Impact of Treated Effluent Discharge on the Macroinvertebrate Community in the Los Angeles River, California

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ABSTRACT

Anthropogenic impact on the environment had created a negative impact on nature. However, possible positive impacts can result from treated effluent discharge to urban waterways. This study focuses on how treated effluent discharge impacts the water quality and health of the benthic macroinvertebrate community in the Los Angeles River. The study site focused on the major point source treated effluent discharge site of the Donald C. Tillman Water Reclamation Plant located on the main channel of the Los Angeles River. Water quality data were collected along 3 upstream sites and 3 downstream sites through fieldwork in July 2022. The benthic macroinvertebrate data retrieved from the CEDEN database from the year 2000 to 2022. Improvement in water quality downstream of the treated effluent discharge site was observed with indicators like a lower average temperature of 29.2 degree Celsius, lower specific conductance around 1100us/cm, and higher dissolved oxygen of an average around 190%. More healthy benthic macroinvertebrate communities occurred at downstream sites indicated by higher diversity and higher abundance of less pollution tolerant species with 29 %EPT score compared to 17% upstream and a Shannon's diversity score average of 1.25 compared to 0.59 upstream. The difference between water quality and benthic macroinvertebrate community upstream and downstream of the treated effluent discharge site was most likely resulted from the input flow of treated effluent discharge, indicating a positive impact of treated effluent discharge for the Los Angeles River.

KEYWORDS

CEDEN, freshwater ecology, water-quality, wastewater discharge, urban river

INTRODUCTION

Human activities, such as residential, commercial, and industrial usage heavily impact urban water quality. Urban rivers receive much of their water from runoff from residential areas and industrial wastewater discharges from the city (Zan et al. 2023). Possible discharge sources can include wastewater discharges, surface runoffs, industry discharges, and residential discharges (Yang et al. 2022). In an urban environment, surfaces are covered by roads, concrete grounds, roofs of buildings, and other non-organism surfaces, resulting in water unable to be channeled on these surfaces; thus, urban rivers act as conduits for watersheds (Locke et al. 2020). Flashy flows result in times of high precipitation, runoffs also collect pollutants and contaminants along the way.

As water cycles through the urban waterways, contaminants along the pathway increase the concentration of pollutants. Chemical residuals from factory discharge and runoffs remain in urban rivers, resulting in a possible cycle of these chemicals into human water sources (Pal et al. 2014). Direct discharge was mostly a major impact on water quality for water bodies. Wastewater discharge impact on water quality varies by location. It adds to the water flow of the local water bodies. The effect on the ecosystem can also be seasonal, where the discharge distributes the flow rate through natural rainfalls (Cravo et al. 2022).

Water discharge was a significant input for the Los Angeles River. The discharge supports the water flow and the ecosystem in and around the river (Wolfand et al. 2022). It was generally thought that wastewater will have negative impacts on the waterways. Even treated effluent discharge based on their regulation difference will add on to chemical and metal concentration of the waterways (Zhao et al. 2023). Problems like runoff presence of heavy metal and increase in bio contaminants can pose serious public health problems like potential cancer risks (Shivarajappa et al. 2023).

In the Los Angeles River, the area of interest for this study, it was important to identify the impact of wastewater discharges on the river's water quality. In this study, I explored the impact of treated effluent point source discharge on the LA river quality. Specifically, I explored how wastewater discharge impacts water quality and the health of the benthic macroinvertebrate community in the area of interest. To determine this impact, I focused on water quality indexes and benthic macroinvertebrate communities. Information about the river’s water quality was captured to analyze the difference in water quality between different upstream and downstream of the discharge site.

METHODS

Study site

I conducted water quality sampling in the LA River. I conducted sampling in 6 sites along the river, with three of the sites upstream of the treated effluent discharge site, Donald C. Tillman Water Reclamation Plant, and three downstream of the treated effluent discharge site (Figure 1). Donald C. Tillman Water Reclamation Plant was located in the Sepulveda basin. It was designed to treat 40 to 80 million gallons of wastewater per day with tertiary treatments. The corresponding percentage of the LA river daily flow depends highly on the season. The three upstream sites were located at site 1: 34.19016, -118.54023, site 2: 34.18370, -118.51149, site 3: 34.29590, -118.28310. The treated effluent discharge site was located at 34.18420, -118.47341. The downstream sites are located at site 4: 34.10296, -118.24230, site 5: 33.98599, -118.17121, site 6: 33.80438, -118.20555.

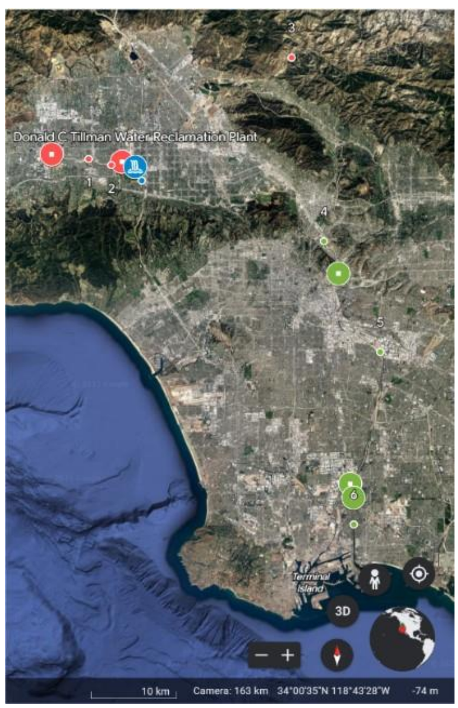

Figure. 1. Map of Study Site Location. a) The small dots indicate where the field data is collected with red indicating upstream and green downstream of the wastewater discharge site with site number on top. b) Large dots indicate sampling station location for benthic macroinvertebrate data with the same color indication. c) Large blue dot indicates the location of the wastewater discharge site.

Field work

I went to the 6 sites indicated on the map to collect water quality data. Site composition information was recorded based on vegetation coverage, site composition of concrete or soft bottom, canopy coverage, and water abundance. The equipment used was a water quality monitor that was able to digitally take data on the temperature, specific conductance, and dissolved oxygen of the river. A separate pH meter was used to measure the pH. Lastly, a meter stick and a smartphone was being used to measure the depth and flow rate of the river. In total, six variables were collected at each site. Each site was separated into three transacts that are 60 meters apart. Transacts were measured out upstream from the sampling location. Variables were measured three times at each transact to ensure accuracy. Temperature, specific conductance, and dissolved oxygen was measured by dipping the measuring end of the monitor into the river without completely submerging the head in the water and taking a record of the data shown on the screen. The pH level was measured by taking water from the river using the cap of the pH meter and dipping the measuring end into the cap. The data was then recorded from the screen. The Depth was measured by taking the meter stick and sticking it into the river until it meets a solid base. The depth was taken at 25%, 50%, and 75% away from the shore perpendicular to the river flow direction across the river to ensure accuracy. Lastly, the flow rate was measured by measuring out the length of one meter, then dropping a leaf upstream of the mark, and recording the time the leaf takes to pass through the one meter length using a smartphone.

Water quality analysis

To find correlations between the variable and the upstream or downstream treated effluent discharge site difference, I used Python to analyze the data. Data was grouped into two categories, the upstream group, and the downstream group.I plotted a boxplot for each variable with the left blue boxplot being data from the three upstream sites and the right orange boxplot being the three sites downstream of the treated effluent discharge location. Other variables like the site environment were recorded and used as a reference but not considered in the analysis. Data from each group was plotted against each other in a scatter plot to identify possible trends. Scatter plots were used in plotting all possible pairs of variables against each other in reference to identify possible relationships between variables. It was visually clear to identify if there was a significant difference between the variables for each group.

Benthic macroinvertebrates

To collect data to answer the data collection question, I visited existing databases like the Southern California Coastal Water Research Project and California Environmental Data Exchange Network (CEDEN). The first group was a research institute that has been doing projects on the LA River for an extensive amount of time. They have available data from their previous projects including temperature and water quality monitoring. The CEDEN database was an open platform that allows scientists to exchange their project data and share them with the public. From their site, I retrieved data from the year 2000 to 2022. I first cleaned the data to select sampling stations that were near my fieldwork locations and finalized data that were relevant to my project. When I retrieved the data, I calculated Hilsenhoff Biotic Index (HBI), %EPT, and Shannon's diversity index for each site. HBI is a quantitative method to analyze the overall tolerance of macroinvertebrates in designated communities. A tolerance value was assigned to each family level with a higher score indicating more tolerant organisms (Hilsenhoff 1987). In the formula, n_i is the number of counts in taxa i, a is the tolerance value of taxa i, and N is the total number of counts in the sample.

$$HBI = \frac{\sum n_i \times a_i}{N}$$

Eq. 1 (Hilsenhoff 1987)

The percent EPT measures the relative abundance of organisms in Ephemeroptera, Plecoptera, and Trichoptera, these three orders. Species in EPT were highly sensitive to the level of pollution in the environment. A high abundance of organisms in Ephemeroptera, Plecoptera, and Trichoptera orders indicates a less polluted water quality. The percent EPT was calculated using the total EPT taxa divided by the total taxa found in the sample. Shannon's diversity index is a qualitative analysis that takes into account both species richness in family level and their proportion of occurrence within the sample community (Hill 1973)

$$H = -\sum p_i \times ln(p_i)$$

Eq. 2 (Hill 1973)

RESULTS

Site Characteristics

The sampling location consists of six sites, thesites 1-3 upstream of the treated effluent discharge location and site 4-6 occurring downstream of the discharge location. Site 1 was along the main channel of the Los Angeles River. It consists of a concrete bottom and a concrete levee. The river channel was wide but about 40% on both sides, 80% in total, was dry. The river had shallow water and no canopy coverage or vegetation. Site 2 was also the main channel of the river through the city. It consists of concrete bottoms with shallow sand and concrete levee. Similar to the last site, 80% of the river was dry with no vegetation. Site 3 was a tributary distant from the city with soft bottom and soft levee with some rocks on the bottom. It has a relatively narrow river channel with trees on both sides with vegetation and canopy coverage. Within the sampling range, there were also elevation changes. Site 4 consists of a soft bottom and concrete level. It has a wide river channel but 50% of it was dry. It has trees on both sides with a vegetation island in the middle consisting of 20% canopy coverage. Site 5 has a concrete bottom and concrete levee with pebbles on the bottom. It has a wide river channel with 60% dry. The channel was divided into three smaller channels of equal width in the middle. It has shallow water with no canopy coverage and little vegetation between sub-channels. Site 6 has a concrete bottom and concrete levee with mud on the bottom. It has a wide river channel and shallow water. The site does not have any vegetation or canopy coverage. There were elevation changes within the width of the channel resulting in different flow rates.

Water quality

I measured six parameters of water quality, including temperature, specific conductance, dissolved oxygen, pH, depth, flow rate, and pressure in the six sampling sites. Large variations between sites occurred in some variables like temperature and dissolved oxygen while other variables did not vary much throughout all the sampling sites. Temperature ranged from a low average of 18.8°C at site 3 and a high of 36.4°C at site 1. Pressure did not vary much with the high of 760.2mmHg at site 6 and a low of 723.6mmHg at site 3, the difference was less than 5% (Table 1).

Table 1. Water quality variables at sampling sites along the Los Angeles River. Average water quality parameters collected in the Los Angeles River in July 2022. Each data point is an average of nine data points measured along a 120m interval along the sampling location.

Location	Upstream			Downstream		
	LAR#1	LAR#2	LAR#3	LAR#4	LAR#5	LAR#6
Temperature (C)	36.4	33.3	18.8	29.0	34.1	24.7
Specific Conductance (us/cm)	2056.7	1953.7	538	1116	1117	1168
Dissolved Oxygen (%)	173.8	174.2	80.1	131.7	295.2	165.7
pH	8.8	8.9	8.0	8.5	10.0	8.4
Depth (cm)	3.9	13.9	22.7	36.8	14.4	11.6
Flow Rate (m/s)	0.3	0.2	0.26	0.23	0.22	0.33
Pressure (mmHg)	739.5	736.5	723.6	752.2	757.9	760.2

More variation and extreme temperatures were observed at upstream sites (Figure 2a). Specific conductance and pressure differed between upstream and downstream data. For specific conductance, large variation between sites was observed in upstream sites while the downstream sites were relatively similar ranging between 1000 us/cm to 1200 us/cm (Figure 2b). Though from the above table, I observed pressure was relatively similar throughout sites, when plotted in boxplot I observed that there does not exist an overlap in upstream pressure and downstream pressure values, which was not observed in the result of the variables (Figure 2g).

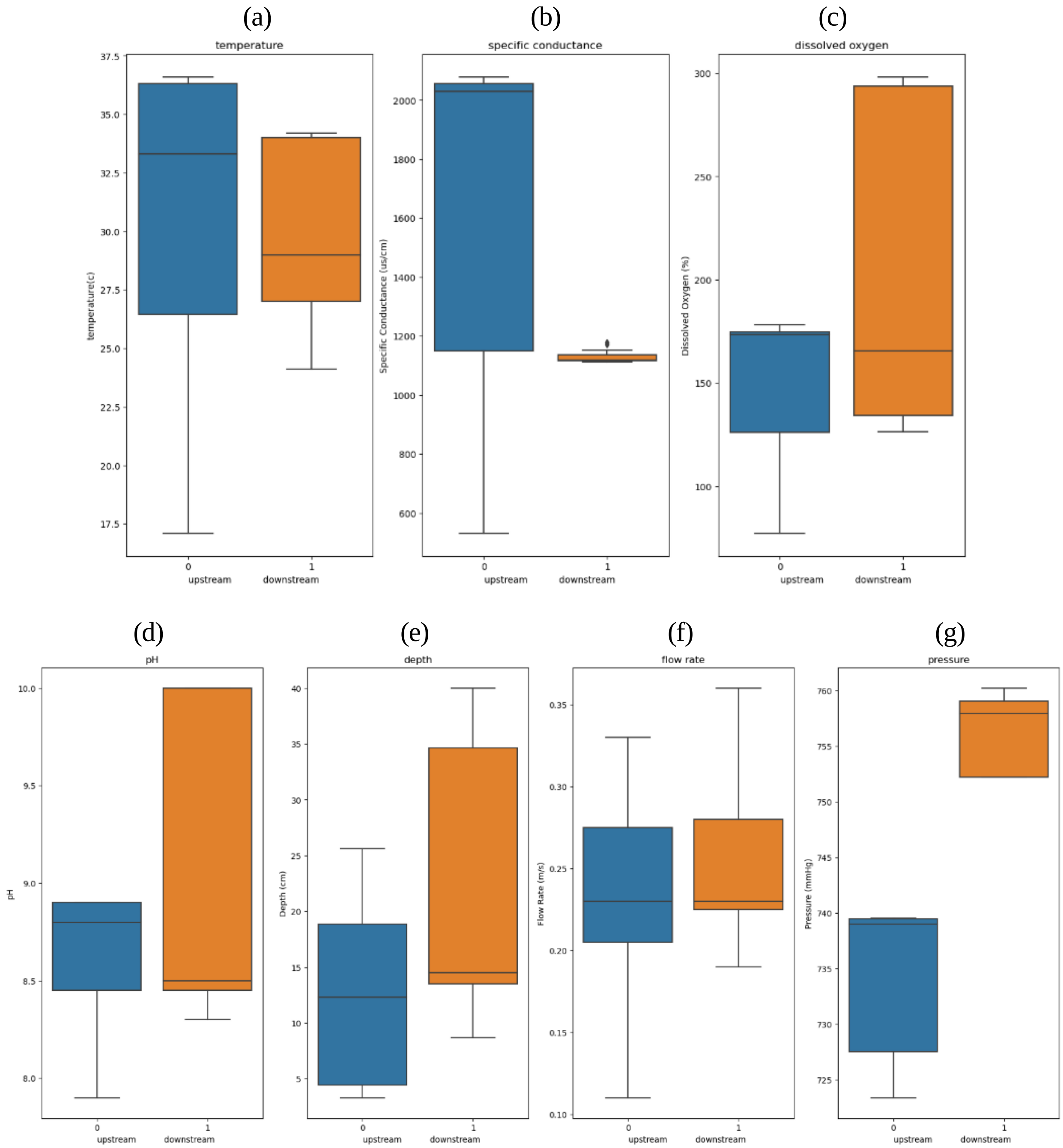

Figure. 2. Boxplot of upstream and downstream data on each water quality variable. Variables include (a) temperature(C), (b) specific conductance(us/cm), (c) dissolved oxygen(%), (d) pH, (e) depth(cm), (f) flow rate(m/s), and (g) pressure(mmHg).

I plotted the scatter plot of each variable against each other to account for possible interferences. Because of the small sample size, not enough data points were plotted to show strong correlations. However, multiple pairs formed between pH and temperature, pH and specific conductance, pH and dissolved oxygen can be observed (Figure 3). The correlation appears to be independent of the site location. Segregations between upstream sites indicated by blue dots and downstream sites indicated by yellow dots within variables are also clear (Figure 3).

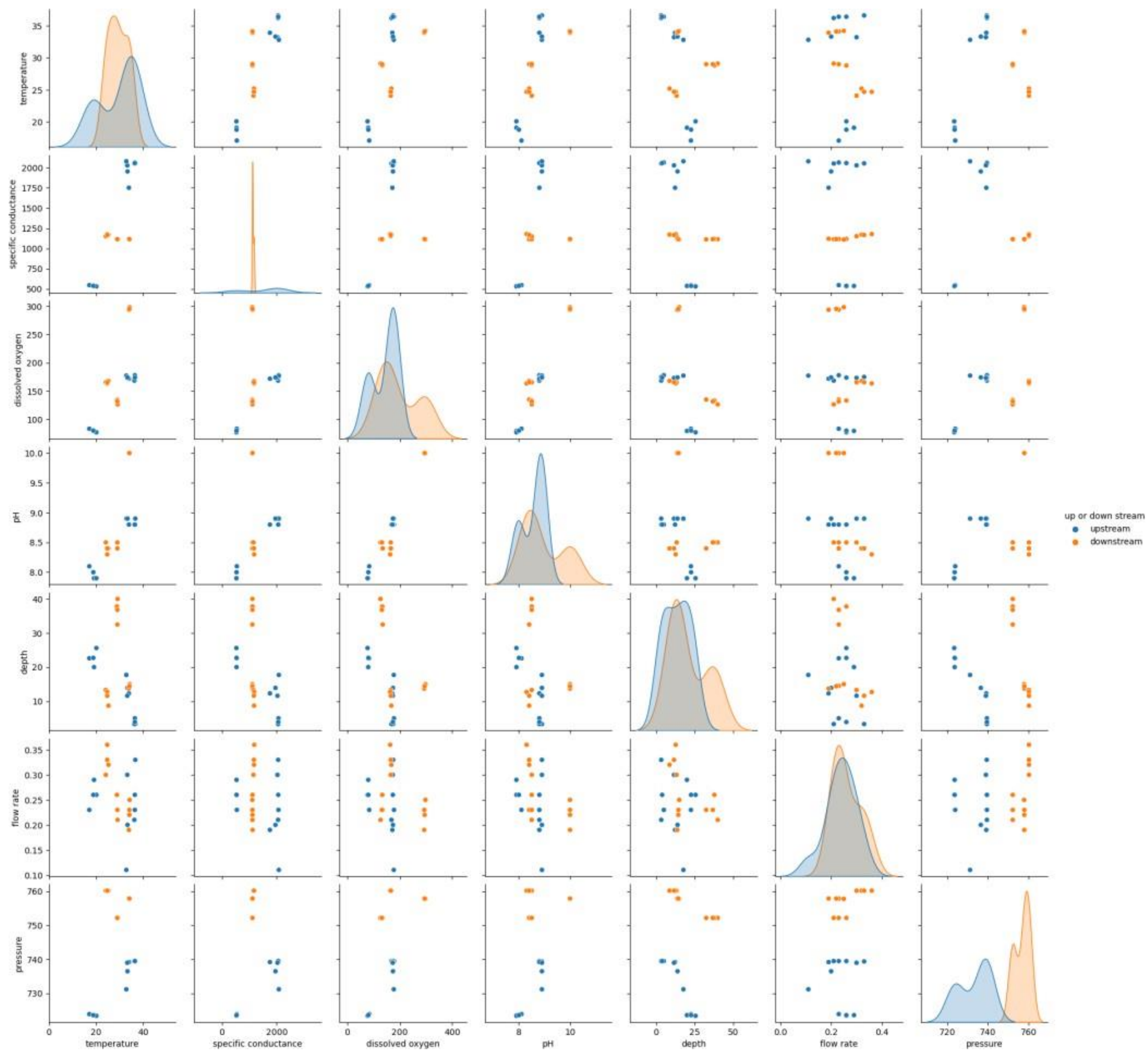

Figure. 3. Scatter Plot of variables. Scatter plot plotting each combination of variables. Upstream sites are in blue and downstream sites are in orange.

Benthic macroinvertebrates

I included only four sites for analysis for benthic macroinvertebrates data because I did not find enough available data. Site 2 upstream also possesses a soft bottom environment that was different from the other five concrete sites.

I observed a significant difference in benthic macroinvertebrate abundance between upstream sites and downstream sites. Upstream sites 1 and 2 have the highest Diptera abundance with site 1 having a count of 513 Diptera. Site 1 and 4 have the most non-insect count while the minimum number of non-insects observed was at site 2 with a count of 27 compared to counts of over a hundred at other sites. Some species orders were not observed in all four sites. For example, Hemiptera and Trichoptera were only observed at downstream sites 4 and 6. Odonata and Coleoptera were only found at site 2 with the count of 1 and 2. Specific abundance within upstream and downstream sites was also different. Ephemeroptera was observed at sites 2 and 4, one being upstream and one downstream (Table 2).

Table 2. Benthic Macroinvertebrate abundance at each sampling site along the Los Angeles River. Counts of abundance of each organism categorized at order level.

Location	Upstream		Downstream	
	LAR#1	LAR#2	LAR#4	LAR#6
Dipetera	513	454	217	358
Amphipoda	19	3	6	119
Basommatophora	1	2	26	30
Ephemeroptera	0	11	135	0
Hemiptera	0	0	7	210
Trichoptera	0	0	3	1
Non-Insects	669	27	596	154
Odonata	0	1	0	0
Coleoptera	0	2	0	0

Table 3. Non-Insects abundance at each sampling site along the Los Angeles River. Counts of abundance of Non-Insects categorized at order level.

Location	Upstream		Downstream	
	LAR#1	LAR#3	LAR#4	LAR#6
Ostracoda	605	0	541	0
Oligochaeta	64	27	55	154

All four sites possess relatively similar abundance with highest count of 513 at site 1 and lowest count of 353 at site 4 (Table 2). The statistical analysis tells significant differences between upstream and downstream sites. The Shannon's diversity index (H) shows a significantly higher diversity in downstream sites than upstream sites. For HBI, site 4 was significantly lower with the number of 6.62 whereas site 1, 2, and 6 were around 9. The percent EPT were highest at site 4 with no identification of EPT species in site 1 and 6 (Table 3).

Table 3. Benthic macroinvertebrate analysis index calculated for each sampling site along the Los Angeles River. Three parameters calculated for each site with total counts of specimens in the first row.

Location	Upstream		Downstream	
	LAR#1	LAR#2	LAR#4	LAR#6
Abundance	513	471	353	376
Species Richness	6	8	10	8
HBI	8.96	8.72	6.62	8.92
%EPT	0	17	29	0
H	0.76	0.42	1.09	1.41

DISCUSSION

Water Quality

The water quality data indicates a higher water quality downstream. The higher temperature, lower dissolved oxygen percentage, higher specific conductance and the low flow rate all indicates a worse water quality downstream (Syeed. et al. 2023). One exception was that site 3 upstream of the discharge point has the best water quality among all points. Site 3 has best parameter values like pH closest to 8, lowest specific conductance, and lowest specific conductance. The higher water quality of site 3 was because it was the only stream site along a tributary that flows into the main channel of the LA River that has an untouched natural environment and not along the main channel of the Los Angeles river. The site difference resulted in a significant increase in water quality at site 3. Although site 3 alone has the best water quality, overall averaged upstream sites demonstrated poor value for evaluating water quality. Site 3 was not discussed because of the exceptional environmental condition.

One of the most important negative impacts of treated effluent discharge into the downstream river was the increase in Nitrogen concentration (Costa-Pierce 1998). Heavy metals are not effectively removed completely from treated wastewaters. The concentration was within the discharge quiteria but in large quantities, creating a burden for the downstream ecosystem. Besides the high concentration of Nitrogen that can be found in some water samples, treated wastewater can be reused for multiple purposes that reduces water usage. For residential usage, it can be used for lawn irrigation, car washing, and toilet flushing. Not only was it beneficial for the residential usage, treated wastewater can also be used to recharge ground aquifers and surface water reservoirs. It was beneficial to create an environment for species that requires sufficient water flow to support the lack of natural flow (EPA 1998). No specific case study on the LA river was found focusing on this topic, but my study results support the treated effluent discharge having positive impacts on the downstream waterbody by having a higher water quality and better benthic macroinvertebrate community. This change was most likely resulted by the difference between water upstream of the discharge site and the treated effluent discharge. Because the LA river was an urban river, multiple sources of contaminations occur with both direct and indirect sources. The best water quality result of site 3 indicates an overall worse environment along the river where anthropogenic activities occurred. The tertiary treated effluent discharge, having a better quality than the original flow, dilutes the contaminants, resulting in better water quality downstream of the discharge site.

Benthic macroinvertebrates

Metrics from benthic macroinvertebrate data indicate congruent patterns with water quality data indicating the presence of better water quality downstream of treated effluent discharge sites. The better analysis score indicates treated effluent discharge has a positive impact on benthic macroinvertebrate communities. Although differences within upstream or downstream sites occur, overall downstream treated effluent discharge sites have a lower HBI score, higher %EPT, and higher Shannon's diversity index score, indicating a more healthy benthic macroinvertebrate community. Shannon’s diversity index reflected higher diversity in downstream sites. In contrast to the high specimen count but low Shannon’s diversity index score, downstream were more suitable for varieties of benthic macroinvertebrates to thrive instead of maintaining pollution-tolerant species. Upstream sites have a higher abundance that mostly consists of Diptera in the family of Chironomidae. High pollution tolerance species were thriving in upstream sites making up around 80% of total collected specimens.

The difference in abundance of collected specimens could be due to the different number of samples taken at different sites. Data was collected from an online database that does conduct congruent sample times for each site, which could result in the count difference between each site as site 1 has the most specimens log number.

Treated effluent discharge having a positive impact on water quality and resulting in a more healthy benthic macroinvertebrate community was not surprising. The Los Angeles River does not have constant flow throughout the year. During summer times, point source discharge was the major input for river flow, especially the treated effluent discharge site of interest can account for 60 to 100 percent of the total flow through the Los Angeles River during dry seasons (Tetra Tech 2002).

Limitations and future directions

This study was a site study that focused on specific locations around one point source of treated effluent discharge site. The sample size of this study was very limited. The benthic macroinvertebrate data collection site was not precisely aligned with the water quality sampling site. Discrepancy can be resulted from different site composition. Through data collected at site 3 I realized the site composition has a major impact on the water quality and benthic macroinvertebrate community quality. Study sites can be more congruent in site composition, for example avoid tributary streams and focus on concrete sites along the main channel of the Los Angeles River. Additional sites closer to the treated effluent discharge site can provide additional information.

Through this study, it was found that treated effluent discharge does have a positive impact in the water quality and health of the benthic macroinvertebrate community. This site study can be useful when considering the possible environmental impact when redirecting treated effluent discharge for recycling use. Further studies can be conducted on the treated effluent discharge site of interest as it was one of the major point sources of the Los Angeles River.

Management implications

It was clear that there exists a strong environmental benefit of adding treated effluent discharge back into the LA river, especially during summer dry seasons where sections of the river no longer have enough flow to support the local aquatic community. However, it was yet unknown the tradeoff between discharging treated wastewater back into the water body or reusing and recycling the treated wastewater (Kumar et al. 2021). Treated wastewater discharge into water bodies creates environmental and recreational benefits while reusing and recycling creates economical benefits. More research can look into the tradeoff between these two methods in deciding the functionality of treated wastewater.

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