A LONGITUDINAL TEMPERATURE PROFILE OF THE LOS ANGELES RIVER FROM JUNE THROUGH OCTOBER 2016: ESTABLISHING A BASELINE

RESOURCE
CONSERVATION DISTRICT
OF THE
SANTA MONICA MOUNTAINS

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Abstract

A pilot study to develop a longitudinal temperature profile of the Los Angeles River deployed continuously recording temperature loggers in 13 sites throughout the main stem and tributaries between June and October 2016. The river was divided into six zones based on channel conditions (soft bottom, concrete); main stem sites were distributed throughout all zones; and tributary sites were located just above their confluence with the main stem. Locations were selected to reflect representative conditions of water depth and canopy cover. Water temperature was recorded at 30 minute intervals, generating maximum, mean and minimum monthly and seasonal temperatures at each site. Seasonal maximum temperatures ranged between 21-34^{o}C, mean temperatures between 18-26^{o}C and minimum temperatures between 17-25^{o}C. No clear pattern of temperature from the headwaters to the ocean emerged, although diurnal differences between soft bottom and concrete channel reaches were observed. Overall, temperatures were too warm to support re-introduction of native fish species but currently support reproducing populations of several generalist non-native fish species dominated by tilapia and carp. Temperature mitigation throughout the river, but especially in the proposed restoration area will be needed if native fish species are to become re-established in the Los Angeles River. Albeit limited in scope, the present study establishes a baseline profile of summer/fall temperatures in the Los Angeles River, to which future conditions may be compared.

Acknowledgements

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Permitting and access to study locations were provided by CA Department of Parks and Recreation, Los Angeles County Flood Control District, Mountains Recreation and Conservation Authority, US Army Corps of Engineers, and the State Water Resources Control Board.

This study would not have been possible without a core group of dedicated volunteers who not only visited the sites monthly to download data, but also helped troubleshoot problems, coordinated with project managers and each other to shuttle equipment back and forth each month, and provided valuable insights about the river and the study. Although many people made contributions, the core group of volunteers included Robert Blankenship, Katherine Pease, William Bowling, David Banulas, Holly Schiefelbein, Luis Rincon, and Kalisa Myers. Their dedication, resourcefulness, and flexibility were invaluable. Other volunteers who participated in the study include Alys Arenas, Jim Burns, David Hernandez, Gary Ananian, Sierra Raby, Carli Ewert, Ngoc Luu, and Miguel Luna.

Thurston Hertler, a graduate intern from Cal State LOS ANGELES, and Dylan Hofflander, a Watershed Stewards Project member, were invaluable to the success of the study. Both invested hours of their time installing temperature loggers, assisting with volunteer training, collecting water quality data, and managing data and pictures.

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Introduction

The Los Angeles River flows through 14 cities and unincorporated areas in Los Angeles County, including some of the most "park-poor" metropolitan areas of the United States. Approximately 48 of the 51-mile river is contained in concrete flood control channels, leaving only three miles of river with natural channel bottom and riparian vegetation on the mainstem (City of Los Angeles 2007). The soft bottom reaches occur at three locations: the estuary in Long Beach between Willow Street Bridge and the Long Beach Harbor, the Sepulveda Flood Control Basin, and the Glendale Narrows. While portions of the upper Los Angeles River watershed within the Angeles National Forest in the upper Arroyo Seco and Tujunga/Pacoima Creek remain in a fairly natural state, when they enter the more urban areas many of the major tributaries to the river, such as Verdugo Wash, the lower Arroyo Seco, Compton Creek, and Rio Hondo, have a similar pattern of channelization, with only limited levels of natural channel bottom and riparian vegetation remaining depending on proximity to urban areas and flood risk to nearby infrastructure.

While the Los Angeles River is headed for an extraordinary restoration effort, the form and direction of said restoration is yet unclear. One major goal of the biological restoration of the river should be to understand how the contemporary aquatic community will respond to any restoration actions and examine opportunities for re-establishing native species. Without accurate information concerning the existing instream conditions of potential priority restoration reaches, the multi-million-dollar effort to revitalize the Los Angeles River will result in more real estate rather than real ecosystem benefits. Perhaps one of the most difficult issues to address is that of increased temperature due to channelization and other factors. Initiating thermal improvement efforts in the Los Angeles River could make it possible not only to expand the distribution of native fish species, but could, in the long run, also facilitate outmigration of wild rainbow trout from the headwaters of the Los Angeles River watershed to the ocean, which would contribute to the meta-population of endangered southern steelhead trout, as well as provide a road map for restoring other channelized rivers.

Among the suite of factors that influence distribution and abundance of fish species, water temperature is one of the most important. As ectotherms, the body temperature of fish is directly linked to the temperature of the water in which it resides. This means that growth, metabolism, feeding rate, reproduction, and rearing are all tied directly to water temperature (Carter 2005). Furthermore, most other aquatic organisms, such as benthic macroinvertebrates, that fish rely on as food sources are poikilotherms, meaning that food availability is also limited by water temperature.

Currently, native fish species only reside in the upper reaches of the watershed and in the estuary. The obligate freshwater community found in the upper reaches includes Arroyo chub (*Gila orcutti*), Santa Ana speckled dace (*Rhinichthys osculus ssp.*), Santa Ana sucker (*Catastomus santanae*), unarmored stickleback (*Gasterosteus aculeatus williamsoni*), and southern steelhead/rainbow trout (*Onchorhychus mykiss*) (Swift et al. 1993). However, numerous non-native fish species are found throughout the watershed, representing the dominant ichthyofauna of the river reaches that will undergo major restoration efforts (FoLAR 2016, Swift and Drill 2008). Several factors have contributed to the current distribution of fish in the Los Angeles River watershed. These include habitat alteration, pollution, movement barriers, introductions of exotic species, and storm-water inputs.

Data on critical thermal temperatures for fishes historically native to the Los Angeles River watershed are limited in the current literature. While increased summer water temperatures tend to be a major limiting factor for most salmonids, multiple studies conducted in southern California show that steelhead/rainbow trout (*O. mykiss*) demonstrate more flexibility in their temperature range and an ability to acclimate to higher temperatures within the southern extent of their range (Myrick and Cech 2000, Myrick and Cech 2005, Spina 2007). Critical thermal maxima (CTM) ranging from 26.7°C to 31.5°C have been reported for *O. mykiss* in southern California creeks (Bell 1986, Carter 2005, Dagit et al. 2009, Sloat and Osterback 2012). A detailed study of the unarmored stickleback (*G. aculeatus williamsoni*) found CTM for this species was 30.4°C when individuals were acclimated to 8°C, and 34.6°C when acclimated to 22.7°C (Feldmeth and Baskin 1976). This study was conducted on fish collected from the Santa Clarita River, however the species was historically found in parts of the Los Angeles River watershed. Unfortunately, these are the only species for which a detailed study on CTM has been published for fish species native to the Los Angeles River.

Information from past studies and surveys of native fishes of the Los Angeles basin can be utilized to better understand the thermal requirements of these species relative to the conditions currently found in the urbanized portion of the Los Angeles River. Moyle (2002) reports that Santa Ana suckers (*C. santanae*) are found in streams where temperatures do not exceed 22°C. Mortality events are also reported for this species when temperatures exceeded 32.8°C in the Santa Ana River and 26.7°C in Big Tujunga Creek (USFWS 2014). In a survey of the upper San Gabriel River from 2007 and 2008, O'Brien et al. (2011) report mean daily temperatures of ~21°C in the north and east forks of the San Gabriel River and ~ 20°C in the west fork. This study reported Santa Ana sucker, Santa Ana speckled dace (*R. osculus ssp.*) and rainbow trout (*O. mykiss*) in all three forks of the San Gabriel River, while Arroyo chub (*G. orcutti*) were only found in the east and west forks (O'Brien et al. 2011).

In urban streams like the Los Angeles River, land use activities are a strong driver of thermal temperature regimes. Simplifying the physical structure of the river channel eliminates natural thermal buffers and insulators (Pool and Berman 2001), causing water temperature to be more vulnerable to fluctuations in ambient air temperature. Land use activities that increase impervious surfaces outside the stream channel alter not only the amount of water flowing into the stream, but also its timing and temperature (Poole et al. 2001a, 2001b). Confining a stream to a concrete channel also eliminates the stream's connection with groundwater, resulting in loss of the natural buffering effect that groundwater has on stream temperatures. In addition, concrete lining the banks of these natural bottom areas absorbs solar energy and radiates heat both day and night due to the thermal mass of the construction materials.

Even though much of the river has been channelized, there are still areas that could potentially provide suitable fish habitat for native species (i.e. Glendale Narrows). Since water temperature is so closely tied to the distribution and abundance of fish species, including their food sources and habitat requirements, a longitudinal temperature profile of the river can be used as an indicator of habitat quality at the watershed scale (Poole et al. 2001a). Determining where the suitable temperature profiles occur for native fish in the Los Angeles River is an important first step for any proposed restoration effort. If temperatures are in fact suitable for native species, then future efforts can focus on targeted streambank and riparian habitat restoration, and non-native species management. If temperatures in the river are not suitable for native species, future restoration efforts should be developed with a focus on improving the temperature profile of the river for native fishes.

In 2016 a study was initiated to begin to capture a detailed thermal profile of the Los Angeles River watershed. This initial work included installation of continuously recording temperature data loggers at 13 sites throughout the watershed from May through October 2016 attempted to characterize temperature throughout the watershed, to document current baseline conditions at representative locations, and to identify opportunities for restoration of native fish habitat. It also served as a pilot study to test the methodology at a subset of sample locations before implementing the project at a broader scale. We estimate that continuously recording temperature loggers will need to be installed at approximately 35 to 40 locations throughout the watershed for multiple years to provide a complete and reliable analysis of the river's longitudinal temperature profile. Albeit limited in scope, the present study establishes a baseline profile of summer/fall temperatures in the Los Angeles River, to which future conditions may be compared.

This pilot study was funded by USC Sea Grant emergency funds, Trout Unlimited, and the Los Angeles County Fish and Game Commission, and completed with help from numerous partner organizations, universities, and volunteers. While this study provided a broad-brush picture of the temperature conditions, it also identified data gaps that an expanded study would address. This study is the first step toward developing vital tools that would enable project stakeholders to identify the character and locations of critical thermal barriers to fish species recovery.

Materials and Methods

Study Area

The study area includes the main stem and major tributaries of the Los Angeles River watershed, from its headwaters in the Angeles National Forest and western San Fernando Valley, to the estuary in Long Beach (Figure 1). For comparison purposes, we have divided the watershed into six zones based on 1) areas where native aquatic species are still found (Zones 1 and 6); 2) soft bottom reaches of the river where it might be possible to restore native aquatic species (Zones 2 and 3); and, 3) concrete reaches of the river (Zones 4 and 5).

Loggers were installed at 13 locations on May 5, 6, and 9. Sites were selected based on the following criteria: accessibility, safety, location with respect to soft bottom reaches and tributary inputs, and distribution along the river. Due to vandalism, several temperature loggers were lost at multiple sites early on, and because of limited equipment and resources, two sites were eliminated from the study by the beginning of June (one soft-bottom site in Zone 3 and a site in Zone 4 just upstream of the confluence of Rio Hondo).

The Council for Watershed Health deployed data sondes in Zone 1, and have offered to provide temperature data for those locations. Unfortunately, this data was not yet available at the time of writing this report.

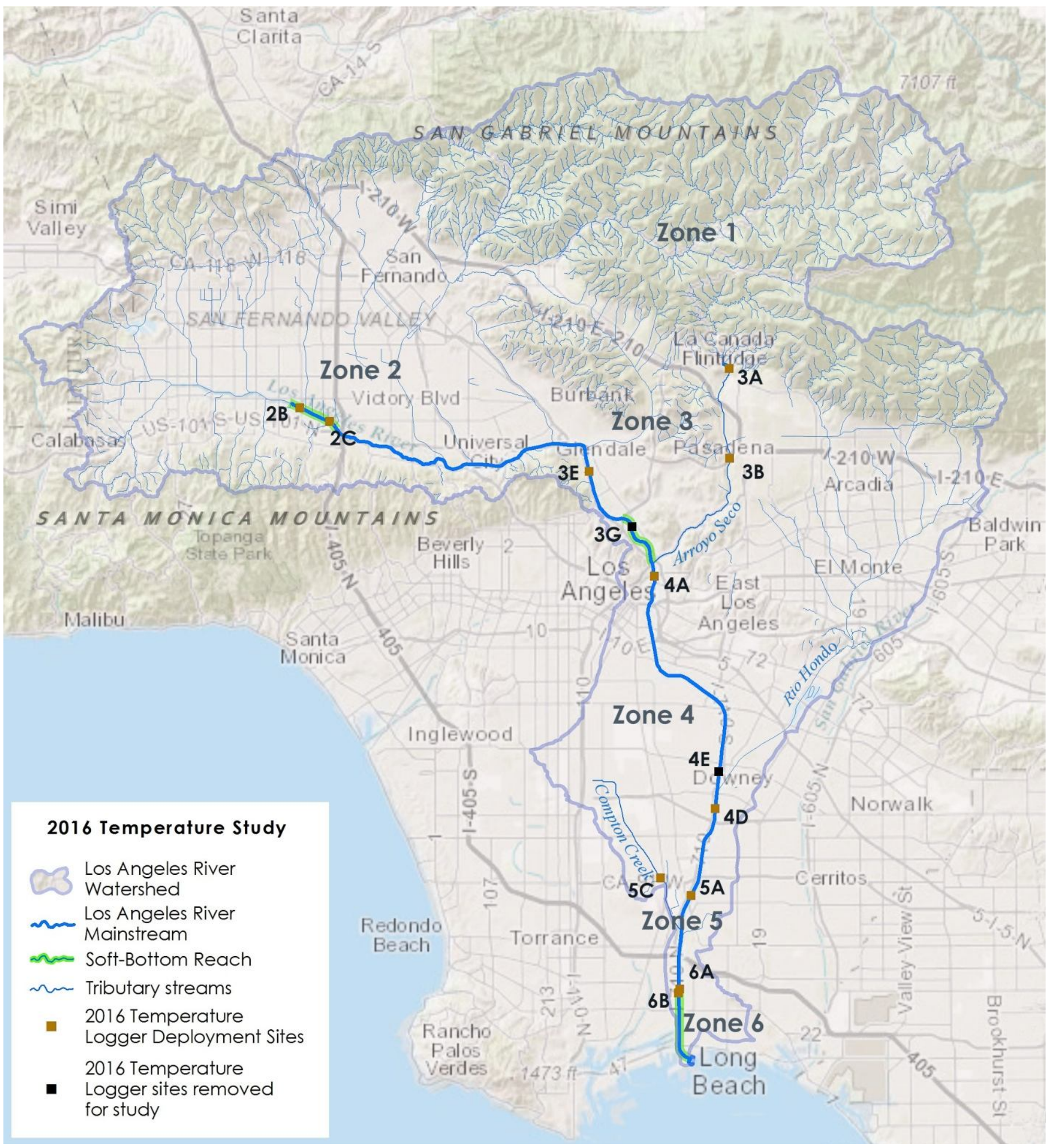

Figure 1. Study Area showing zones and 13 original locations.

Table 1. Site characteristics of the LOS ANGELES River Water Temperature Monitoring locations

Zone	Region	Site	Location	Channel Type	Distance from River Mouth (mi)	Reach Type	Data Range
1	Angeles National Forest	Data from Council for Watershed Health not inlcuded.					*No Data*
2	Western San Fernando Valley	B	Balboa	Soft Bottom	45.9	Main Channel	Jun - Oct
		C	Burbank	Soft Bottom	44.4	Main Channel	Jun - Oct
3	Arroyo Seco	A	Above Devils Gate Dam	Soft Bottom	36.2	Tributary	Jun - Oct
		B	Rose Bowl	Soft Bottom	31.8	Tributary	Jun - Oct
	Glendale Narrows	E	Atwater Park	Soft Bottom	30.5	Main Channel	Jun - Aug
		G	Bowtie Parcel	Soft Bottom	27.0	Main Channel	*No Data*
4	Downtown LOS ANGELES to Rio Hondo	A	LOS ANGELES State Historic Park	Concrete	24.4	Main Channel	Jun - Jul
		D	Hollydale Park (Downstream of Rio Hondo)	Concrete	12.1	Main Channel	Jun - Oct
		E	Upstream of Rio Hondo	Concrete	13.8	Main Channel	*No Data*
5	Compton to Dominguez Gap	A	DeForest Park	Soft Bottom	8.0	Main Channel	Jun - Oct
		C	Compton Creek	Concrete	8.8	Tributary	Jun - Sept
6	Long Beach Estuary	A	Willow St. Bridge	Concrete	3.7	Main Channel	Jun - Oct
		B	Willow St. Bridge	Soft Bottom	3.6	Main Channel	Jun - Oct

Stream Temperature Measurement

Stream temperature was recorded from early June through October 2016 using continuously recording thermometers programmed to record time, date, and temperature at 30-minute intervals. The study period was selected to align with southern California's dry season, which is the time of year with the highest air temperatures and lowest precipitation, when thermal stress on fish would be most likely to occur. Although most of the loggers were deployed in May, many issues arose during this first month that resulted in a total loss of data at multiple sites for that month and unreliable data sets at other sites. For this reason, two sites (3G Bowtie and 4E Upstream of Rio Hondo) were removed from the study completely and all data collected for the month of May was excluded from subsequent analysis.

Water temperature data was collected using a combination of ONSET HOBO TidbiT v2 Water Temperature Data Loggers and HOBO Pendant Temperature Data Loggers (Figure 2). The TidbiT v2 has an accuracy of ±0.21°C and the Pendant has ± 0.53°C accuracy; both are designed for use in outdoor and underwater environments.

Figure 2. Thermometers used in study: ONSET HOBO TidbiT v2 Temp Logger (left) and ONSET HOBO Pendant Temp Logger (right)

All loggers were prepared for deployment in the lower third of the water column with appropriate site specific materials to anchor them in place depending on site conditions (substrate, vegetation, access, etc.). At all sites the loggers were crimped to one end of an approximately one-meter long line of 90lb-test stainless steel trolling wire using 1.40 mm leaden sleeves. The method used to anchor the other end of the wire to the stream channel varied depending on site conditions. For natural flow areas with mature vegetation, the devices were secured to a tree trunk, root, boulder or other stable object at the water's edge in such a way as to allow the logger to hang near the bottom of the water column while keeping it out of plain sight in order to reduce incidents of vandalism. For concrete channels and other areas where the previous method was not feasible, temperature loggers were attached to the channel wall using a concrete screw and washers installed at the water's edge (Figure 3). Weights were added to all HOBOs to help prevent them from being swept up on shore during high flow events. Data loggers were not enclosed in protective housing, and therefore were only protected from direct sunlight where sufficient riparian vegetation was present to provide shading.

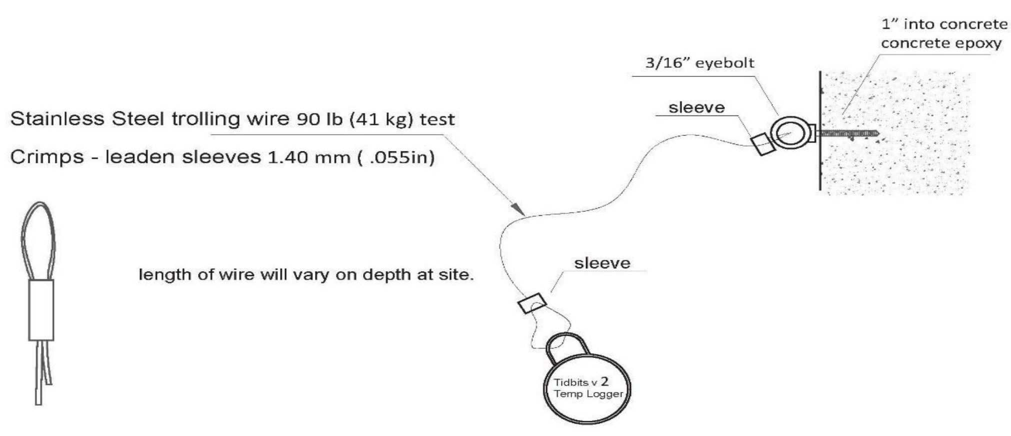

Figure 3. Schematic diagram of attachment method.

Stream Temperature Data Collection

Each location was visited monthly by trained citizen science volunteers to download the recorded data, ensure loggers were secure, and photograph site conditions. If a logger was missing, the volunteers would replace it with a spare from their kit (if available). In instances where dry-down had occurred, the loggers were moved to a new location within 30 meters or across the low flow channel where sufficient water persisted. Data from each logger was offloaded using a HOBO U-DTW-1 Waterproof Shuttle Data Transporter (Shuttle) in the field, which was subsequently uploaded to a computer using Hoboware PRO software, then compiled in an EXCEL database.

Data points available at each site varied due to environmental factors affecting temperature readings (e.g. dry-downs, washouts, etc.), theft or vandalism, and equipment malfunction. These factors affected both the thermometer's ability to record data and its ability to take data representative of river conditions. Of all potential data points, less than 15 percent were absent for the entire study period across all sites. The majority of missing data occurred at sites 3E Atwater, 4A LA State Historic Park, and 5C Compton Creek.

Table 2. Summary of potential and missing data points based on total of 7117 potential data points (148 days) at each site for the study period of June 4, 2016 at 12:00 to October 30, 2016 at 18:00.

	2B	2C	3A	3B	3E	4A	4D	5A	5C	6A	6B
Potential Data Points	7117	7117	7117	7117	7117	7117	7117	7117	7117	7117	7117
Missing Data Points	197	196	98	1	3515	5184	7	21	2140	1	57
Missing Data Days	4	4	2	0	73	108	0	0	45	0	1
					%Potential Data Missing						
total:	2.8	2.8	1.4	0.0	49.4	72.8	0.1	0.3	30.1	0.0	0.8
June:	0.0	0.0	0.0	0.0	0.0	19.2	0.0	0.0	4.5	0.0	0.0
July:	0.0	0.0	0.0	0.0	0.0	39.2	0.0	0.0	0.0	0.0	2.6
Aug:	0.0	0.0	0.0	0.0	43.4	100.0	0.1	0.0	0.0	0.0	0.5
Sept:	0.0	0.0	0.0	0.0	100.0	100.0	0.0	0.0	45.4	0.0	0.0
Oct:	17.2	17.1	10.6	4.0	100.0	100.0	4.0	4.0	100.0	4.0	4.7

Temperature Data Analysis

Temperature data recorded at 30-minute intervals from study reaches were summarized to establish a daily mean, maximum, and minimum temperature for each site. These daily metrics were combined to establish daily, monthly, and seasonal means, maxima, and minima, These temperature metrics were compared between study sites to examine differences between hard and soft bottom locations, sites in the main stem and tributaries, to calculate the frequency of days when temperatures exceed thermal limits for target native fish species, and to map the changes in temperature throughout the river.

A Quality Assurance/Quality Control process to ensure all data were accurate included several levels of review. The first level was when HOBO readings were imported into EXCEL, and included completeness, and examination for unusual outliers or missing information. Then difference in temperature readings between consecutive data points was analyzed in an effort to differentiate between natural extreme changes in temperature, unnatural extreme changes in temperature representative of river conditions, and unnatural extreme changes in temperature that are not representative of river conditions (HOBO being handled or out of water during temperature recording).

Air Temperature, Precipitation, and Flow

Precipitation and air temperatures were monitored informally throughout the course of the study. No significant storm events occurred during the study period. A rain event did occur in early May, around the time that the thermometers were initially deployed, and again at the end of October, after most of the thermometers had already been removed from the channel. Rainfall data is in the process of being acquired from Los Angeles Department of Public Works for rain gauges in the vicinity of study locations. When obtained, these data will be analyzed with respect to variations in water temperature. Comparing ambient air temperatures and precipitation data to stream water temperatures could provide insights into various patterns found in the data.

Flow into the Los Angeles River during June – October is comprised of releases from several water reclamation plants, non-point source "urban drool" surface run off, and rain events. It was not possible to obtain data on flow levels in time for this report. However, the Donald C. Tillman Water Reclamation Plant, a leading producer of reclaimed water in the San Fernando Valley, releases approximately 80 million gallons of tertiary treated water per day in to the Los Angeles River Basin. Treated water is distributed to three nearby lakes (the Japanese Garden Lake, the Wildlife Lake, and the Balboa Recreation Lake) as well as directly into the Los Angeles River (Los Angeles City Sanitation website 2017). These releases, augmented by those from other reclamation plants, account for the majority of the Los Angeles River's baseflow. Data from stream gauges at various locations in the Los Angeles River have been requested and will be reviewed with respect to temperature patterns identified at each location once available.

Volunteer Training and Recruitment

Working with partners from the Arroyo Seco Foundation, Friends of the Los Angeles River, Heal the Bay, Los Angeles Fly Fishers and Trout Unlimited, a total of 12 volunteers attended a training session held at the River Center on 4 June 2016. During this 3 hour event, they were provided instruction on how to upload the hobos, and detailed directions on how to find the temperature loggers, upload and trouble shoot, and ensure that the loggers were in proper position. The logistics of getting the shuttles to and from the RCDSMM office to be uploaded into EXCEL were organized and dates set for collecting data. Directions to the sites and information regarding access are included in Appendix A. The training materials provided are included in Appendix B. During the course of the project, a total of at least 200 volunteer hours were contributed to gathering the data, and volunteer contribution towards data management exceeded another 200 hours.

Results

Daily Maximum Temperatures

Daily maximum temperatures at all sites between June and October 2016 (Figure 4) indicate that the highest daily maximum temperatures consistently occurred in main stem concrete reaches (4A LA State Historic Park, 4D Hollydale Park, 5A De Forest), while lower temperatures consistently occurred in soft-bottom tributary reaches (3A Above Devils Gate Dam, 3B Rose Bowl, 5C Compton Creek). Site 3E Atwater Park exhibited some of the highest daily maximum temperatures, despite having soft bottom and riparian vegetation at this site. Sites 2B Balboa and 2C Burbank in the Sepulveda Basin show moderate daily maximum temperatures compared to other sites, while the estuary sites (6A Willow St concrete and 6B Willow St soft) demonstrate more variability in maximum daily temperatures across the season than other sites.

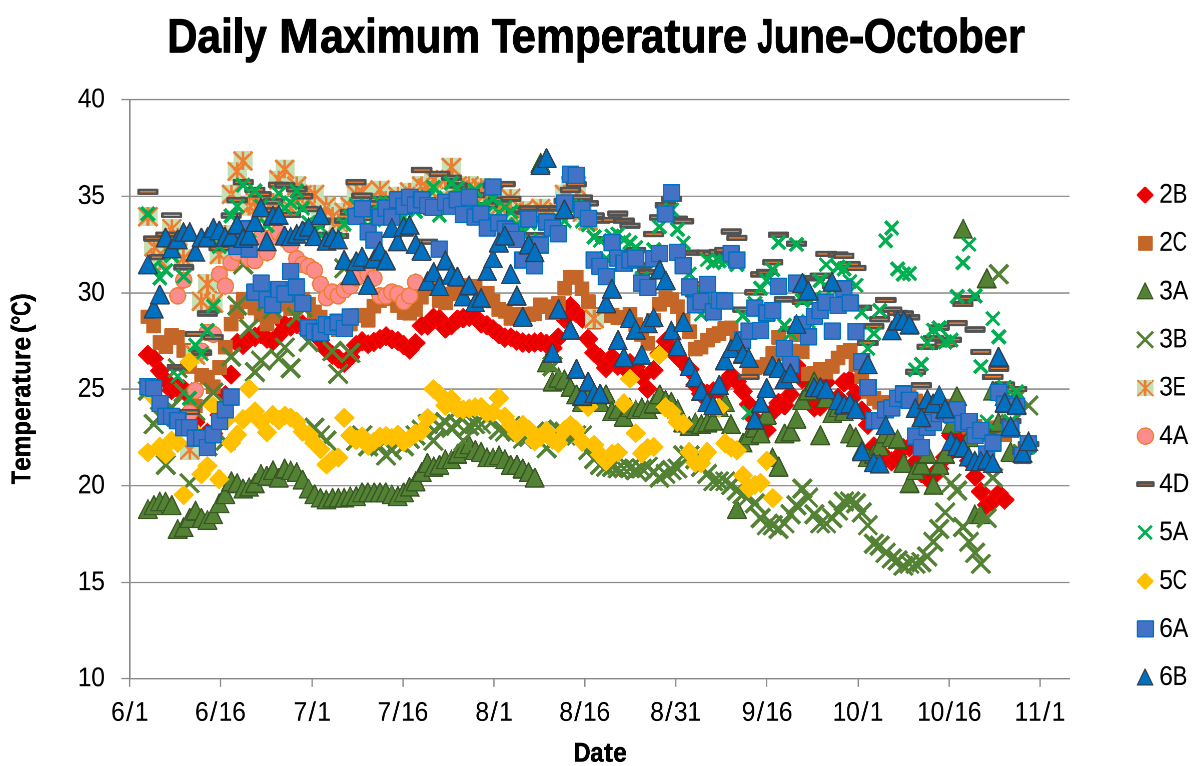

Figure 4. Daily maximum temperatures at all sites plotted by date between June – October 2016.

Monthly Maximum, Minimum, and Average Temperatures

The maximum water temperatures observed in all study sites are shown by month in Table 3. Maximum temperatures showed the widest range in June, with readings ranging from

20.9°C to 36.8°C. The highest single temperature reading occurred in August at the Long Beach Estuary (site 6A Willow St concrete). A sewage spill into the Long Beach estuary on 17 July 2016 caused an algal bloom that was observed through August and could have contributed to these higher temperatures. Soft bottomed site 6B Willow St also experienced its highest temperature during the month of August, as did 2B Balboa, 2C Burbank, and 3A Above Devils Gate Dam. Sites 3B Rose Bowl, 3E Atwater, and 4A LA State Historic Park reached their highest temperatures in the month of June, while two other sites (4D Hollydale Park and 5A DeForest Park) reached their maximum temperatures in July. 5C Compton Creek was the only site to record its highest maximum temperature in September. Site specific details are provided in Appendix A.

Table 3. Maximum temperatures (Max), Minimum temperatures (Min), and Range between Maximum and Minimum temperatures each month. Highest Maximum Temperatures for each month shown in bold; Highest Maximum Temperature for each site underlined.

	June			July			Aug.			Sept.			Oct.		
SITE	MAX	MIN	RANGE	MAX	MIN	RANGE	MAX	MIN	RANGE	MAX	MIN	RANGE	MAX	MIN	RANGE
2B*	28.4	21.2	7.1	28.7	25.1	3.6	29.3	23.8	5.5	26.7	21.7	5.0	24.8	18.4	6.3
2C*	29.9	22.8	7.0	30.5	25.9	4.6	30.8	25.5	5.4	29.3	23.3	6.0	26.3	19.9	6.4
3A*	20.9	15.2	5.7	22.1	17.8	4.4	36.7	16.0	20.7	25.4	14.4	11.0	33.3	13.4	20.0
3B*	31.5	14.4	17.1	31.3	17.8	13.5	26.2	19.7	6.5	21.6	17.2	4.4	31.0	15.1	15.9
3E*	**36.8**	17.1	19.7	**36.5**	19.8	16.8	35.5	19.1	16.5	-	-	-	-	-	-
4A	33.2	20.0	13.2	31.5	23.5	8.0	-	-	-	-	-	-	-	-	-
4D	35.7	17.2	18.6	36.4	20.6	15.7	35.6	19.8	15.8	**33.8**	17.4	16.4	31.3	17.0	14.3
5A	35.6	16.7	18.9	35.7	20.4	15.3	34.9	19.5	15.4	33.3	17.0	16.3	**33.4**	13.2	20.1
5C	26.4	16.5	9.9	25.0	19.7	5.4	26.8	19.6	7.2	29.5	17.7	11.8	-	-	-
6A	33.3	20.9	12.4	34.9	20.3	14.6	36.1	19.6	16.5	32.1	17.5	14.6	28.0	17.5	10.5
6B*	34.4	21.3	13.1	34.0	20.2	13.8	**37.0**	18.6	18.4	30.6	17.5	13.1	28.6	15.4	13.1

** indicates soft-bottom location*

Monthly maximum temperatures

Zone 2 sites had the most consistent monthly maximums. All other sites showed extreme variation in maximums from month to month. In August, sites 6A Willow St. concrete and 6B Willow St. soft in the Long Beach Estuary had the warmest temperatures of the data set. Throughout the month, site 6A Willow St. concrete recorded its warmest temperatures in the late afternoon and early evening with Site 6B Willow St. soft showing similar warming patterns 2-3 hours later. It is not clear how the tidal inputs affected these patterns. Site 5A DeForest Park showed unusually high monthly temperatures during October closely coinciding, although more extreme, with upstream site 4D Hollydale Park.

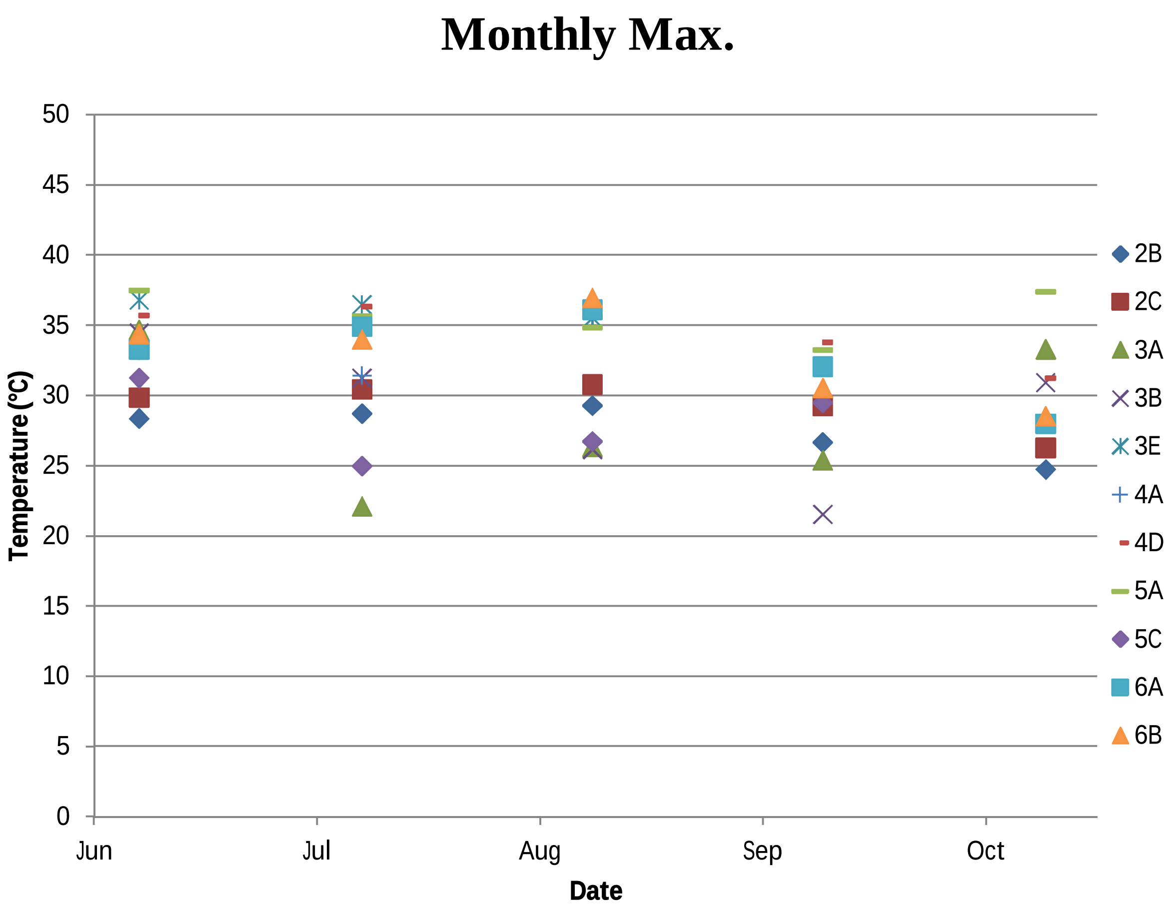

Figure 5. Monthly Maximum Temperatures taken at 11 sites in Los Angeles River between June 4, 2016 at 12:00 and October 30, 2016 at 18:00.

Monthly Minimum Temperatures

Site 2B Balboa and 2C Burbank had the warmest minimum temperatures, but also had one of the smallest monthly ranges (3.6-7.1^{o}C) and also recorded relatively cool maximums as compared to other sites. Site 3A Above Devil's Gate Dam is a fairly natural tributary to the river and consistently recorded the coolest minimums. Nearby in the tributary, site 3B Rose Bowl also recorded relatively low minimums during June and July. In sites with concrete bottoms, the range between monthly maximum and minimum is much greater (13.2-20.1^{o}C).

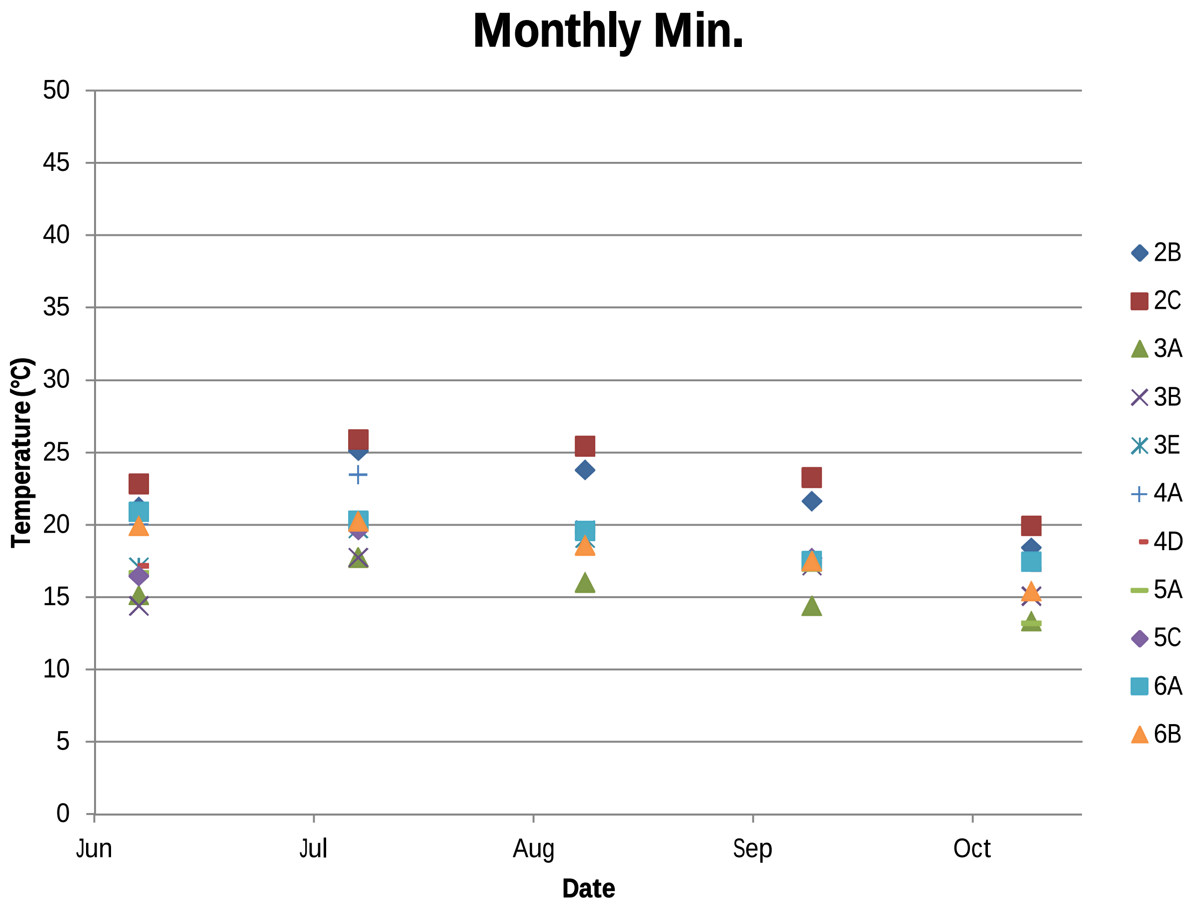

Figure 6. Monthly minimum temperatures taken at 11 sites in Los Angeles River between June 4, 2016 at 12:00 and October 30, 2016 at 18:00.

Average Monthly Temperatures

The tributaries in the Glendale Narrows at sites 3A Above Devils Gate Dam, 3B Rose Bowl, and the 5C Compton Creek tributary in the Dominguez Gap had the coolest average temperatures of all the sites. The sites 2B Balboa and 2C Burbank in Zone 2 in the upper watershed in the San Fernando Valley had the warmest averages and the smallest ranges of temperatures.

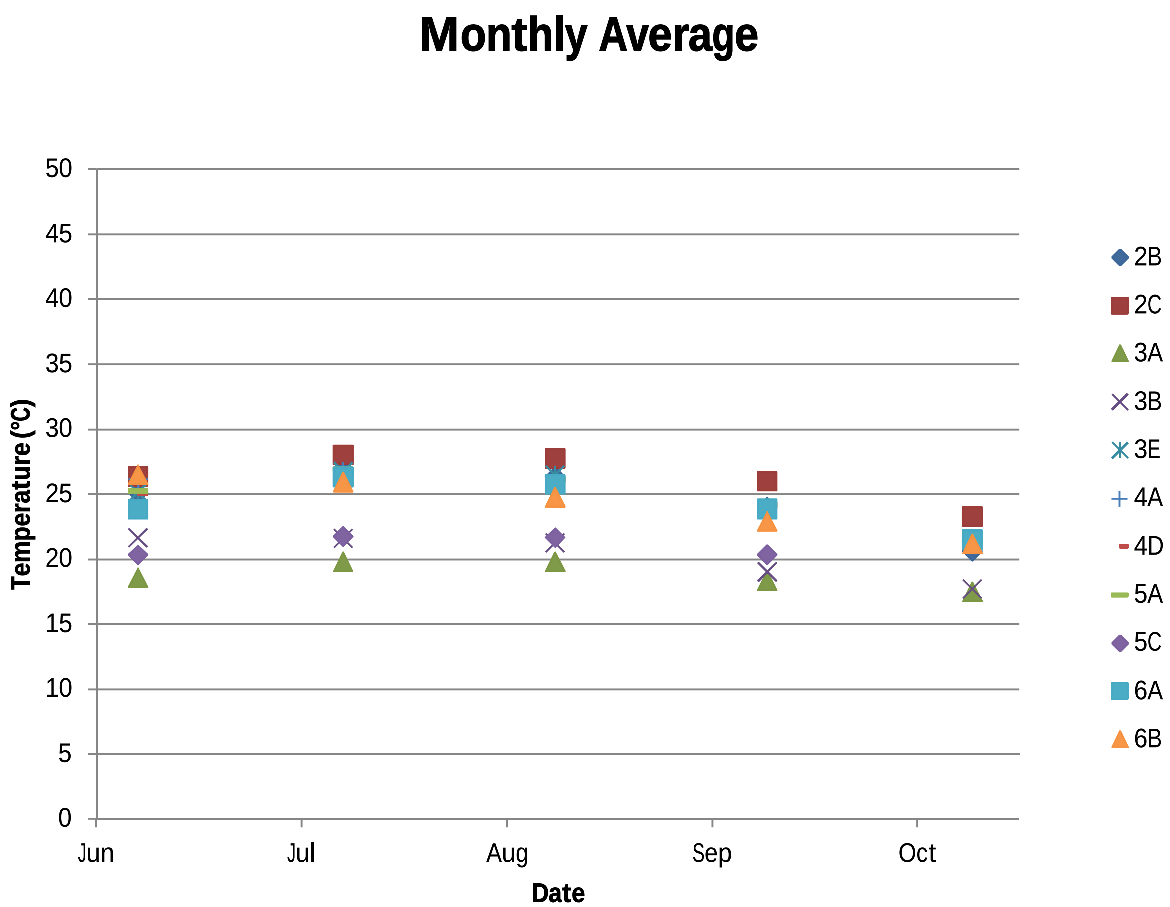

Figure 7. Monthly mean temperatures taken at 11 sites in Los Angeles River between June 4, 2016 at 12:00 and October 30, 2016 at 18:00.

Longitudinal Temperature Profile of the Los Angeles River June through October 2016

As expected, the highest temperatures occurred in the most heavily developed portions of the watershed, namely 3E Atwater Park, 4A Los Angeles State Historic Park, 4D Hollydale Park, and 5A DeForest Park, all with average maximum temperatures for the season topping 30°C (Table 4). The 3E Atwater Park site had the highest temperatures of the season (average maximum T= 34.1°C), despite having a soft bottom channel and some riparian vegetation. This site also demonstrated the largest difference between average maximum and average minimum season temperatures. The coolest temperatures in the watershed were found at the Arroyo Seco sites (3A Above Devils Gate Dam, 3B Rose Bowl). Of the mainstem channel reaches, the Sepulveda Basin sites (2B Balboa and 2C Burbank) showed the most stability with only a 1.4° and 2.3° difference between average maximum and average minimum temperatures. Figures 8 and 9 illustrate these changes in water temperature along the longitudinal continuum of the river.

Table 4. Seasonal Average Maximum, Mean and Minimum Temperatures at each site from June 4, 2016 to October 30, 2016.

Site	Max	Mean	Min	Notes
2B	25.6	24.8	24.2	Soft bottom, head-water reach with natural riparian vegetation.
2C	27.6	26.4	25.3	Soft bottom, tributary reach in urbanized area downstream of Devil's Gate Dam
3A	22.0	18.8	17.3	Soft Bottom main channel reach with native riparian vegetation.
3B	21.8	20.2	19.0	Soft Bottom main channel reach with native riparian vegetation.
3E	34.1	26.2	20.7	Soft bottom. Limited riparian vegetation. Just upstream of Glendale Water Reclamation Plant.
4A	30.5	26.5	23.7	Concrete channel in heavily urbanized area.
4D	31.9	24.8	20.5	Concrete channel in heavily urbanized area.
5A	31.6	24.8	19.9	Concrete channel in heavily urbanized area.
5C	22.8	21.2	20.2	Soft bottom, tributary reach in urbanized area
6A	29.2	24.4	21.1	At end of concrete channel entering estuary.
6B	28.7	24.3	21.1	Soft bottom estuary.

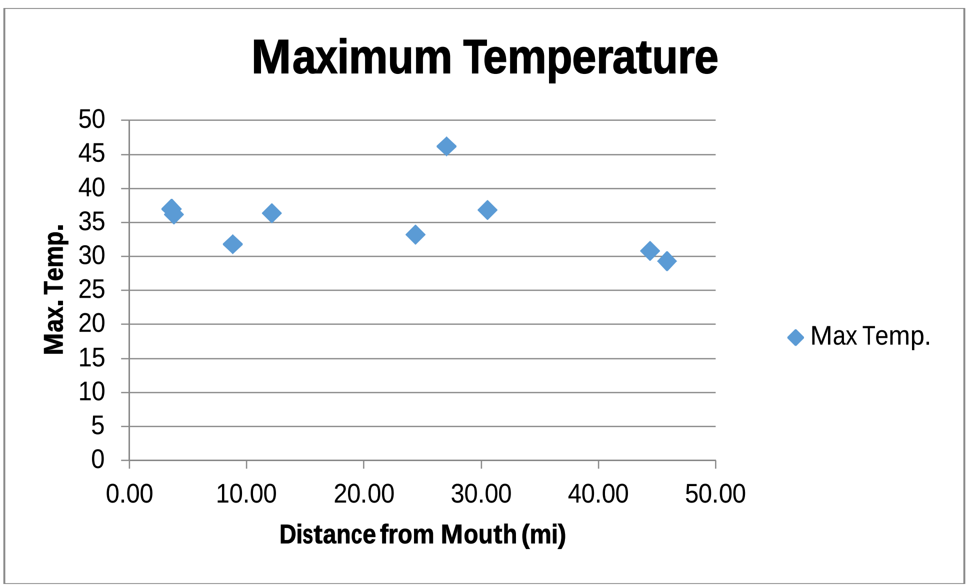

Figure 8. Los Angeles River Seasonal Average Maximum Seasonal Temperatures from Estuary to Headwaters

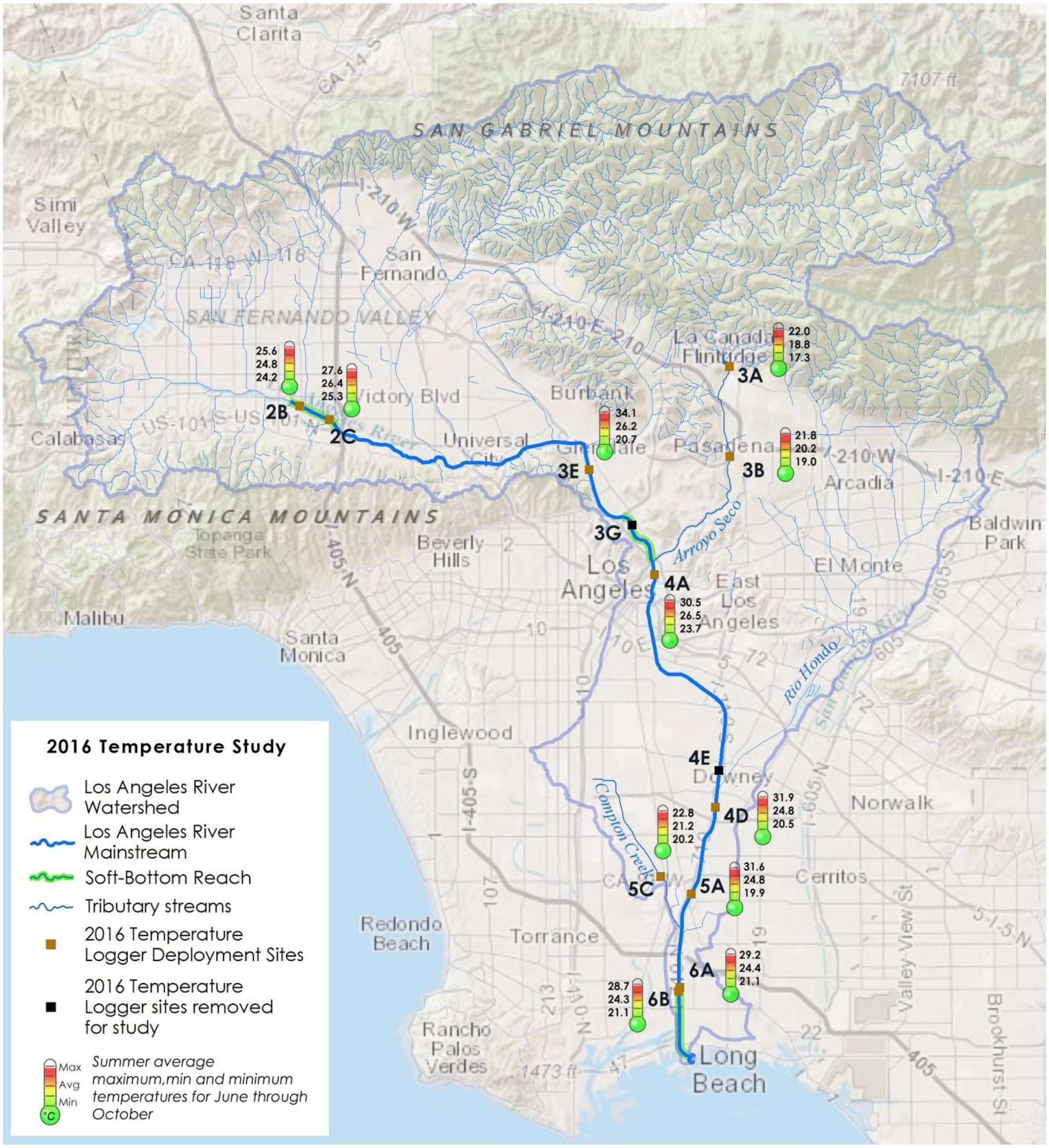

Figure 9. Average Maximum, Average and Minimum Stream Temperatures in the Los Angeles River Watershed, June – October 2006.

Timing and Duration of Temperatures

Diurnal hourly variation is shown in Figure 10. Throughout the study period, the coolest temperatures in the Los Angeles River were mostly recorded in the early morning, between the hours of 06:00 and 08:00, with the exception of site 6B Willow St. soft whose coolest hour was 11:00 (Table 5). The highest temperatures occurred between the hours of 14:00 and 20:00, with the majority of sites peaking between 14:00 and 16:00.

Greater diurnal variation occurred in highly urbanized zones at 4A Los Angeles State Historic Park, 4D Hollydale Park, 5C Compton Creek, and 6A Willow St. concrete, while diurnal variation was much diminished in more natural sites with soft bottoms and riparian vegetation such as sites 3A Above Devil's Gate Dam and 3B Rose Bowl.

Interestingly, in the more natural San Fernando Valley Region, both sites 2B Balboa and 2C Burbank were warmer overnight throughout the whole season. Night time temperatures were 0.53°C warmer than daytime temperatures at site 2B Balboa and 0.86° warmer at site 2C Burbank. This pattern of warmer overnight temperatures was also observed at the estuary sites 6A Willow St. concrete and 6B Willow St. soft. Night time temperatures were 3.07°C warmer at 6A Willow St. concrete, and 0.95°C warmer at 6B Willow St. Bridge throughout the study period.

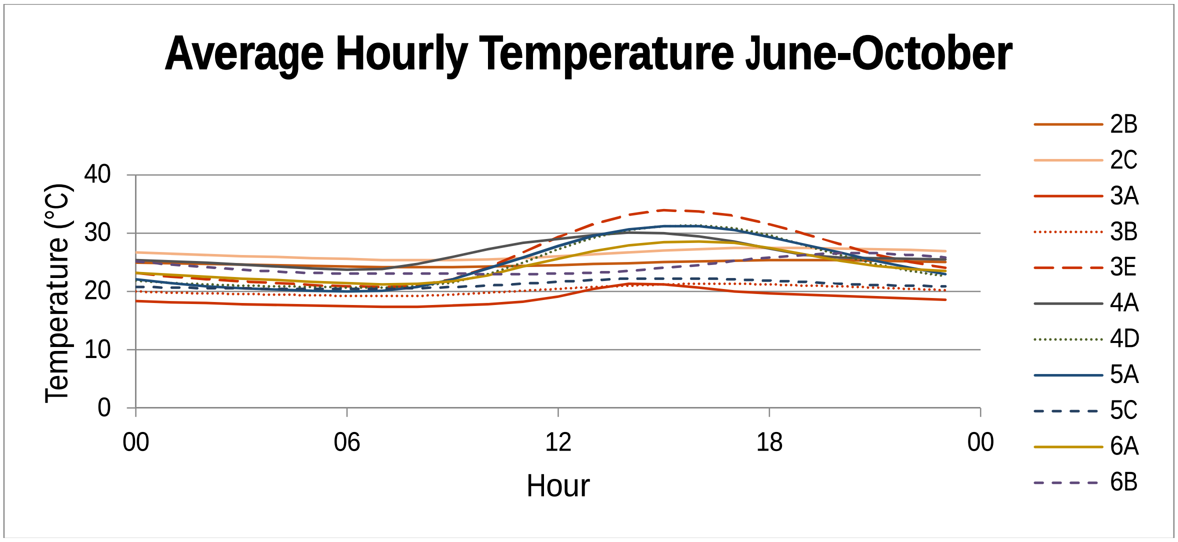

Figure 10. Average hourly temperatures of 11 sites in the Los Angeles River between June 4, 2016 at 12:00 and October 31, 2016 at 18:00.

Table 5. Timing of maximum and minimum average hourly temperatures at sites in Los Angeles River.

Average hourly temp. summary table

	MAX		MIN	
SITE	TIME	°C	TIME2	°C2
2B	19:00	25.43	8:00	24.19
2C	18:00	27.49	8:00	25.36
3A	14:00	21.36	7:00	17.37
3B	16:00	21.35	7:00	19.24
3E	15:00	33.93	7:00	20.77
4A	14:00	30.09	6:00	23.76
4D	16:00	31.28	7:00	20.65
5A	15:00	31.24	6:00	20.01
5C	15:00	22.24	6:00	20.44
6A	16:00	28.63	7:00	21.25
6B	20:00	26.59	11:00	23.00

Native Fish Potential in Relation to Temperature

Table 6 lists the native and non-native fish species documented in the Los Angeles River both historically and currently. Many of the non-native species are commonly introduced either by vector control for mosquito abatement or were released from aquariums and became naturalized.

Table 6. Fish species of the Los Angeles River (FoLAR 2016)

Common name	Scientific name	Location
NATIVE SPECIES		
Arroyo chub	*Gila orcutti*	Upper watershed
Santa Ana speckled dace	*Rhinichthys osculus* ssp.	Upper watershed
Santa Ana sucker	*Catastomus santanae*	Upper watershed
Rainbow trout	*Onchorhychus mykiss*	Upper watershed
California killifish	*Fundulus parvipinnis*	Lower river end of concrete Long Beach
Northern anchovy	*Engraulis mordax*	Lower river end of concrete Long Beach
Stripped mullet	*Mugil cephalus*	Lower river end of concrete Long Beach
Topsmelt	*Atherinops affinis*	Lower river end of concrete Long Beach
NON-NATIVE SPECIES		
Amazon sailfin catfish	*Pteroplichthys pardalis*	Glendale narrows, expected in concrete area
Black bullhead catfish	*Ameiurus melass*	
Carp	*Cyprinus carpio*	Entire channelized reach
Fathead minnow	*Pimephales promelas*	Glendale narrows, expected in concrete area
Gold shiner	*Notemigonus crysoleucas*	Sepulveda Dam area, expected in concrete area
Goldfish	*Carassius auratus*	Entire channelized reach
Green sunfish	*Lepomis cyanellus*	Entire channelized reach
Largemouth bass	*Micropterus salmoides*	Entire channelized reach
Mosquitofish	*Gambusia affinis*	Sepulveda Dam area, expected in concrete area
Suckermouth catfish	*Hypostomus plecostomus*	Sepulveda Dam area, expected in concrete area
Tilapia	*Oreochromis sp.*	Entire channelized reach

Using the estimated upper critical thermal maximum for the majority of native fishes of between 20-30^{o}C as a guide, conditions throughout the Los Angeles River sites indicate that water temperatures between June and October shown in Figure 11 would be exceedingly challenging for southern steelhead trout, arroyo chub, unarmoured stickleback, Santa Ana suckers, and Santa Ana speckled dace and in the estuary reach, California killifish. There were few reaches that provided temperatures below the critical thermal limits for all species at any time during the study period. Acquiring data from the Council for Watershed Health for stream temperature data in Zone 1 will allow comparison of temperature data between areas where some native fish species currently occur in the more natural upper tributaries and the rest of the watershed.

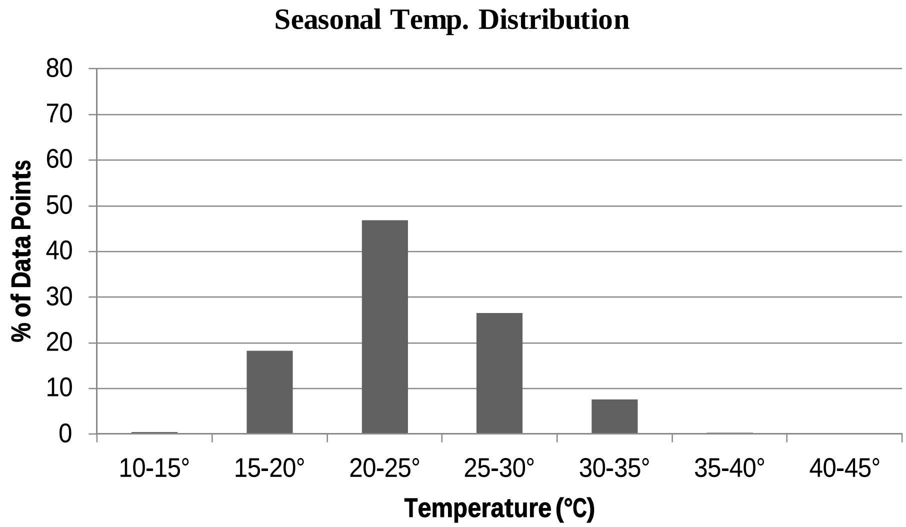

Figure 11. Seasonal Distribution of Temperatures of 11 sites in LOS ANGELES River between June 4, 2016 at 12:00 and October 30, 2016 at 18:00

Air Temperature, Precipitation, and Flow

Data on air temperature, rainfall, and flow from stream gauges has been requested but not yet been obtained.

Discussion

The smallest range of temperatures occurred in the upper watershed in the Sepulveda Basin, western San Fernando Valley, where the channel has a soft bottom, significant depth, and extensive riparian vegetation lining the banks and overhanging the wetted channel. While the natural conditions of this reach seem to moderate water temperatures from extreme fluctuations, the overall temperatures of the two sites (2B Balboa, 2C Burbank) remained fairly high. Temperatures in July never dropped below 25°C, which is often considered the critical thermal maxima for steelhead trout (Myrick and Cech 2000, Myrick and Cech 2005). Within this zone, only 36% of days at site 2B Balboa and 27% of days at site 2C Burbank did not exceed 25°C. The current fish community is comprised of non-native generalist species that share a higher tolerance and preference for water temperatures over 25^{o}C. These species presumably possess the ability to reproduce in microhabitats created by concrete channels and have wide ranging food preferences that have allowed them to become successful invaders.

Downstream in the main stem of the river near 3E Atwater Park, the temperature range broadens, with differences in monthly maximum and minimum temperatures ranging from 16.5 to 19.7°C. Although this site does have a soft bottom, its location in the heart of an urban center makes is more vulnerable to fluctuations in ambient air temperatures and heat island effects. The site is located downstream of a long stretch of simplified concrete channel surrounded by State

Highway Route 5 a multi-lane freeway, miles of impervious surfaces that are largely devoid of thermal buffers and insulators, save a small amount of heavily managed in-channel and riparian vegetation. Additionally, the concrete lining along the stream banks absorbs solar energy and radiates heat day and night due to the thermal mass of the construction materials. Not surprisingly, the monthly minimums and maximums at 3E Atwater Park were more extreme than those observed in Zone 2 (2B Balboa, 2C Burbank). 3E Atwater Park recorded monthly maximums in the mid-30s in June, July and August, and monthly minimums in the teens, whereas in Zone 2 monthly maximums did not exceed 30.8°C and minimums did not drop below 21°C in the same months.

Difficulties with maintaining thermometers in the highly visible concrete channels resulted in limited data sets for a large geographic area along the central main stem of the river. Sites 3G Bowtie and 4E Rio Hondo were both removed from the study early on due to limited equipment and unforeseen complications. This left the long stretch of river between sites 3E Atwater Park and 4D Hollydale Park with only one thermometer, which collected temperature for three months before going missing as well. Despite the limited data, trends appear to be fairly consistent in the main channel from site 3E Atwater Park down to 5A DeForest Park. Sites in Zones 4 and 5 follow very similar patterns to those exhibited in 3E Atwater Park.

The Long Beach Estuary showed some unusual trends, especially at site 6B Willow St. Soft where maximum average hourly temperatures peaked at 20:00 and minimum average hourly temperatures occurred at 11:00. Site 6A Willow St. Concrete, only one-tenth of a mile upstream, did not display this same trend. At 6A Willow St. Concrete temperatures peaked at 16:00 and minimum temperatures occurred at 7:00, which is more in line with the diurnal fluctuations of sites upstream. This could be a result of thermal transfer from the concrete into the water overnight. The only other sites with a somewhat similar pattern are 2B Balboa and 2C Burbank, where temperatures peaked at 19:00 and 18:00 respectively. These three sites have the most water depth and potentially more thermal capacity. This could possibly explain the more narrow range of temperatures at 2B Balboa and 2C Burbank as compared to more shallow sites having less canopy cover.

Temperatures in all of the tributaries were overall lower than those in the mainstem. The two Arroyo Seco sites (3A Above Devils Gate Dam, 3B Rose Bowl) displayed the coolest temperatures, and even 5C Compton Creek, surrounded by impervious surfaces in all directions remained cooler than any of the mainstem locations.

Conclusion

Results of this pilot study indicate that the majority of the Los Angeles River is currently too warm during the months of June – October to support native fish species, but these warm temperatures do support a wide range of non-native fish species. Comparison of the soft bottom to concrete lined channel reaches suggest that the thermal banking of concrete widens the temperature range (higher maximim, lower minimum) and continues to warm the water throughout the night, creating warmer night versus day temperatures in some reaches. If this pattern holds up in additional studies it is a crucial component in determining what a restored Los Angeles River should look like, especially if a goal of future restoration projects is the re-establishment of native fishes throughout the entire watershed.

Under the present conditions the tributaries are more conducive to supporting native fish than main stem. Future restoration planning should consider ways to mitigate the temperature challenges in order to restore conditions that could support native species. The pending data from the natural upper watershed areas of Zone 1 may provide a road map to developing temperature profiles more conducive to supporting natives.

The longitudinal profile of the river provided by this one season of sampling suggests that the soft bottom and tributary areas have potential for restoring a more natural thermal range, but no real pattern emerged. Future work should focus on regions that contain larger introduced fish communities (e.g. Glendale Narrows) and explore the potential for different microhabitats that might maintain optimal thermal regimes for native species throughout the summer months. Additional information on other limiting abiotic factors, such as dissolved oxygen, would also be useful in identifying restoration targets.

Finally, the role of discharges from the various reclamation plants needs further examination. It has not yet been possible to obtain sufficient data on amount, timing, duration and temperature of discharges, which might provide some explanation for some of the temperature variation observed. While this pilot study provides a useful broad brush overview of current conditions, expanding this effort to include more sites over more years is needed in order to develop sufficient information to direct and guide restoration planning.

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