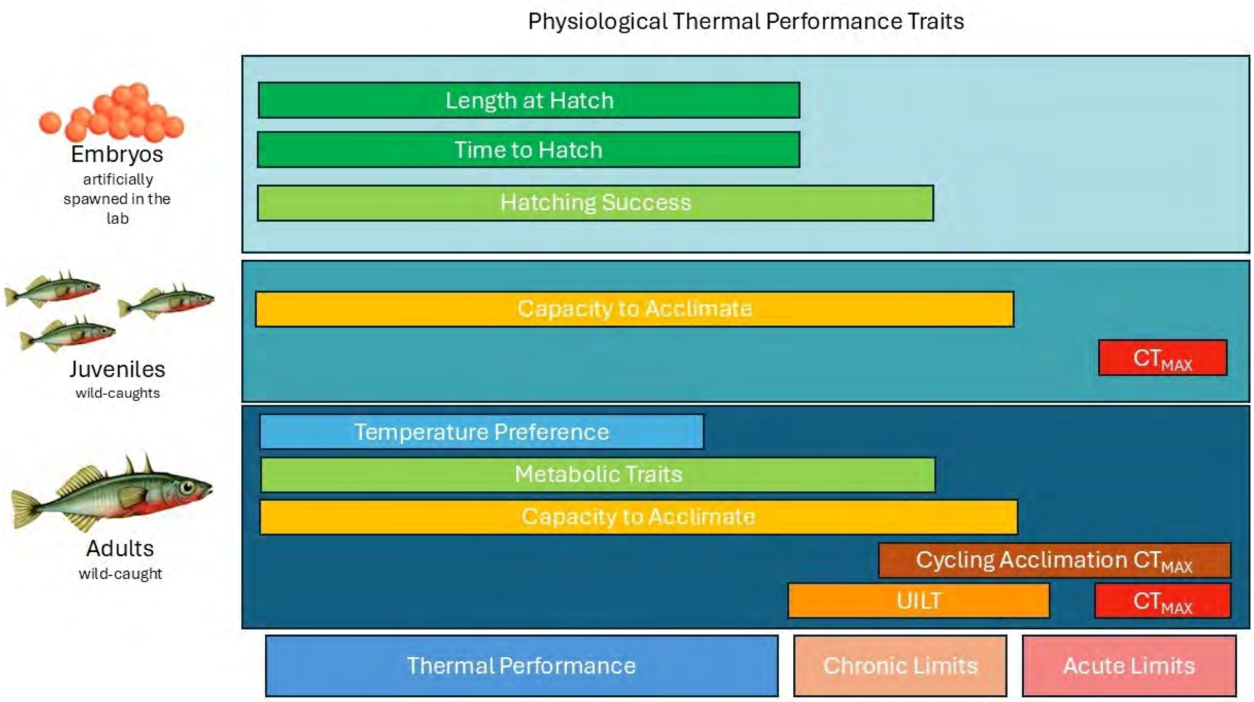
6.2.1 Study Overview

The UTS is federally listed as endangered and is a State of California fully protected species; therefore, research directly on UTS cannot be readily permitted. However, a population of partially armored threespine stickleback (PATS) in the lower Santa Clara River could serve as a surrogate species for UTS (Richmond et al. 2015). This population is located within the same watershed as UTS, but it is genetically distinct, as described in Section 5.4.1.1, *Unarmored Threespine Stickleback* (Richmond et al. 2015).

The thermal physiology study sought to determine the fundamental thermal physiology of PATS across life stages and compare findings to Feldmeth and Baskin's (1976) work of UTS. Researchers measured thermal sensitivity in adults, juveniles, and embryos under varying temperatures. Adult PATS from the lower Santa Clara River were collected and held in captivity to measure the acute and chronic critical temperature tolerance, metabolism, temperature preference, acclimation and survival, and parental behavior. Additionally, wild-caught adult PATS were spawned to produce embryos for incubation and hatching studies. Juvenile PATS were collected to test thermal tolerance.

The experimental design is depicted conceptually in **Figure 6-1**. The 2-year project included the following:

- **Year 1:** Experiments on wild-caught adults to measure CT_{MAX}, UILT, aerobic metabolism, and temperature preference.
- **Year 2:** Experiments on wild-caught adults for thermal tolerance (CT_{MAX}) and survival under cycling temperatures; captive-spawned eggs for embryo survival; and wild-caught juveniles for thermal tolerance (CT_{MAX}).



SOURCE: UC Davis 2025 (Appendix D)

Figure 6-1
Graphical Representation of the Multiple Physiological Traits Measured on Partially Unarmored Threespine Stickleback at Three Different Life Stages

6.2.2 Fish Collection

A California Department of Fish and Wildlife Scientific Collecting Permit[19] was obtained to allow collection of PATS for captivity and lab experiments. PATS were captured from the lower Santa Clara River from two sites located approximately 29 miles downstream of the Valencia WRP (Figure 1-1): (1) on United Water Conservation District (UWCD) property primarily along the mainstem river and secondarily at the Todd Barranca site (**Figure 6-2**), and (2) on The Nature Conservancy's Prairie Pacific property (**Figure 6-3**). Three collecting trips were conducted:

- **April 15–18, 2024:** A total of 295 adult fish were captured from UWCD property for experiments on acute and chronic thermal tolerance, temperature preference, and aerobic scope.
- **March 17–20, 2025:** The second collection was conducted at the UWCD Todd Barranca site and The Nature Conservancy's Prairie Pacific property. A total of 748 adult fish were captured for use in cycling-temperature experiments and to spawn for early-life-stage work.
- **July 14–16, 2025:** The final collection was conducted primarily from The Nature Conservancy's Prairie Pacific property and secondarily from the UWCD Todd Barranca site. A total of 44 gravid adult females and 120 juveniles were captured for use in tests on additional, earlier life stages.

Sampling locations focused on shallow, vegetated side channels with slow but consistent water flow. Water depth was generally less than 46 centimeters, with some deeper pools reaching 61 to 91 centimeters. Ambient water and air temperatures were recorded at the time of collection. To better charterize the environmental conditions that support the local stickleback population, temperature sensors were installed at the Todd Barranca and Prairie Pacific collection sites. These sensors continuously recorded water temperature from March 18 to October 30, 2025.

Before being transported to UC Davis, fish were held overnight in a transport tank with water temperatures ranging from 71 degrees Fahrenheit (°F) to 75°F and dissolved oxygen levels between 7.76 and 8.36 milligrams per liter.

6.2.3 Fish Maintenance and Acclimation

Fish were group-housed in tanks at the UC Davis Center for Aquatic Biology and Aquaculture during the physiological experiments. Before the experiments, fish were held in quarantine at a constant temperature of 65.5°F; the quarantine period was greater than 2 weeks for adults and 4 days for juveniles. Tank temperatures were increased from this initial holding temperature to each target acclimation temperature by increasing or decreasing the temperature by 3.6°F to 5.4°F per day. All groups achieved their target temperatures within 4 days.

[19] California Department of Fish and Wildlife Scientific Collecting Permit issued to Joel Mulder, Environmental Science Associates.

Figure 6-2
Fish Collection locations
Locations of 2024 Fish Collections in lower Santa Clara River, United Water Conservation District Property, April 2024

ESA

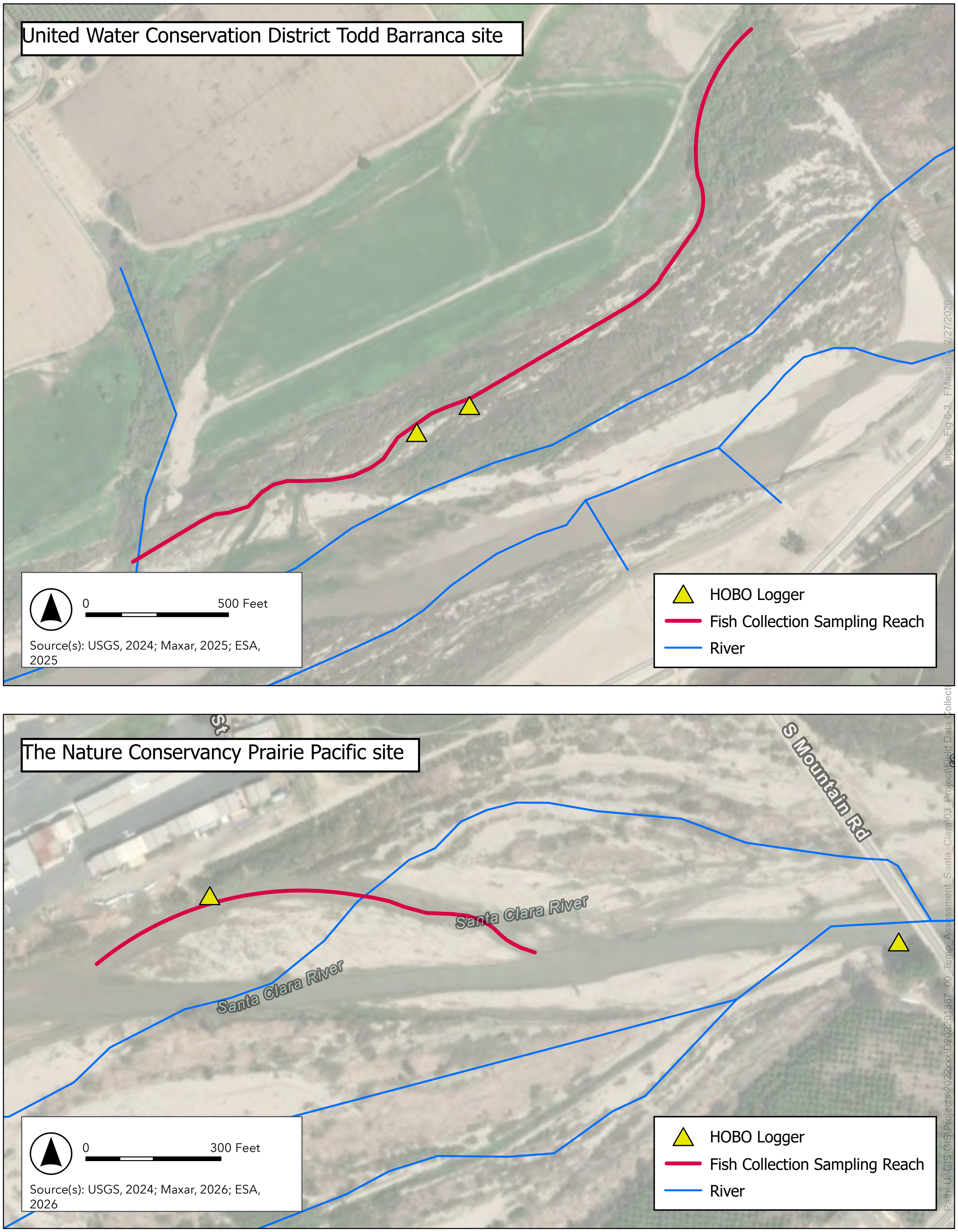


Figure 6-3

Fish Collection locations

Locations of 2025 Fish Collections in lower Santa Clara River, March and July 2025

6.2.4 Critical Thermal Maximum (CT_{MAX}) Methods

CT_{MAX} is measured by exposing fish to a rapidly increasing thermal gradient (Beitinger and Lutterschmidt 2011) and identifying the temperature at which a fish loses equilibrium and is unable to right itself. This endpoint is equivalent to ecological death as a fish in the wild would be unable to escape the dangerous situation. In this Study, adult and juvenile PATS were acclimated for 2 weeks to constant temperatures of 60.0°F, 65.5°F, and 72.9°F, and adults to 77.0°F before measuring CT_{MAX}. Juvenile fish could not be successfully acclimated to 77.0°F. Fish were continuously observed and removed from the CT_{MAX} chamber at the loss of equilibrium temperature and recovered in aerated water at their acclimation temperature. If a fish failed to recover, it was humanely euthanized.

Another set of trials was conducted to examine the effect of variable temperatures that emulated diurnal fluctuations. CT_{MAX} was measured on adult fish exposed to a cycling thermal regime that oscillated between 73°F and 83°F with a mean temperature of 78°F. This regime was based on July 2024 monitoring downstream of the Valencia WRP. Simultaneously, other groups of adults acclimated to constant temperatures of 78°F and 80°F. The minimum of the temperature cycle occurred at 3 a.m. and the maximum of the temperature cycle occurred at 3 p.m.

For CT_{MAX} trials of cycling-acclimated fish, fish were sampled from when they were experiencing either the minimum (“a.m.” timepoint) or the maximum (“p.m.” timepoint) of their daily temperature regime. Fish acclimated to a constant temperature of 78°F or 80°F were also sampled at these two timepoints during the first week of acclimation. An insufficient number of fish survived to the 2-week acclimation to also sample the 78°F and 80°F fish at the full 2-week timepoint.

CT_{MAX} values are reported as the observed mean as well as the model-estimated mean from a linear mixed-effect model, as detailed in Appendix D.

6.2.5 Upper Incipient Lethal Temperature (UILT) Methods

The Upper Incipient Lethal Temperature (UILT) is a measure of chronic thermal tolerance. UILT experiments seek to develop thermal resistance curves that describe the relationship between thermal exposure and time-limited thermal tolerance. UILT experiments identify, for example, the warmest temperature at which some proportion of fish (typically 50 percent, i.e., LT50) can theoretically survive indefinitely. The same experimental design can also estimate how long a fish can withstand chronic thermal exposure—essentially, the duration it can “resist” temperatures that will ultimately lead to death.

The UILT trials involved fish acclimated to 72.9°F. Each fish was plunged directly into water at one of eight thermal challenge temperatures, ranging from 78.8° to 87.8°F. Fish remained in these conditions for up to 72 hours or until loss of equilibrium. Fish were continuously monitored visually and upon losing equilibrium, fish were removed and, if possible, recovered; those that failed to recover were humanely euthanized. Time of removal was recorded for each fish. Each exposure tank contained a calibrated HOBO® temperature logger that recorded temperatures every 10 minutes, enabling researchers to reconstruct each fish’s temperature profile up to the point of removal.

6.2.6 Aerobic Metabolism Methods

The thermal physiology study assessed four metabolic traits: resting metabolic rate (RMR), maximum metabolic rate (MMR), absolute aerobic scope (AAS), and factorial aerobic scope (FAS), as defined in Section 5.2, *Thermal Physiology Framework and Metrics*. Measuring these traits across a range of acclimation temperatures helps identify conditions that optimize or minimize fish performance.

Researchers measured the RMR and MMR of adult PATS acclimated to two temperatures: 65.5°F and 77.0°F. Fish from each acclimation group were then tested at eight temperatures, ranging from 60.8°F to 83.3°F. Intermittent respirometry measured oxygen consumption under resting conditions (RMR) and following exhaustive chasing (MMR) (Zillig et al. 2023; Zillig 2024; Svendsen et al. 2016). During measurements, fish were contained in sealed chambers where oxygen concentration was monitored and recorded. Respirometry chambers were sequentially flushed with fresh, oxygenated water and then sealed, enabling repeated metabolic rate measurements. Each fish was assessed for both RMR and MMR. The AAS and FAS were subsequently calculated as the difference between the MMR and RMR or the quotient of the MMR to the RMR, respectively.

6.2.7 Temperature Preference Methods

A fish's preferred temperature is estimated from their behaviorally selected temperatures over time (Beitinger and Fitzpatrick 1979).

In this Study, temperature preference was measured for fish acclimated to 65.5°F using a two-chambered, 300 x 300 millimeter Loligo Systems shuttle box. Fish were acclimated to the shuttle box overnight before trials. During the trials, the fish's movement between chambers triggered gradual temperature changes: entering the hotter chamber increased the temperature of both chambers, while entering the colder chamber decreased it. This oscillation continued until the fish stabilized near its preferred temperature. Movements were tracked via overhead camera, and trials concluded after 8 hours. Individual preference was calculated as the mean temperature during the final 2 hours, and overall preference was determined by averaging across all fish.

6.2.8 Spawning and Embryo Tolerance Methods

The researchers assessed hatching success, time to hatch, and size at hatch for groups of embryos incubated to four different temperatures, ranging from 60.0°F to 77.0°F, while accounting for differences in fertilization success among spawning pairs.

Embryos were produced by performing seven total parental crosses using one male and one female each. Adults were acclimated to 65.5°F, and egg fertilization was performed at 65.5°F. Eggs were maintained in individually aerated cups suspended in larger, temperature-controlled water baths. A daily count was conducted, during which researchers tabulated the number of developing embryos, successful hatches, and deceased or otherwise nonviable eggs. Larvae were removed from replicates as they hatched, at which time hatch dates were recorded and size of all hatched larvae was measured.

6.3 Results

6.3.1 Fish Collection Field Observations

Large numbers (several hundreds) of PATS including adults, gravid females, and juveniles were found in the lower Santa Clara River collection sites during collection trips April 15–18, 2024, March 17–20, 2025, and July 14–16, 2025. **Table 6-1** summarizes the number of fish collected and ambient conditions (water temperatures and dissolved oxygen [DO] levels) during each fish collection trip.

TABLE 6-1
AMBIENT SITE CONDITIONS DURING THE FISH COLLECTION TRIPS

Date	Location	Number of Fish Collected	Water Temperature (grab sample)	Water Temperature (continuous)	DO (mg/l)
April 16 and 18, 2024	UWCD, Todd Barranca	295 adults	64°F–75°F (8 a.m. – 5 p.m.)	Not available	6.1–9.1
March 18 and 19, 2025[b]	Todd Barranca, Prairie Pacific	748 adults	54°F–76°F (8 a.m. – 4 p.m.)	Mean daily: 60°F—65°F Range: 50°F–80°F	13.1–14.2
July 15, 2025[c]	Todd Barranca, Prairie Pacific	44 gravid females, 120 juveniles	75°F (1 p.m.)	Mean daily: 70°F Range: 60°F–83°F	8.1

NOTES: °F = degrees Fahrenheit; mg/l = milligrams per liter; UWCD = United Water Conservation District
SOURCE: Data compiled by University of California, Davis, Fish Physiology Laboratory in 2024 and 2025 (see Appendix D)

In 2025, temperature sensors installed at the fish collection sites measured mean daily temperatures on fish collection days of around 60°F to 65°F in March 2025 (lows around 50°F to 55°F, highs around 75°F to 80°F) and around 70°F in July 2025 (lows around 60°F to 65°F, highs around 80°F to 83°F) **(Figure 6-4)**. Diurnal temperature fluctuations were approximately 25°F in March 2025 and 20°F in July 2025. During the period from March to July 2025, water temperatures were above 80°F on 52 days between the first (March 17) and final (July 16) collection trips (43 percent of the days), with an additional 12 exceedances in the following month.

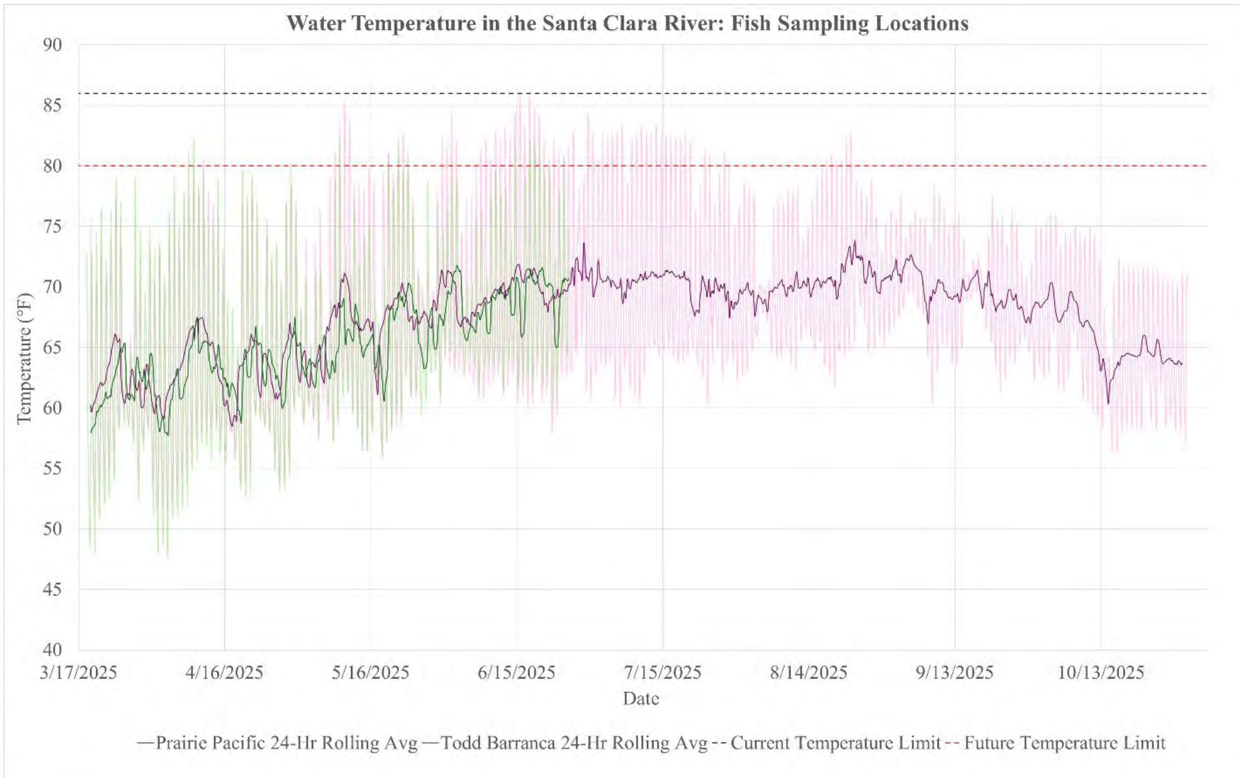


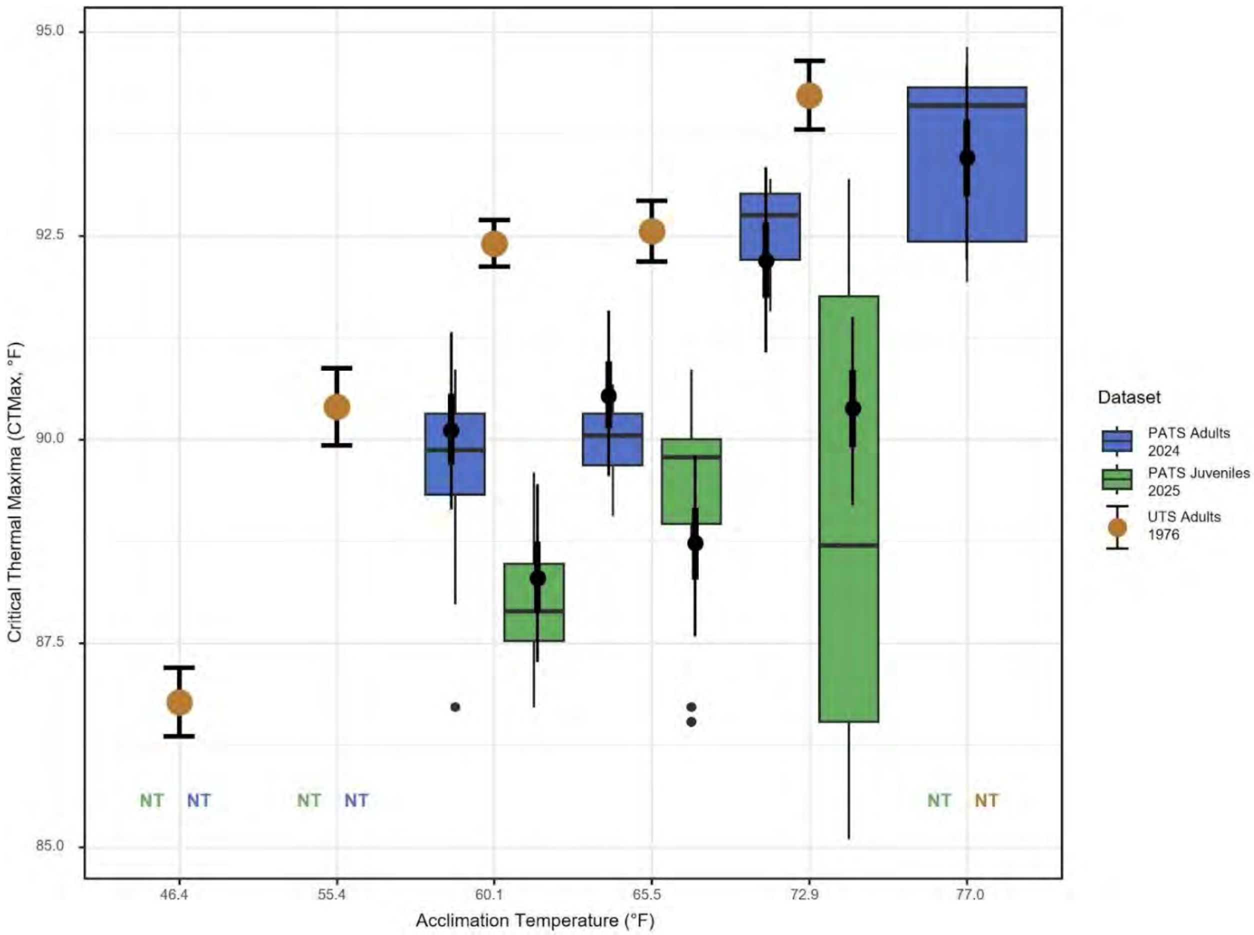
Figure 6-4
Water Temperature at PATS Collection Sites

Adult mortalities during capture and following transport were very low (2% or less) for all three collection trips. Young-of-the-year juveniles were not encountered during spring sampling. However, in July 2025 when juveniles were collected, substantial mortality occurred following capture (25%) and within a day of transport (19%). Water temperature at the time of capture (July 15, 1 p.m.) measured 74°F.

6.3.2 Critical Thermal Maximum (CT_{MAX}) Results

6.3.2.1 Constant Temperature Acclimated Fish (Adults and Juveniles)

Thermal tolerance increased with increasing acclimation temperature. The model-estimated mean CT_{MAX} of PATS ranged from 88.3°F to 93.4°F, depending on acclimation temperature and life stage (**Figure 6-5**, **Table 6-2**). Observed CT_{MAX} values for adults ranged from 89.6°F to 93.6°F. Juvenile PATS CT_{MAX} values were lower (88°F to 99°F). Both adults and juveniles exhibited higher CT_{MAX} when acclimated to warmer water, but adults were consistently more heat-tolerant than juveniles by approximately 1.5°F.



NOTES: UTS data (orange points) are taken from Feldmeth and Baskin (1976) and are represented as the mean and estimated standard error of their data. PATS data are represented as boxplots (observed data) and black point intervals (model-estimated mean and 50% and 89% credible intervals). *NT*s on the X-axis indicate that the CT_{MAX} for that acclimation temperature were not tested. Note that the X-axis is not to scale.

Figure 6-5

Critical Thermal Maxima of PATS and UTS of the Santa Clara River

6.3.2.2 Temperature Acclimation Survival Results

Cycling temperatures provided survival benefits for adults compared to fish acclimated to warm, constant temperatures. Adult fish acclimated to constant temperatures at or exceeding 78.0°F showed notably reduced survival compared to fish that had been acclimated to cycling temperatures oscillating between 73°F and 83°F (**Table 6-3**). The onset of mortality occurred approximately 7 days into exposure for fish acclimated to a constant 80.0°F or constant 78.0°F, compared to approximately 14 days for fish acclimated to the 73°F to 83°F cycle.

Observations of fish mortality from the first year of experiments also support this thermal acclimation limit. During the 2024 experiments, the 77.0°F group was originally intended to be acclimated to 80.0°F, but high mortality at 1 week forced a reduction in acclimation temperature to preserve fish. The fish acclimated to cycling temperatures demonstrated much lower mortality.

TABLE 6-2
COMPARISON OF CRITICAL THERMAL MAXIMA VALUES FOR PARTIALLY ARMORED THREESPINE STICKLEBACK FROM THE SANTA CLARA RIVER WITH VALUES FOR UNARMORED THREESPINE STICKLEBACK MEASURED BY FELDMETH AND BASKIN (1976)

Acclimation Temperature (°F)	PATS Adults			PATS Juveniles			UTS Feldmeth and Baskin (1976)
	CT_{MAX} (°F)	CF	n	CT_{MAX} (°F)	CF	n	CT_{MAX} (°F)
46.4	–	–	–	–	–	–	86.9
55.4	–	–	–	–	–	–	90.3
60.1	89.6 ± 1.2 90.2 (89.1–91.3)	1.1±0.2	12	88.0 ± 0.8 88.3 (87.2–89.4)	1.1±0.3	12	92.3
65.5	90.0 ± 0.5 90.6 (89.5–91.5)	1.0±0.1	12	89.2 ± 1.3 88.7 (87.6–89.8)	1.1±0.2	12	–
72.9	92.6 ± 0.6 92.2 (91.1–93.3)	0.9±0.1	12	89.0 ± 2.9 90.4 (89.2–91.5)	1.2±0.1	9	92.4
77.0	93.6 ± 1.1 93.4 (92.3–94.6)	0.9±0.1	12	DNS	DNS	DNS	–
78.0	89.7 ± 2.1 90.5 (89.9–91.2)	0.9±0.1	11	–	–	–	–
80.0	93.1 ± 1.7 93.5 (92.9–94.2)	0.8±0.1	11	–	–	–	–
*Cycling (73–83)	92.4 ± 1.8 92.8 (92.2–93.5)	0.9±0.1	24	–	–	–	–

NOTES: – = treatment was not tested; °F = degrees Fahrenheit; CF = condition factor; CT_{MAX} = Critical Thermal Maximum; DNS = fish were not able to survive the acclimation condition; n = number of fish; PATS = partially armored threespine stickleback; UTS = unarmored threespine stickleback

CT_{MAX} levels are reported as the observed mean and standard deviation as well as the model-estimated mean (with 89% credible intervals). Condition Factors (CFs) are given as the mean and standard deviation. The sample sizes for each group are also provided. Data on UTS are reported as the mean from Feldmeth and Baskin (1976).

* Data for this group represent fish trialed at both the a.m. and p.m. timepoints; they have been grouped as they were not found to be significantly different.

SOURCE: Data compiled by University of California, Davis, Fish Physiology Laboratory in 2024 and 2025 (see Appendix D, Table 1)

TABLE 6-3
PERCENTAGE POINT SURVIVAL FOR CYCLING-ACCLIMATED ADULT PATS AND THE 78°F AND 80°F CONTROL TEMPERATURES

Treatment	Starting Number of Fish	Percent Survival at End of 2 Weeks
78°F	36	31%
80°F	36	33%
73°F–83°F Cycle	36	83%

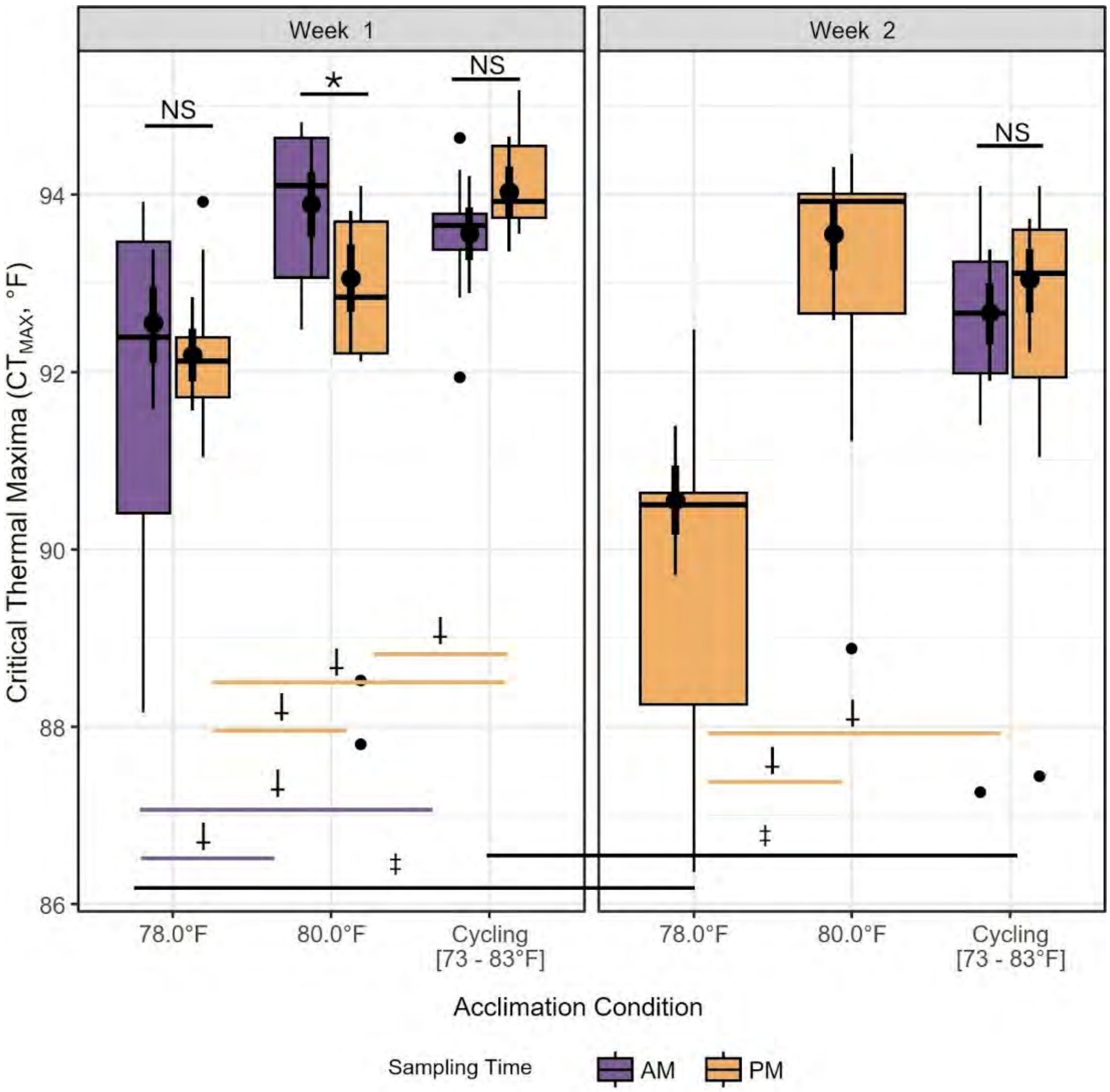
NOTE: °F = degrees Fahrenheit

SOURCE: Data compiled by University of California, Davis, Fish Physiology Laboratory in 2024 and 2025 (see Appendix D, Table 2)

Juvenile fish were less tolerant than adults to chronic thermal exposure. They could not survive acclimation to 77.0°F, exhibiting 47 percent mortality after 1 week, preventing CT_{MAX} data collection and ending that group trial early. Even at 72.9°F, survival was impacted: 23 percent died the day before the trial, and 50 percent died on the trial day following the 2-week acclimation period. In contrast, groups acclimated to 60.0°F and 65.5°F had little or no juvenile mortality.

6.3.2.3 Cycling Temperature Acclimated Adults

Thermal cycling and chronic heat stress affected resilience. Fish exposed to daily temperature cycles initially showed higher CT_{MAX} when tested at the warm part of the daily cycle. However, individuals held at high constant temperatures at or above 78.0°F began to succumb to heat stress after about 2 weeks (**Figure 6-6**, Table 6-2), indicating that prolonged exposure near their upper limits causes cumulative stress and increased mortality.



NOTES: ✱ = significance in CT_{MAX} between fish trialed in the a.m. or p.m.; ⸸ = significance in CT_{MAX} between fish tested in the a.m. or p.m. within the same week; ‡ = significance between Week 1 and Week 2; for these comparisons, sampling time was collapsed. See Appendix D, Figure 5.

Figure 6-6

Critical Thermal Maxima (CT_{MAX}) of PATS Exposed to Either Stable (78.1°F or 80.1°F) or Cycling (73°F to 83°F) Thermal Regimes

6.3.3 Upper Incipient Lethal Temperature (UILT) Results

6.3.3.1 UILT Survival

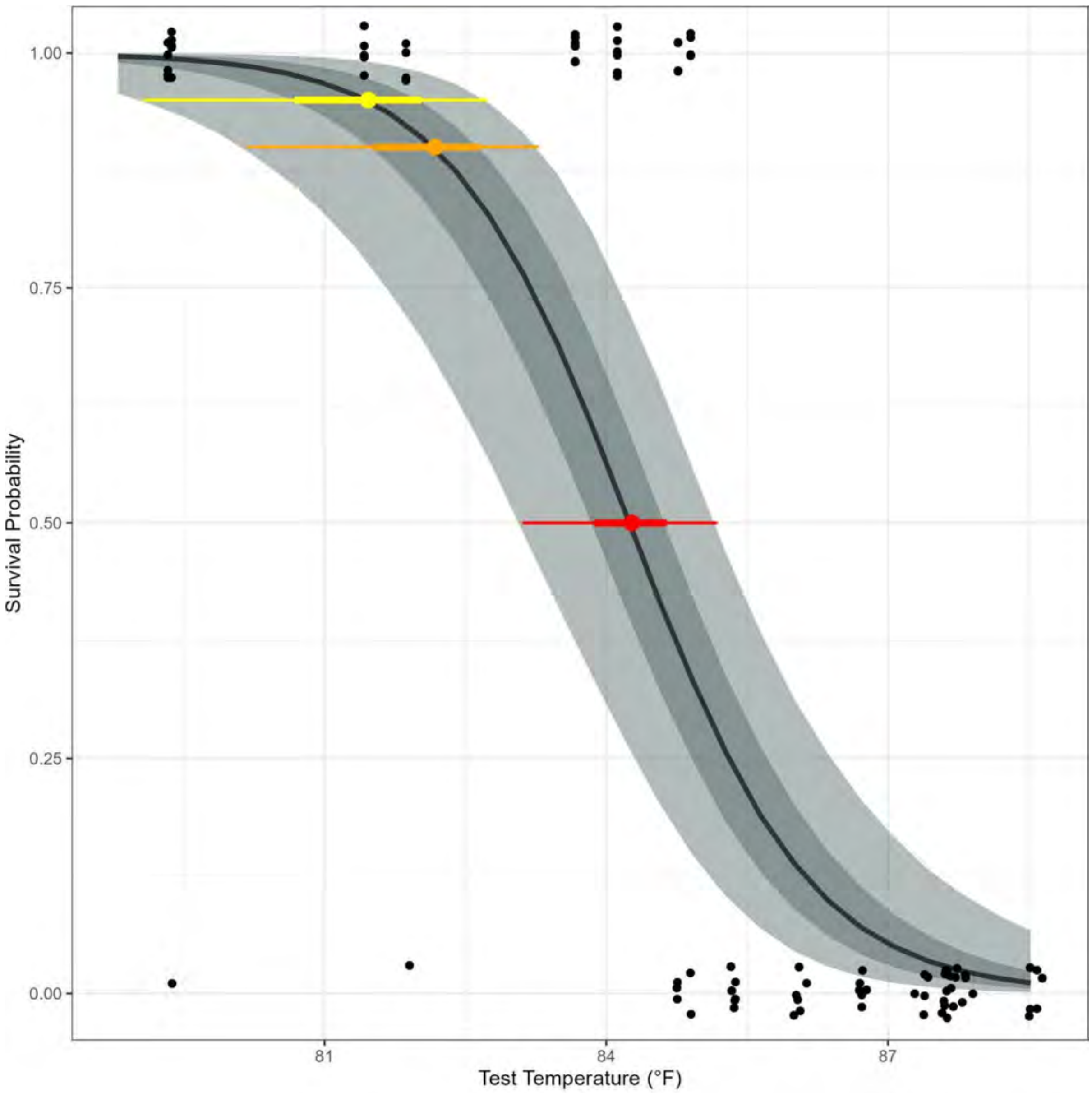
Higher test temperatures sharply reduced survival. As test temperature increased, fish died faster and in greater numbers (**Figure 6-7**, **Table 6-4**). The median lethal temperature (LT_{50}) for PATS acclimated to 72.9°F was 84.3°F, meaning that half of fish are not expected to survive indefinitely at this exposure temperature. Adult survival for a 3-day exposure was estimated at 95 percent for 81.2°F and 75 percent for 83.1°F.

TABLE 6-4
EXPOSURE TEMPERATURE FOR EACH UILT TANK AND THE NUMBER OF FISH THAT SURVIVED 3-DAY EXPOSURE

Target Temperature	Tank ID	Mean Temperature (°F ± SD)	Fraction that Survived	Percentage
78.8°F	A	79.3 ± 0.5	6/6	100%
	B	79.4 ± 0.5	5/6	83%
81.5°F	A	81.4 ± 0.5	5/5	100%
	B	81.9 ± 0.5	5/6	85%
83.3°F	A	84.1 ± 0.7	6/6	100%
	B	83.7 ± 0.5	6/6	100%
84.2°F	A	84.8 ± 0.5	4/7	57%
	B	84.9 ± 0.5	4/6	68%
85.1°F	A	85.3 ± 0.6	0/6	0%
	B	86.0 ± 0.6	0/6	0%
86.0°F	A	86.5 ± 0.6	0/6	0%
	B	87.2 ± 0.6	0/5	0%
86.9°F	A	87.5 ± 0.8	0/6	0%
	B	Not Recorded	0/6	0%
87.8°F	A	88.0 ± 0.7	0/5	0%
	B	88.9 ± 1.0	0/6	0%

NOTES: °F = degrees Fahrenheit; ID = identification; SD = standard deviation

SOURCE: Data compiled by University of California, Davis, Fish Physiology Laboratory in 2024 and 2025 (see Appendix D, Table 3)



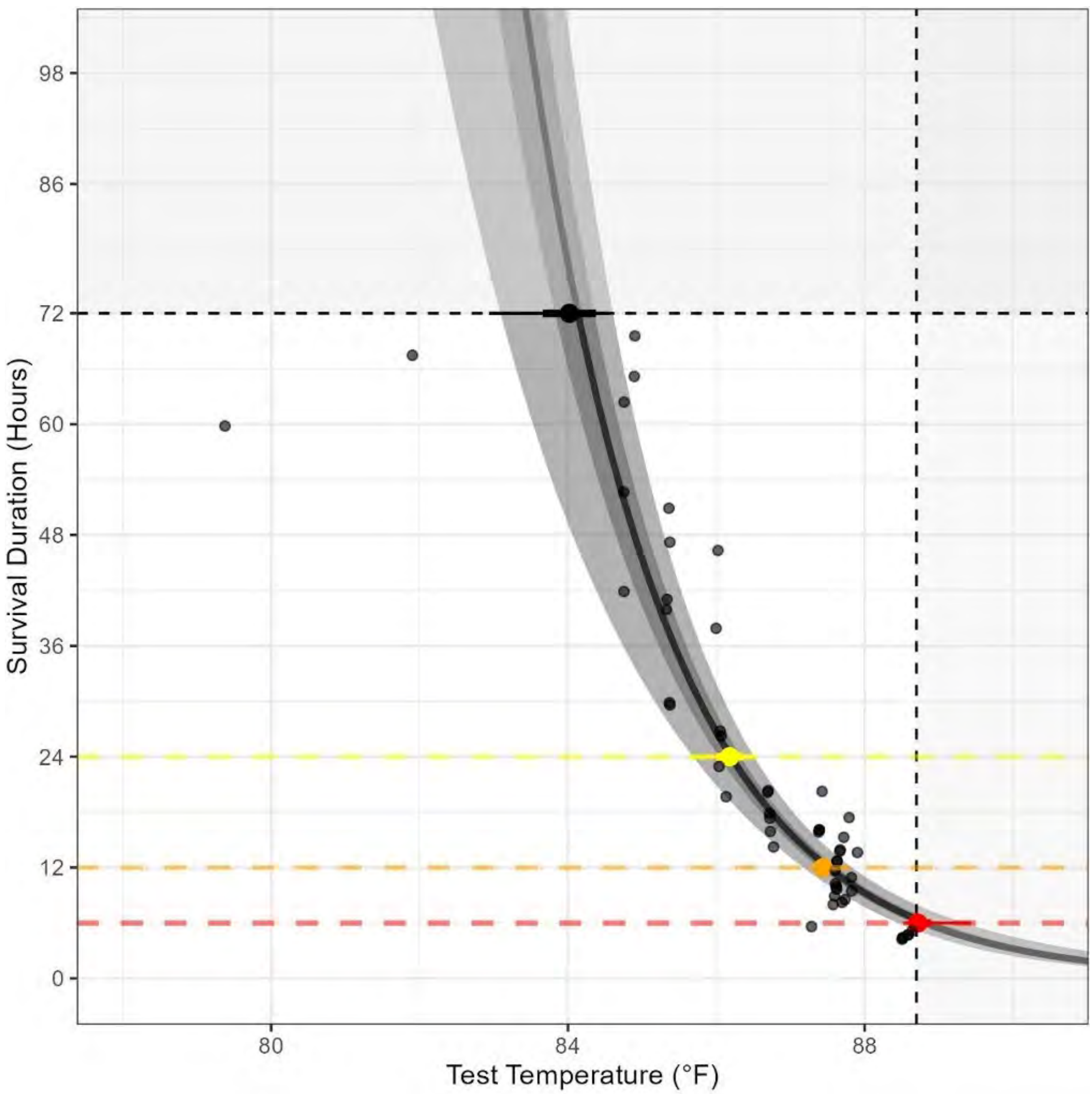
NOTE: Points represent the observed fish that either survived or were removed from a 3-day Upper Incipient Lethal Temperature trial. The line represents the posterior of the selected model, with the shaded region representing the 50% and 89% credible intervals (dark, light, respectively). The colored point intervals highlight the temperatures associated with the LT_{50}, LT_{90}, and LT_{95} (red, orange, yellow, respectively), with intervals representing the 50% and 89% credible intervals (thick, thin, respectively). See Appendix D, Figure 6.

Figure 6-7

Survival Probability of Partially Armored Threespine Stickleback Exposed to a Range of Temperatures

6.3.3.2 UILT Resistance

Thermal limits are time-dependent. Fish could tolerate 3 days below 83.0°F, but survival dropped rapidly at temperatures above that (**Figure 6-8**). At 88.5°F, nearly all fish died within 6 hours, showing that both temperature and exposure duration strongly govern lethal limits.



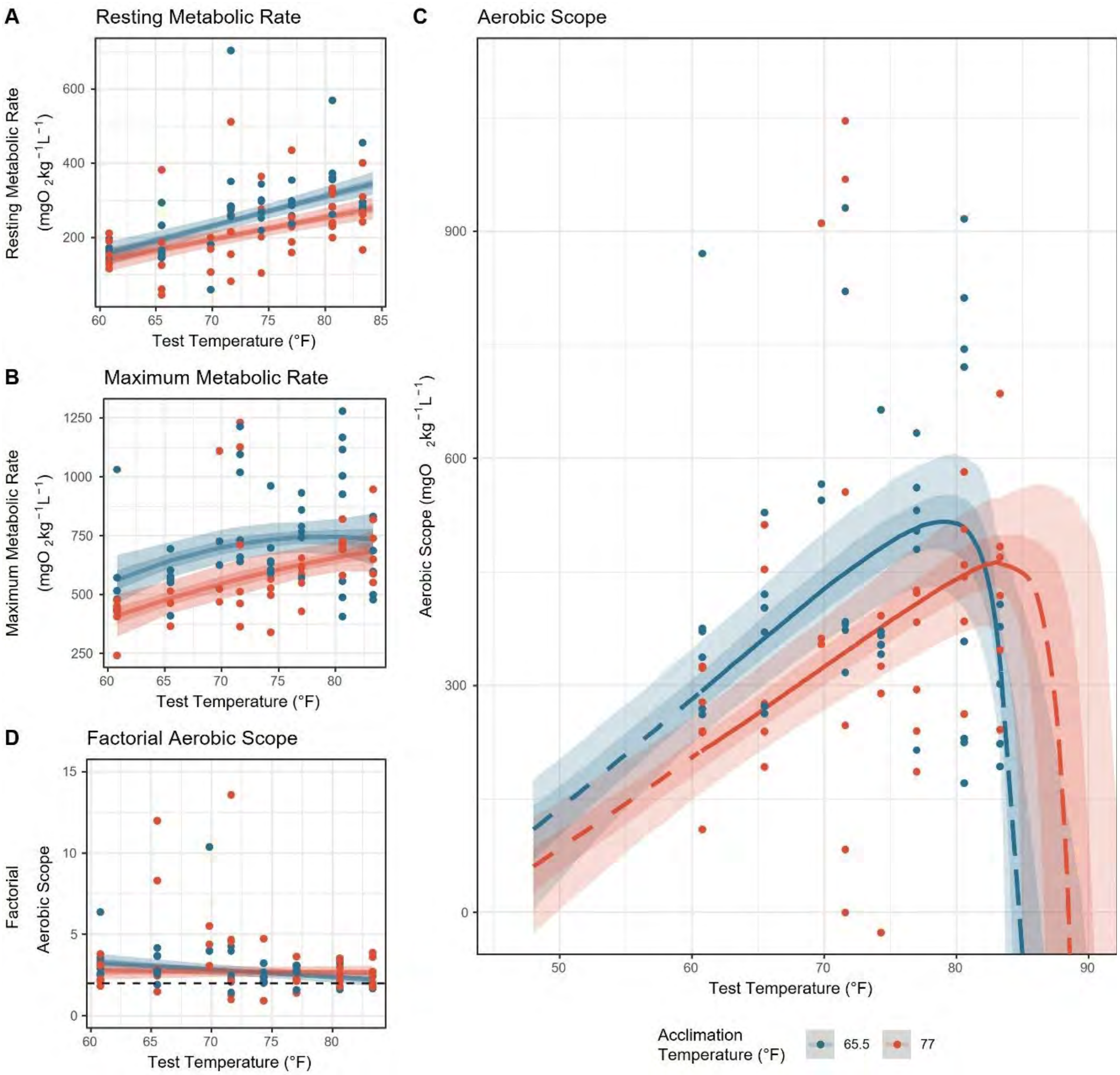
NOTE: Line represents the model-estimated resistance duration with the 50% and 90% credible intervals represented by the dark and light shading, respectively. Colored intervals identify the region of temperatures that a fish could tolerate for 6 hours (red), 12 hours (orange), 24 hours (yellow), and 72 hours (black). The shaded background region identifies portions of the plot that were not directly tested by our experiment and are extrapolations from the selected model. See Appendix D, Figure 7.

Figure 6-8

Duration of Chronic Thermal Tolerance for PATS Acclimated to 72.9°F

6.3.4 Aerobic Metabolism Results

Both the resting metabolic rate (RMR) (**Figure 6-9, A**) and maximum metabolic rate (MMR) (Figure 6-9, **B**) of adult PATS increased as test temperatures rose. However, fish acclimated to cooler water had overall higher metabolic rates than those acclimated to warmer water, especially at higher test temperatures.



NOTE: The Resting Metabolic Rate (A), maximum metabolic rate (B), aerobic scope (C), and factorial aerobic scope (D) are all presented with the raw data (points) and modeled estimated thermal performance curves with 50% and 89% credible intervals shaded in dark and light, respectively. In plot D, there is a horizontal dashed line indicating a FAS value equal to 2. Note that in C, the x-axis spans a broader range of temperatures, and the dashed line segments indicate portions of the thermal performance curve that were not measured and are extrapolations of the model intervals (thick, thin, respectively). See Appendix D, Figure 8.

Figure 6-9

Metabolic Traits of Partially Armored Threespine Stickleback Acclimated to 65.5°F and 77.0°F

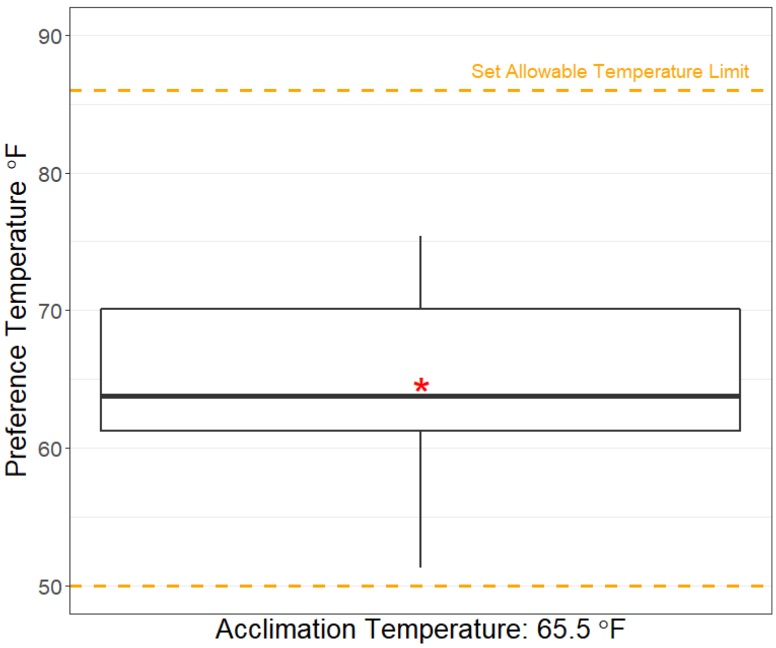
Warm acclimation shifted thermal limits but reduced metabolic capacity. Warm-acclimated adult fish operated at higher thermal limits (upper and lower thermal limits [T_{min}, T_{max}] and optimum temperature

[T_{opt}]) but exhibited lower overall aerobic capacity than cool-acclimated fish (Figure 6-9, **C**). This indicates a tradeoff between expanding thermal tolerance and sustaining metabolic performance.

Despite this, metabolic efficiency was maintained: factorial aerobic scope remained above 2 across all test temperatures (Figure 6-9 **D**), indicating sufficient aerobic capacity to support activity even near upper thermal limits. Note that some experimental temperatures (>80°F) exceed upper incipient lethal thresholds reported elsewhere, so performance at these extremes should be interpreted cautiously.

6.3.5 Temperature Preference Results

Figure 6-10 shows the temperature preference for fish acclimated to 65.5°F. Fish preferred a relatively cool temperature of 64.4°F. Within the Study temperature range of 50°F to 86°F, fish generally selected colder temperatures and avoided high, potentially lethal temperatures.



NOTE: This plot characterizes the median measured temperature preference and the spread of measured data. The red star shows the mean temperature preference. See Appendix D, Figure 9.

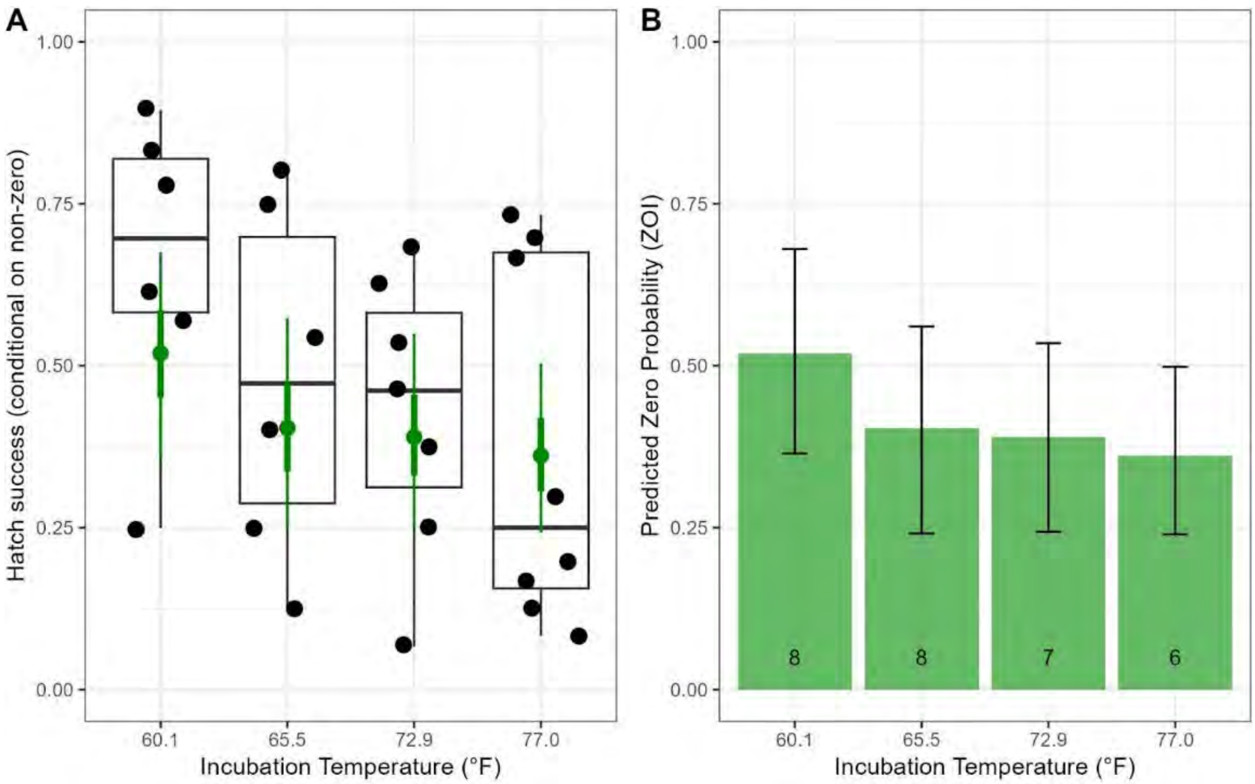
Figure 6-10
Temperature Preference for Fish Acclimated to 65.5°F

6.3.6 Embryo Tolerance Results

PATS embryos hatched between 5 and 11 days post-fertilization. Warmer water sped up the time to hatching; embryos incubated at higher temperatures hatched sooner, with time to hatch decreasing steadily with temperature up to about 72.9°F. Beyond 72.9°F to 77.0°F, hatch timing reached a plateau at around 6 days.

Warm incubation produced smaller hatchlings. Embryos reared at 72.9°F or 77.0°F hatched at significantly shorter lengths (approximately 0.47 centimeter) than those from cooler temperatures (0.49–0.52 centimeter), showing an inverse relationship between incubation temperature and size at hatch.

Finally, hatching success was temperature-independent but family-dependent. Embryos successfully hatched across all incubation temperatures from 60.1°F to 77.0°F (**Figure 6-11**). However, family identity had a strong effect: A few families showed very low survival, while others accounted for most of the successful hatching.



NOTE: (A) Proportion of successful hatching embryos with failed clutches (0% hatch) removed. Point intervals represent the model-estimated mean hatching success as well as the 50% and 89% credible intervals. (B) Proportion of cohorts at each incubation temperature which did not have any successful hatchings. Error whiskers span the 89% highest posterior density region. Numbers represent the count of cohorts with zero successful hatchings. See Appendix D, Figure 10.

Figure 6-11

Hatching Proportion of PATS Embryos Incubated at Four Different Temperatures

6.4 Discussion

6.4.1 Field Observations

PATS of all life stages were abundant in the lower Santa Clara River at sites that experienced wide diurnal temperature fluctuations (approximately 60°F to 83°F in July) and daily maximum temperatures above 80°F on numerous dates. Mortality of collected adult PATS was low (less than 2%) on all collection dates. However, observed mortalities of juveniles collected at 73°F in July 2025 (25% during capture, 19% after transport) suggest that these fish may have been close to their thermal limits or were otherwise unable to tolerate other stresses and conditions associated with capture activities. It is common for juvenile fishes to experience higher mortality rates from capture and handling than adults of the same species due to their smaller size that makes juveniles more prone to physiology stress and injury during physical handling,.

6.4.2 Acute (CT_{MAX}) and Chronic (UILT) Thermal Limits

Based on 2 years of trials, in which fish acclimated to 78.0°F and 80.0°F could not consistently survive a 2-week acclimation, the researchers concluded that 77.0°F likely represents the upper temperature that adult fish can tolerate for extended exposure (less than 2 weeks). Longer thermal exposures were not evaluated. In natural systems, temperatures fluctuate diurnally and spatially due to ambient air temperatures, groundwater seeps, bathymetry, shading, and vegetation, providing potential thermal refugia that fish may exploit. Understanding how thermal limits respond to varying exposure magnitudes and durations is critical for predicting species' persistence.

The UILT results indicated that 95 percent of fish could tolerate a 3-day exposure of 81.5°F or an exposure of 6 hours or less to temperatures below 88.8°F. Fifty percent would be expected to survive a 3-day exposure of approximately 84°F.

Fish acclimated to a cycling thermal regime (73.0°F to 83.0°F) survived a 2-week acclimation, highlighting the importance of cooler diurnal refugia. Temperature preference results also suggest that fish actively seek cooler water when available.

Assuming nightly temperature relief, short-term exposures (on the order of 2–3 hours) to daily high temperatures better represent afternoon thermal peaks in the river. Under temperature cycling conditions, 95 percent of PATS are expected to survive temperatures below 88.8°F for 6 hours or less. This value is near the metabolically estimated thermal maximum of 88.7°F. Habitats exceeding this threshold for multiple hours in a day, even intermittently, are unlikely to sustain PATS. Importantly, tolerance to brief high temperatures in a 24-hour experiment does not imply long-term survival. Cumulative stress could lead to chronic biochemical damage, excess energy use, disease, or mortality. The cycling-temperature study addressed only a single 2-week thermal regime. Long-term consequences of acute exposures or cycling regimes with different thermal characteristics remain unknown.

For acute thermal exposures, adults were slightly more tolerant than juveniles (by approximately 1.5°F). Observed mean CT_{MAX} values for adults ranged from 89.6°F to 93.6°F. Juvenile PATS CT_{MAX} values were lower (88°F to 89°F). Across life stages, higher acclimation temperature increased CT_{MAX}. However, adults held under cycling conditions did not exhibit higher CT_{MAX} than those at constant temperatures, suggesting an acclimatory limit near 73°F.

At all shared acclimation temperatures, PATS exhibited a lower CT_{MAX} than historical data on UTS (Feldmeth and Baskin 1976), averaging approximately 2°F lower. This difference may reflect methodological differences: Feldmeth and Baskin used death as an endpoint, whereas UC Davis used the loss of equilibrium (LOE) to allow fish to recover, which is also consistent with the technical definition of CT_{MAX}. Because death follows LOE, CT_{MAX} values based on mortality are inherently higher. The reported difference (2.0°F to 2.3°F) equates to only 3 to 4 minutes of exposure. Accounting for endpoint and duration differences, there is strong evidence that PATS and UTS have the same thermal tolerance.

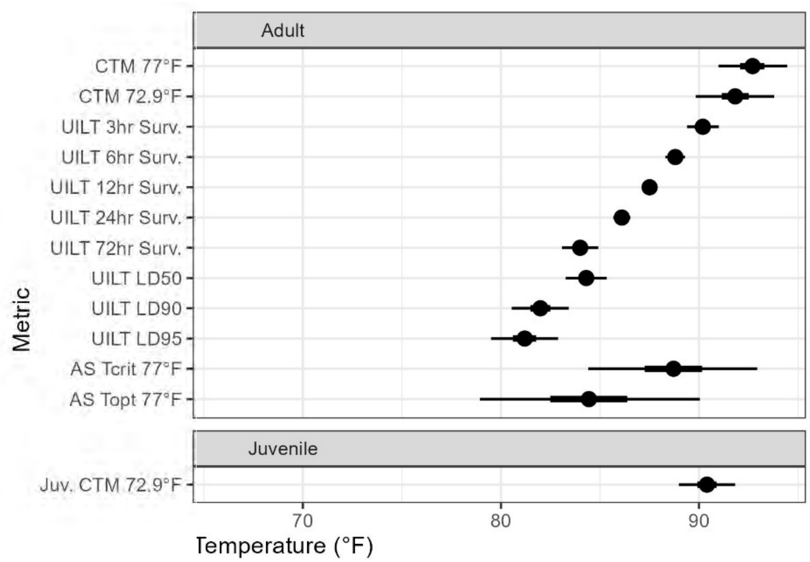
6.4.3 Metabolic Performance

Adult stickleback appear to maintain aerobic capacity across a range of temperatures approaching their chronically lethal temperatures exceeding 80.0°F. At sub-lethal temperatures, stickleback are capable of necessary metabolic activity. Across all measured temperatures (60.8°F to 83.3°F), PATS are able to at least double their resting metabolic rate, which is a coarse threshold for metabolic viability.

Acclimation to warmer temperatures shifted the metabolic thermal performance curve such that the thermal optima also shifted to warmer temperatures. This shift is the expected response found across other fish species in response to warm acclimation (Zillig et al. 2023; Healy and Schulte 2012).

6.4.4 Integrated Thermal Performance

Multiple thermal physiological metrics were integrated to provide a holistic view of the expected impact of environmental temperature on PATS. As shown in **Figure 6-12**, the thermal physiology study found that juvenile PATS are less thermally tolerant than their adult counterparts, with a CT_{MAX} approximately 2°F less. Over the vast majority of the thermal range, this difference is likely negligible, and PATS adults and juveniles would perform similarly. However, as temperatures approach upper limits (warmer than 26.7°C [80.0°F]), this difference could become limiting.



NOTES: Environmental Temperature (°F). Point intervals of specific thermal traits for both adult and juvenile PATS. The whiskers represent the 50% (thick) and 89% (thin) credible intervals. CTM °F = CT_{MAX} and acclimation temperature °F; UILT xhr Surv. = percent survival for x hour exposure; UILT LDx = x percent survival for 3-day exposure; AS Tcrit °F = aerobic scope critical temperature; AS Topt = aerobic scope optimal temperature and acclimation temperature.

SOURCE: UC Davis. Appendix D, Figure 11.

Figure 6-12

Conceptual Integration of Thermal Physiological Traits of Partially Armored Threespine Stickleback

6.4.5 Male Behavior and Embryo Tolerance

Male parental care is essential for stickleback. Hopkins et al. (2011) reported that elevated temperatures reduce males' ability to perform egg-care behaviors, leading to reduced embryo survival. In this thermal physiology study, these trials could not be conducted with PATS due to limited availability of gravid females.

Despite this limitation, PATS embryos successfully hatched at 77.0°F, a temperature near the chronic thermal tolerance threshold for adults and potentially above that of juveniles. No significant decline in hatching success or increase in failures was observed as temperatures increased, suggesting that this life stage is thermally robust across the tested temperature range.

Adults showed no mortality up to 77.0°F but could not tolerate prolonged exposure to 80.0°F. Based on these results, researchers inferred that egg-care behavior by PATS males may fail at a temperatures lower than those limiting embryo survival. Thus, adult male physiology and behavior appear to be the thermally limiting stage, rather than embryo incubation.

Embryos incubated at cooler temperatures of 60.1°F both took longer to hatch and emerged at a larger sizes. While larger hatchlings may swim and forage more efficiently (China and Holzman 2014), extended incubation increases the risks such as nest predation or abandonment and may reduce endogenous energy stores at hatching (Laurel 2008). Development rates and hatch timing were consistent with other threespine stickleback populations (Van Iersel 1953; Barnes et al. 2024), although this thermal physiology study uniquely evaluated incubation at temperatures exceeding 73.4°F. Thermal cycling was not assessed and may better reflect natural conditions. Future research could investigate how cycling incubation temperatures affect hatchling performance.

6.5 Conclusions

The thermal physiology study aimed to characterize the fundamental thermal physiology of PATS as a surrogate for UTS across multiple life stages and to inform management strategies to support threespine stickleback in the upper Santa Clara River. This assessment demonstrated that PATS exhibit stage-specific thermal sensitivities. Adults tolerated a wide thermal range, maintaining aerobic capacity near chronic limits, whereas juveniles showed slightly lower thermal maxima, suggesting modest age-related constraints. Embryos demonstrated high tolerance, successfully hatching at temperatures near adult limits; however, cooler incubations produced slower development and larger hatchlings, indicating trade-offs between growth and thermal risk. Diurnal temperature cycling reduced thermal stress and improved survival at otherwise lethal temperatures, highlighting its role as natural thermal buffers. Although male reproductive behavior was not directly assessed, evidence suggests that thermal stress on parental care may impose stronger constraints on reproductive success than embryo intolerance. Collectively, these physiological and behavioral insights provide a framework for identifying thermally suitable habitats and guiding conservation efforts under warming conditions.

CHAPTER 7
Study Conclusions

7.1 Study Questions Addressed

The Study has addressed the following primary questions:

1. How does temperature vary spatially and temporally in the Study Area of the Santa Clara River, at time scales ranging from diurnal to seasonal?
2. How much, and over what distance, does effluent from the Valencia WRP raise water temperatures in the Study Area?
3. What are the target taxa representative of the WARM beneficial use in the Study Area?
4. How do differing levels and durations of exposure to higher water temperature affect target taxa?
5. How effective are different potential management strategies (e.g., reducing the volume or cooling the temperature of WRP effluent) likely to be at reducing the overall temperature in the Study Area or meeting temperature objectives?

In addition to these primary questions, the Study has sought to understand how dissolved oxygen (DO) and other physical parameters that affect aquatic habitat vary upstream and downstream of the WRPs, and whether there are differences in benthic macroinvertebrate communities in the vicinity of the WRPs.

7.2 Synthesis of Studies

These questions have been investigated by the following Study approaches:

- Installing temperature monitors and loggers in the Study Area for 2 years to assess temporal and spatial patterns upstream and downstream of the Saugus and Valencia WRPs.
- Conducting intensive mapping of temperature and other factors that affect aquatic habitat (DO, velocity, depth, substrate, and cover) around the Valencia WRP to understand differences upstream and downstream of the WRP and determine whether there are patches of cooler water within the warmer downstream reach that might provide thermal refugia.
- Characterizing the aquatic-dependent communities in the Study Area and assessing their thermal preferences and tolerances based on available data in the literature.
- Conducting benthic macroinvertebrate (BMI) and algal surveys in the Study Area and analyzing historic BMI data to assess whether water temperature affects stream condition and food supply for aquatic organisms.

- Performing laboratory experiments on the partially armored threespine stickleback (PATS), a species that is closely related to the federally listed unarmored threespine stickleback (UTS), to assess its response to elevated water temperatures and identify the limits of its thermal tolerance.
- Modeling potential temperature management scenarios for two 6-month periods that represent wetter and drier than average climate conditions, to determine the impact of those management scenarios on downstream river temperatures.
- Modeling river temperatures without WRP discharge to understand the "natural condition" of seasonal and diurnal waterbody temperature.

7.3 Summary of Findings

7.3.1 Temperature Monitoring

- During the Study period, mean daily river temperatures (24-hour moving mean of continuously measured values) upstream of the Valencia WRP ranged from a low of around 55 degrees Fahrenheit (°F) in the winter to a high of around 73°F in the summer.
- Mean daily temperatures immediately downstream of the Valencia WRP ranged from a low of around 65°F in the winter to a high of around 80°F in the summer.
- The temperature difference upstream and downstream of the Valencia WRP was greater than Δ5°F throughout the Study period; typical differences were around 6°F to 14°F (mean of 9°F), depending on the time of day, season, and upstream water volume.
- Continuous temperature measurements showed there were 3 days when river temperatures upstream of the Valencia WRP were above 80°F for a few hours during the 2-year Study, in July 2024.
- Continuous temperature measurements showed that there were 100 days during summer and fall 2024 and more than 75 days during summer and fall 2025 when temperatures just downstream of the Valencia WRP were above 80°F for part of the day (typically 1 to 12 hours). Temperatures above 80°F began in June and occurred almost daily between July and the middle of September in both 2024 and 2025. Peak temperatures were around 82°F to 83°F during the warmest periods of July and August of both summers, while nighttime temperatures dropped to about 75°F.
- About half the water temperature increase from the Valencia WRP was lost by the Castaic Creek confluence (2.5 miles downstream of the WRP), and most of the remaining increase was lost by Newhall Orchards (10 miles downstream).
- Diurnal fluctuations in temperature ranged as follows.
  - Temperatures immediately upstream of the Valencia WRP varied by 10°F to 12°F, peaking at around 2 p.m. and reaching the minimum at around 7 a.m.
  - Temperatures corresponding to mean daily temperatures downstream of the Valencia WRP occur at around 10 a.m.
  - The temperature of effluent from the Valencia WRP was much more consistent, varying by about 2°F.
  - Flows 300 to 700 feet downstream of the Valencia WRP (downstream of the mixing zone) reflected both water sources and had a diurnal range of about 5°F to 7°F.

7.3.2 Temperature Mapping (and Other Physical Property Mapping and Monitoring)

- There is a high degree of lateral stratification across the river downstream of the Valencia WRP, with warmer water from the WRP taking several hundred feet to mix with cooler water from upstream. The mixing zone ranged from around 300 feet to 700 feet long during the Study period, depending on the time of year and the volume of water flowing from upstream of the Valencia WRP.
- No substantial areas of cool water were found downstream of the Valencia WRP (within about 1 mile). There were some patches of cooler water (a few square feet) in side channels and bank seeps, but these often had very low DO values, suggesting that they would not be suitable thermal refugia for aquatic life.
- Almost all DO measurements made upstream and downstream of the Valencia WRP were greater than 6 milligrams per liter (mg/l), above the 5 mg/l threshold, which is identified as a suitable value for a waterbody with a WARM beneficial use designation (e.g., EPA 2021). Daytime DO values from grab samples were typically 8–9 mg/l upstream of the Valencia WRP and 7–8 mg/l downstream, indicating that the WRP has little effect on DO.
- Continuous 24-hour monitoring of DO levels found that the lowest values occurred at night or early in the morning but generally exceeded 6 mg/l. The lowest nighttime values recorded were around 6 mg/l downstream of the Valencia WRP, about 1 mg/l below the high values for the same day.
- Velocity and depth were similar upstream and downstream of the Valencia WRP, but with higher velocities and deeper conditions downstream because of the greater discharge. Velocities were around 0.5 to 1.0 foot per second faster and depths 3–5 inches deeper in the downstream reach. Velocities and depths upstream of the Valencia WRP were more likely to overlap with conditions believed to be suitable for UTS than those downstream, because of the higher flows downstream. For Santa Ana sucker (SAS), the opposite is true: velocity and depth are generally too low for SAS upstream of the Valencia WRP but are more suitable downstream.
- Channel conditions (channel width, depth, location, vegetation cover, and substrate) varied considerably throughout the 2-year Study in response to high flows that scoured vegetation and created bare sand bars that were subsequently recolonized and stabilized by riparian vegetation.

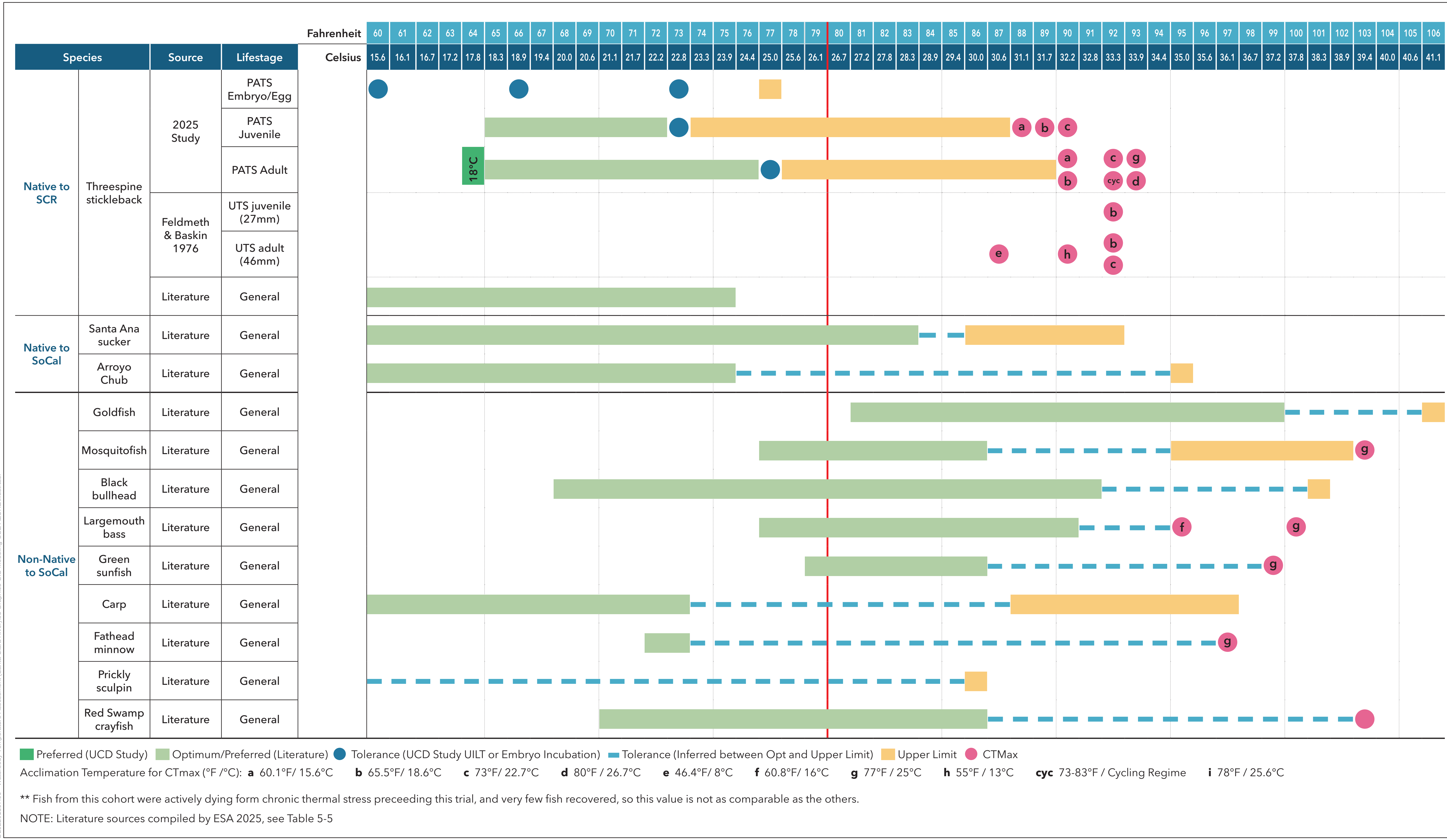
7.3.3 Aquatic-Dependent Taxa

- The aquatic community in the upper Santa Clara River Study Area is dominated by non-native species, with only three native Southern California species documented: UTS, SAS, and arroyo chub. UTS is both federally listed and state-listed as endangered and was selected as the target taxon for thermal evaluation because of its greater sensitivity to temperature, as reported in a single study by Feldmeth and Baskin (1976). Elevated water temperatures can directly affect UTS through physiological and behavioral stress responses.
- Warmer temperatures could indirectly affect UTS by giving their predators and competitors a thermal advantage. **Figure 7-1** illustrates the thermal preferences of and upper limits for species in the Study Area based on literature values (Table 5-5) and results from the PATS thermal physiology study (Chapter 6). Many non-native species documented in the Santa Clara River can tolerate—and often thrive—at temperatures at or above 80°F, further intensifying competitive and predation pressures on UTS.

- The BMI community was assessed to evaluate food resource availability for UTS and potential impacts of the Valencia WRP discharge. The California Stream Condition Index (CSCI) values from historic surveys and June 2025 data collection show that the BMI community in the Study Area has consistently oscillated around the commonly used “reference threshold” of 0.79. The sand-bedded, intermittently connected channel and variable flows inherently limit BMI diversity and favor taxa that tolerate disturbance. Analysis of 2025 CSCI values found no indication that Valencia WRP effluent discharge is adversely impacting BMI condition. The sites downstream of the WRP discharge often showed slightly higher scores than sites upstream, but this is not ecologically meaningfulre.
- Algal communities (diatoms) upstream and downstream of the Valencia WRP were highly similar, with tolerant diatom genera dominant at all sites, and similar to expected levels for this stream type without disturbance. Other factors known to influence algal composition (light, flow, nutrients, substrate) were not evaluated as part of this Study. Nevertheless, these results indicate that the effluent is not producing meaningful changes, whether by thermal discharge or any other pollutant.

7.3.4 Thermal Tolerance of Stickleback

- The ability of fishes to tolerate elevated temperatures is complex; even within the single species studied in the laboratory for this Study, there is significant variability by life stage, exposure time, and acclimation temperature. No single temperature threshold will capture all these factors.
- The thermal physiology study used PATS as a surrogate for UTS for laboratory experiments of fundamental thermal physiology. Results should be extrapolated to natural river systems with care. In laboratory settings, fish are confined to test containers and exposed to simplified thermal regimes, limiting behavioral avoidance of stressful conditions, whereas fish in rivers could move to cooler microhabitats if available, albeit with associated energetic or ecological trade-offs. Laboratory settings also exclude interacting stressors such as flow variability, food limitation, and predators, which may overestimate thermal tolerance.
- PATS of all life stages (adults, gravid females, and juveniles) were abundant in the lower Santa Clara River approximately 29 miles downstream and outside the influence of the Valencia WRP. Temperature monitoring during March–July 2025 suggests that adult stickleback at these locations can tolerate wide diurnal temperature fluctuations (July lows around 60°F to 65°F, highs around 80°F to 83°F) and exposure to daily maximum temperatures approaching 83°F. High mortality of juveniles during collection in July (river temperature 73°F) suggests these young fish may have been stressed or injured during capture activities.



SOURCE: ESA, 2026

ESA

Figure 7-1
Thermal Criteria for Santa Clara River Fish and Crayfish

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- Adult stickleback acclimated to constant temperatures between 60°F and 77°F experienced little or no mortality during the 2-week acclimation process. However, adults acclimated to a constant 80°F experienced significant mortality rates (67 percent) 1 week into the treatment, with most adults dying after 2 weeks of exposure.
- Thermal cycling experiments found that adult PATS that were exposed to 24-hour cycles of water temperature from 73°F to 83°F (mean of 78°F) had a much lower mortality rate than those held at a constant 78°F temperature (17 percent mortality for cycled fish versus 69 percent for fish held at a constant 78°F). This suggests that fish can recover from daytime thermal stress during cooler nighttime conditions. Results from the laboratory cycling experiments coupled with observations of PATS at downstream collection sites suggest that the amount of mortality experienced by PATS when temperatures vary diurnally is affected by both the daytime high temperatures and the nighttime low temperatures.
- Critical Thermal Maximum (CT_{MAX}) (a measure of acute stress leading to mortality) temperature values for adults ranged from 89.6°F to 93.6°F, with higher CT_{MAX} at higher acclimation temperatures. Juvenile PATS CT_{MAX} values were lower (88.3°F to 90.4°F). The CT_{MAX} values measured for PATS by UC Davis and for UTS by Feldmeth and Baskin (1976) are similar when methodological differences are considered. As such, PATS serves as an excellent surrogate for UTS.
- Chronic temperature tolerance declines sharply as temperatures rise. Results for Upper Incipient Lethal Temperature (UILT) (a measure of chronic stress) indicate that 95 percent of fish could tolerate a 3-day exposure of 81.5°F and only 50 percent would survive a 3-day exposure of approximately 84°F. Resistance time experiments showed that PATS could only withstand temperatures around 86°F for around 12–24 hours.
- Aerobic scope experiments found that, for a given acclimation temperature, PATS' aerobic capacity peaked near their chronic thermal limit, but aerobic capacity declined precipitously as temperatures reached chronic lethal limits.
- In temperature preference experiments with a study range of 50°F to 86°F, adult PATS (acclimated to 65.5°F) chose water temperatures between 51.3°F and 75.4°F, with a mean of 64.4°F. This suggests that, given access to a range of temperatures and equal habitat conditions, PATS would choose cooler environments and avoid warmer areas.
- Across all experiments, juveniles exhibited the lowest thermal tolerance of any life stage. Juvenile stickleback survived acclimation to a constant 65.5°F but were unable to survive acclimation at a constant 77°F (47 percent mortality after 1 week). Although juveniles were abundant at downstream field sites where daily maximum temperatures periodically exceeded 80°F, juvenile tolerance to diurnally cycling temperatures was not directly evaluated under laboratory conditions. Accordingly, inferences regarding juvenile tolerance to short-term temperature excursions are based on field observations and should be interpreted cautiously.
- Embryos proved remarkably tolerant, hatching successfully at temperatures approaching adult limits, although cooler incubation led to slower development and larger hatchlings, indicating potential trade-offs between growth and exposure risk.
- The chronic exposure thermal physiology study concluded that PATS can survive for 2 weeks at temperatures up to about 73°F for juveniles and 77°F for adults with little evidence of stress or

elevated mortality rates. Between those temperatures and approximately 80°F, PATS experience increasing stress and risk of mortality, with juveniles more vulnerable than adults.

- The likelihood that PATS can survive at a constant temperature of 80.0°F for more than 7–14 days is very low. However, temperature cycling experiments (experimental range 73°F to 83°F) demonstrate that brief exposures to temperatures up to 82°F with adequate diurnal thermal refugia (i.e., periods of lower temperatures down to 73°F) could be tolerated for 1 week or so before mortalities started to increase toward the end of the 2-week trial. Although juvenile PATS were not tested in the thermal cycling experiments in the laboratory, the presence of abundant juvenile PATS at the site where PATS were collected from the river suggests that juveniles may also tolerate short exposures to temperatures periodically reaching 83°F, as long as adequate thermal refugia exists the remainder of the time (daily lows around 60°F to 65°F, highs around 80°F to 83°F). These Study findings underscore the importance of exposure duration when addressing the reaction of PATS to temperatures at or slightly above 80°F

7.3.5 Temperature Modeling of Management Strategies

Modeling existing conditions and a series of potential management scenarios for two periods that represent wetter than average and drier than average ambient conditions yielded the following results:

- Under existing conditions across a range of years with higher and lower than average dilution from upstream flows, the proposed 80°F temperature threshold is likely to be exceeded for around 80–150 days per year, depending on upstream flow rates, temperatures, and ambient weather conditions.
- The Δ5°F limit is also likely to be seasonally exceeded in both wetter and drier than average water years.
- Reducing Valencia WRP discharges to 50 percent of their existing level had some benefits to average water temperature, especially in the wetter than average year modeled, but had almost no effect with an upstream river flow of 0.4 cubic foot per second (2022) because of the greater volume of effluent relative to background flow. There were still many days when the maximum daily temperature exceeded 80°F, due to conditions other than wastes discharged, under this management scenario. This scenario also did not meet the Δ5°F limit for either year.
- Capping Valencia WRP discharge to not exceed 80°F also reduced average water temperatures but did not prevent large numbers of days when maximum temperature exceeded 80°F. This scenario did not meet the Δ5°F limit (particularly during cool seasons) for either year simulated.
- Completely eliminating the Valencia WRP discharge was the only management scenario that met the proposed regulations in the vicinity of the WRP in both years simulated. In the modified 2022 scenario, the water temperature still exceeded 80°F farther downstream on some occasions because of warming from natural processes.
- Canopy shade has an increasingly large effect on water temperature with the increasing length of channel shaded, potentially reducing summer water temperatures by 7°F if all of the channel between the Valencia WRP and the Castaic Creek confluence (2.5 miles) were shaded to 100 percent from its existing level. However, the river’s natural dynamism means that the riparian corridor is eroded out roughly every decade or so, setting cover to almost zero until vegetation reestablishes and shades the river again.

7.4 Implications of the Study for Managing Water Temperature

The laboratory experiments for the thermal physiology study show that as water temperatures approach and exceed 80°F for longer periods of time and with more exceedance cycles, threespine stickleback mortality increases, especially for juveniles. Field evidence indicates that PATS survived 50 or more excursions of 80°F when nighttime temperatures dropped to 65°F or less at collection sites 29 miles downstream of the Valencia WRP. The cyclical laboratory experiment showed increasing numbers of fatalities for PATS cycled between 73°F and 83°F after 1–2 weeks of exposure, a condition that is more representative of present conditions downstream of the WRP. These findings indicate that the diurnal lows are an important factor affecting chronic survival when daily highs reach and exceed 80°F.

No experiments were performed to directly address the Δ5°F limit, but information can be inferred from the field collection of PATS and associated laboratory experiments. PATS in the lower Santa Clara River routinely experienced wide diurnal temperature fluctuations of 10°F to 25°F (range approximately 60°F to 83°F in July) in the shallow side channels that they favor as habitat. Immediately upstream of the Valencia WRP (where UTS have been found periodically over the last 20 years), water temperatures in summer frequently vary by more than 12°F, with peaks around 75°F to 80°F. The thermal preference experiments indicated that when presented with the ability to move freely between tanks with different temperatures (range 50°F to 86°F), PATS chose those with temperatures ranging from 51°F to 75°F (mean of 64°F).

A potential inference from this is that, at least for temperatures up to 75°F, the Δ5°F limitation does not have a clear biological basis. For example, during the winter months, temperature increases from the Valencia WRP largely bring temperatures from the low end of the fishes' preferred range to the high end of the preferred range. The temperature modeling shows that completely eliminating effluent discharges is the only strategy tested that would likely prevent the maximum daily temperature from being greater than 80°F immediately downstream of the Valencia WRP, as well as making the Δ5°F limit non-applicable.[20] There were still occasions during the summer months under the 100 percent Valencia WRP effluent reduction scenario when water temperatures rose above 80°F downstream of the Valencia WRP due to ambient weather conditions. There were also a few days in the simulation period where peak water temperatures at the warmest part of the day were higher with no effluent release than under existing conditions because the volume of water was so low and had less thermal inertia, although nighttime temperatures dropped lower for the same reason.

Reducing Valencia WRP effluent volume by 50 percent was not effective in a below-average flow year because the volume of cooler water from upstream of the WRP was too low to sufficiently cool the volume of effluent. Although completely shading the river channel would lower temperatures, accomplishing this would depend on natural cycles of river erosion that are outside the District's control. Habitat suitability modeling performed for the Santa Clarita Valley Water Agency and measurements of velocity and depth upstream and downstream of the Valencia WRP taken during this Study indicate that reducing the volume of water from the WRP would also likely improve instream hydraulic conditions for UTS.

[20] Note that additional strategies for managing water temperature are being considered but were not assessed in this Study.

The study found no evidence that the current river temperatures downstream of the Valencia WRP are adversely affecting the BMI, algae or amphibian populations and communities, nor most fish populations within the study reach. During the Study period, water temperatures were within preferred ranges for UTS in winter and spring. In summer and fall, however, temperatures downstream of the Valencia WRP approached and at times were greater than the thermal limits of UTS (as evaluated using the surrogate PATS), depending on exposure duration.

The thermal tolerance studies conducted by the UC Davis Fish Physiology Laboratory indicate that adult PATS can tolerate temperatures above 80°F for periods of hours to days without mortality. Field observations were consistent with these results: adult and juvenile PATS were abundant in the river 29 miles downstream of the Valencia WRP (where the collection of PATS for laboratory studies occurred) even though daily temperatures there were greater than 80°F on 52 days between March and July 2025 collection events. Together, laboratory and field findings indicate that PATS (and thus UTS) can tolerate short-term excursions of 80°F during the warm-weather months of the year if diurnal thermal refugia are available during the evening and early morning. However, sustained excursions near or above 80°F pose substantial risk, especially to juveniles. Hydraulic habitat constraints further limit where UTS are likely to occur and therefore where thermal exposure is biologically relevant.

Collectively, these findings demonstrate that temperature variability, exposure duration, life stage sensitivity, and habitat suitability are critical factors in assessing WARM beneficial use support and that neither the 80°F absolute limit nor the Δ5°F criterion alone fully captures biological risk in this dynamic river system.

CHAPTER 8
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