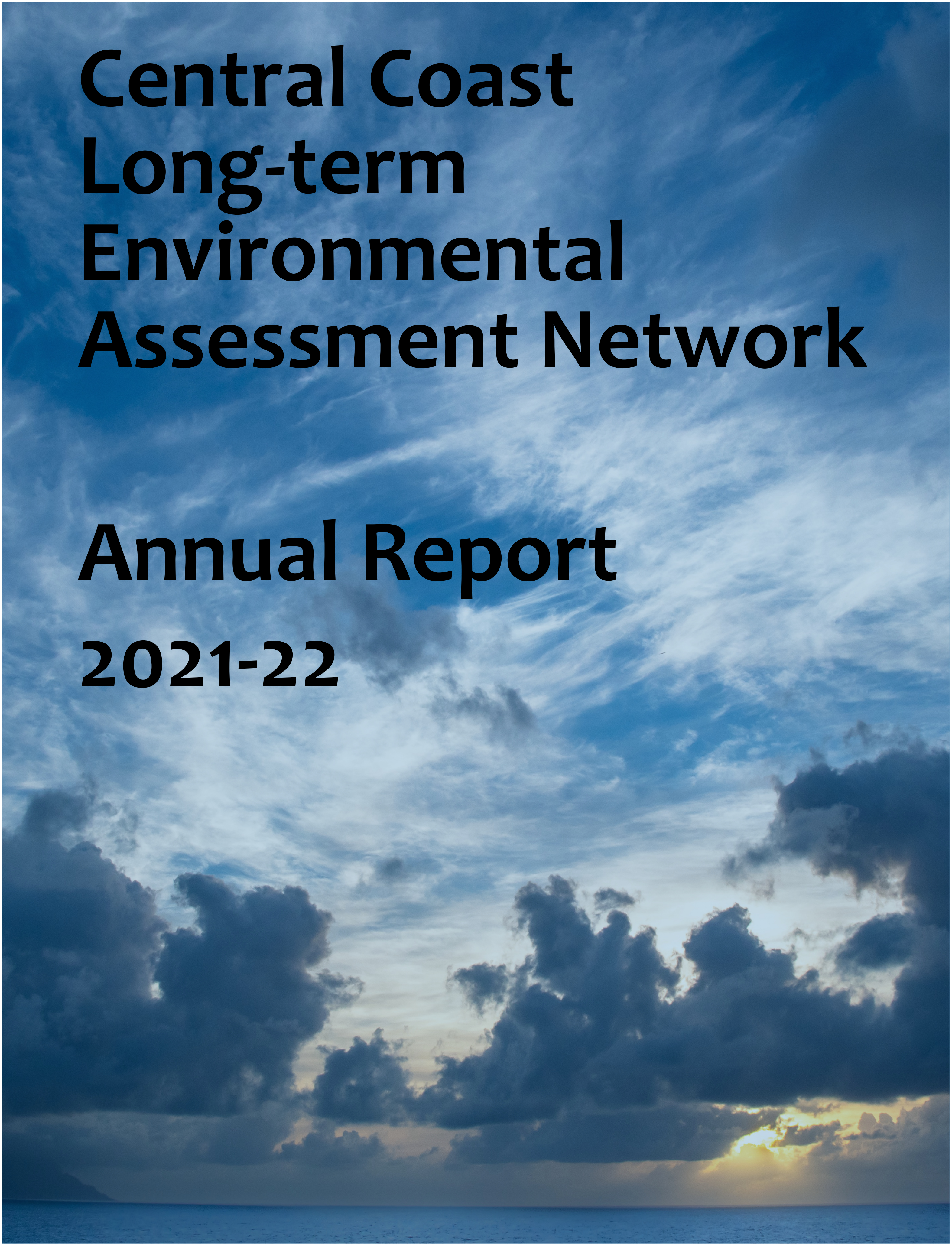


Central Coast Long-term Environmental Assessment Network

Annual Report

2021-22

A report of the Central Coast Long-term Environmental Assessment Network (CCLEAN)

Prepared by: Applied Marine Sciences, Inc

911 Center St. Suite A, Santa Cruz, CA 95060

Version 1.1 [5/22/2023]

CONTENTS

PROGRAM HIGHLIGHTS

PROGRAM HIGHLIGHTS

1 Helping protect the quality of nearshore marine waters in the Monterey Bay area

CCLEAN serves to support municipal agencies and resource managers in meeting regulatory requirements intended to protect the quality of nearshore marine waters in the Monterey Bay area. The CCLEAN Steering Committee adaptively manages the monitoring program by making adjustments to address new management needs that may be impacting beneficial uses in the region. Towards this goal, CCLEAN initiated a pilot study in 2021, to gain a better understanding of the types and quantities of microplastic particles being discharged into Monterey Bay from surrounding sources. CCLEAN measured microplastics during the wet and dry season in effluent sources and rivers discharging into Monterey Bay National Marine Sanctuary. The results of this work are presented in the Feature Article of this report.

2 Support updates to status of Beneficial Uses in the Monterey Bay area

CCLEAN worked closely with State and Regional Water Board staff this year to explain the nuances of its high-volume in situ solid-phase extraction sampling methods. These samples are typically collected over a 30-day period and the resulting data directly apply to 30-day average water quality objectives in the California Ocean Plan and chronic values in the California Toxics Rule. Based on their evaluation of CCLEAN data, Water Board staff recommended updates to the 303d list to designate Monterey Bay as impaired due to concentrations of PCBs, DDTs, chlordanes, dieldrin, and toxaphene, which could lead to implementation of measures to reduce inputs of these contaminants into Monterey Bay.

3 Generating high quality data over time on water quality in the Monterey Bay area

CCLEAN participates in the California Environmental Data Exchange Network (CEDEN) users group. In 2022, the Program worked to ensure accurate distinctions among data derived from grab samples, in situ passive adsorption samples, and in situ pumped samples across solid-phase extraction media. Recommendations were made to require submitted data be accompanied by information on sampling duration and sample volume.

CEDEN
CALIFORNIA ENVIRONMENTAL DATA EXCHANGE NETWORK

4 Resource management coordination within the Monterey Bay National Marine Sanctuary

CCLEAN provides technical guidance and expertise to resource managers in the Monterey Bay area to enhance the use and application of CCLEAN data. CCLEAN has put a strong emphasis on information sharing and has helped characterize current and trending water quality issues for managers, and share information on focus areas being undertaken by the Program. In Program Year 21, CCLEAN continued its collaborations with the Monterey Bay National Marine Sanctuary (MBNMS) Water Quality Protection Program (WQPP). CCLEAN's coordination with the WQPP has provided opportunities to present the results of the last 20 years of CCLEAN data on currently used and legacy organic pollutants.

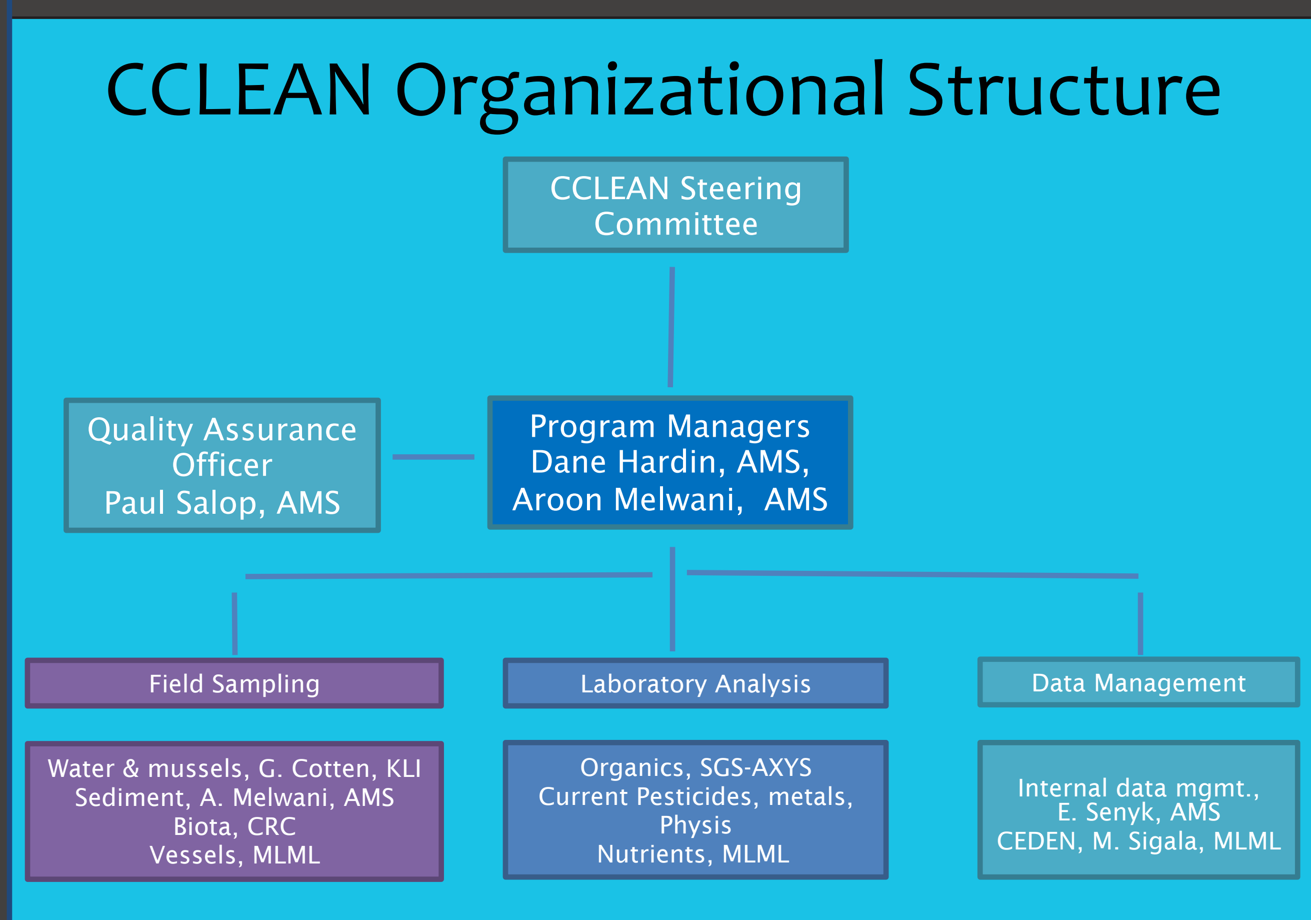
CCLEAN DIRECTOR’S REPORT

PROGRAM SUMMARY

CCLEAN is a long-term monitoring program for Monterey Bay committed to environmental stewardship that has been designed by subscribing agencies to fulfill several regulatory objectives.

CCLEAN is currently funded by the City of Santa Cruz, the City of Scotts Valley, the City of Watsonville, Dynegy's Moss Landing Power Plant, Monterey One Water (M1W), and Carmel Area Wastewater District (CAWD), under the direction of the Central Coast Regional Water Quality Control Board (Central Coast Water Board).

Together with a representative of the Water Board, each subscribing agency is a member of the CCLEAN Steering Committee. The technical elements of the CCLEAN Program are managed by Applied Marine Sciences, Inc. with significant support provided by partner labs and consultants. A complete list of collaborators supporting the CCLEAN Program is provided on Pages 14-15.



CCLEAN fulfills a significant component of the subscribing agencies' compliance to their National Pollutant Discharge Elimination System (NPDES) monitoring commitments, with an emphasis on receiving water quality. In addition, CCLEAN is the current mechanism by which the Water Board fulfills part of its obligations under a monitoring framework to provide an ecosystem-based Water Quality Protection Program for the MBNMS.

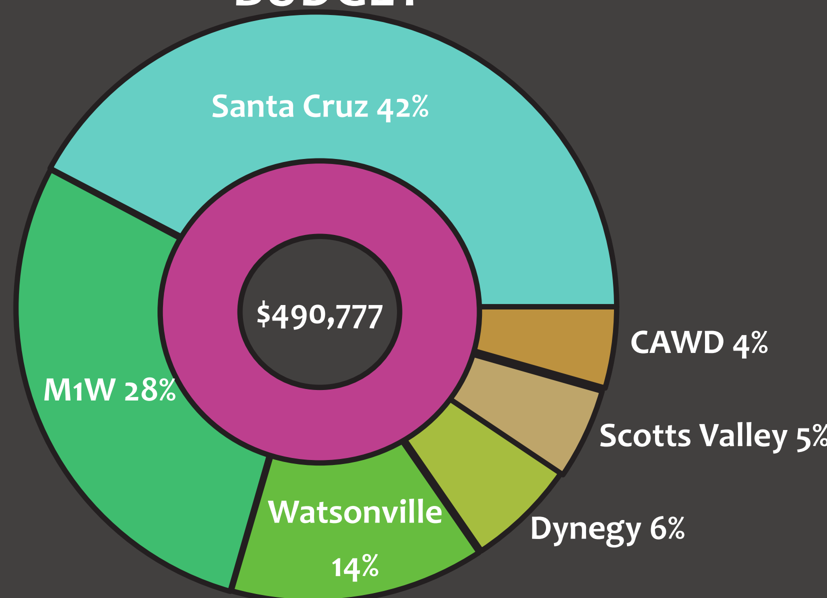
CCLEAN focuses on measuring Persistent Organic Pollutants (POPs) and several current-use pesticides, classed as Chemicals of Emerging Concern (CECs). Monitoring occurs seasonally in wastewater, ocean water, mussels, and sediments along the central California coast. CCLEAN has been underway since 2001 and its Quality Assurance Project Plan (QAPP) is regularly revised to incorporate program changes, and to retain consistency with the Water Board's Surface Water Ambient Monitoring Program (SWAMP) requirements for data compatibility.

The schematic below summarizes the monitoring activities under the CCLEAN Program in the current program year (June 1 2021 to May 31 2022). Dry season monitoring occurs during the months of June through November, and wet season monitoring activities between December through May.

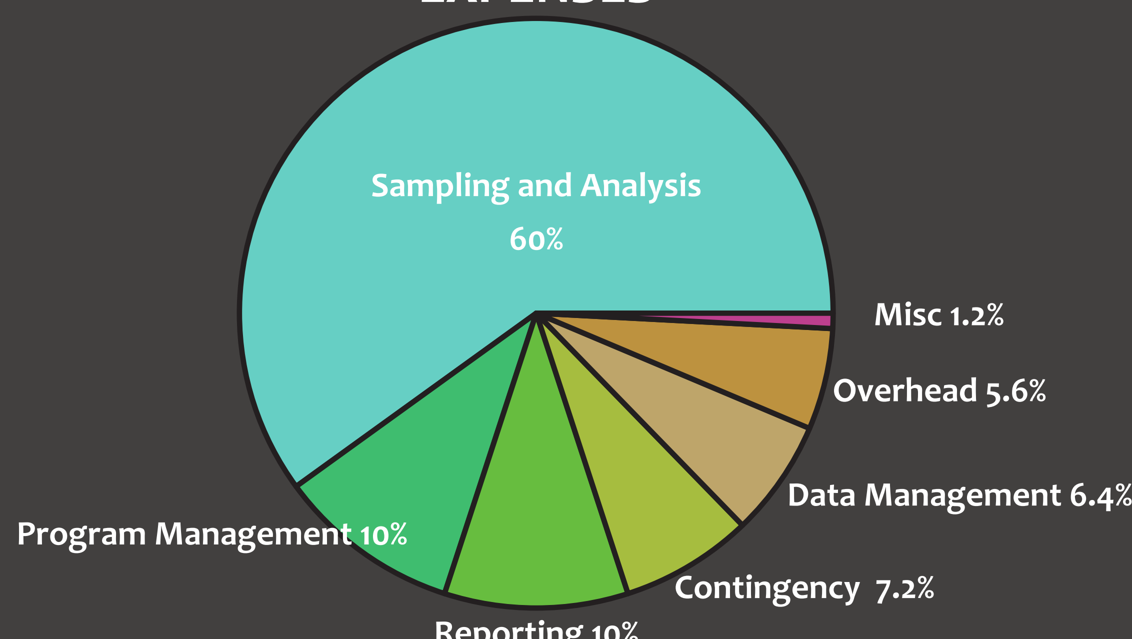
PROGRAM YEAR FINANCIAL SUMMARY

YEAR 21

BUDGET



EXPENSES



DATA MANAGEMENT

CCLEAN manages and delivers high quality data based upon a rigorous QAPP that was developed and is reviewed regularly to ensure that all reported data are comparable with SWAMP requirements.

On an annual basis, the CCLEAN Quality Assurance Officer (QAO) conducts a full review of laboratory electronic data deliverables (EDDs) for data quality. Every datapoint is assessed against established criteria in manner that indicates their ability to be used to address CCLEAN management questions. CCLEAN submits EDDs to the CEDEN data node at Moss Landing Marine Laboratories where the data are compiled and made publicly available.

One of the principal uses of the CCLEAN data available in CEDEN is to inform development of the California Integrated Report (IR), a federally mandated process for which CCLEAN provides additional support in clarifying data quality with respect to IR requirements.

All of CCLEAN's data are also available by contacting the CCLEAN Program Director, Dane Hardin of Applied Marine Sciences, Inc.

COORDINATION ACTIVITIES

- September 2022 - Dane Hardin gave a presentation to the MBNMS WQPP on a 20-year retrospective of CCLEAN monitoring
- December 2022 - Aroon Melwani gave a presentation to the MBNMS WQPP on long-term trends in Monterey Bay benthic communities
- Ongoing - Dane Hardin coordinated with Water Board staff on 303d listing review for Toxaphene and Heptachlor Epoxide

CCLEAN STEERING COMMITTEE

Carmel Area Wastewater District

City of Santa Cruz

City of Watsonville

Monterey One Water

City of Scotts Valley

Regional Water Quality Control Board, Central Coast Region

CCLEAN COLLABORATORS

Applied Marine Sciences, Inc.

Kinnetic Environmental

Moss Landing Marine Laboratories

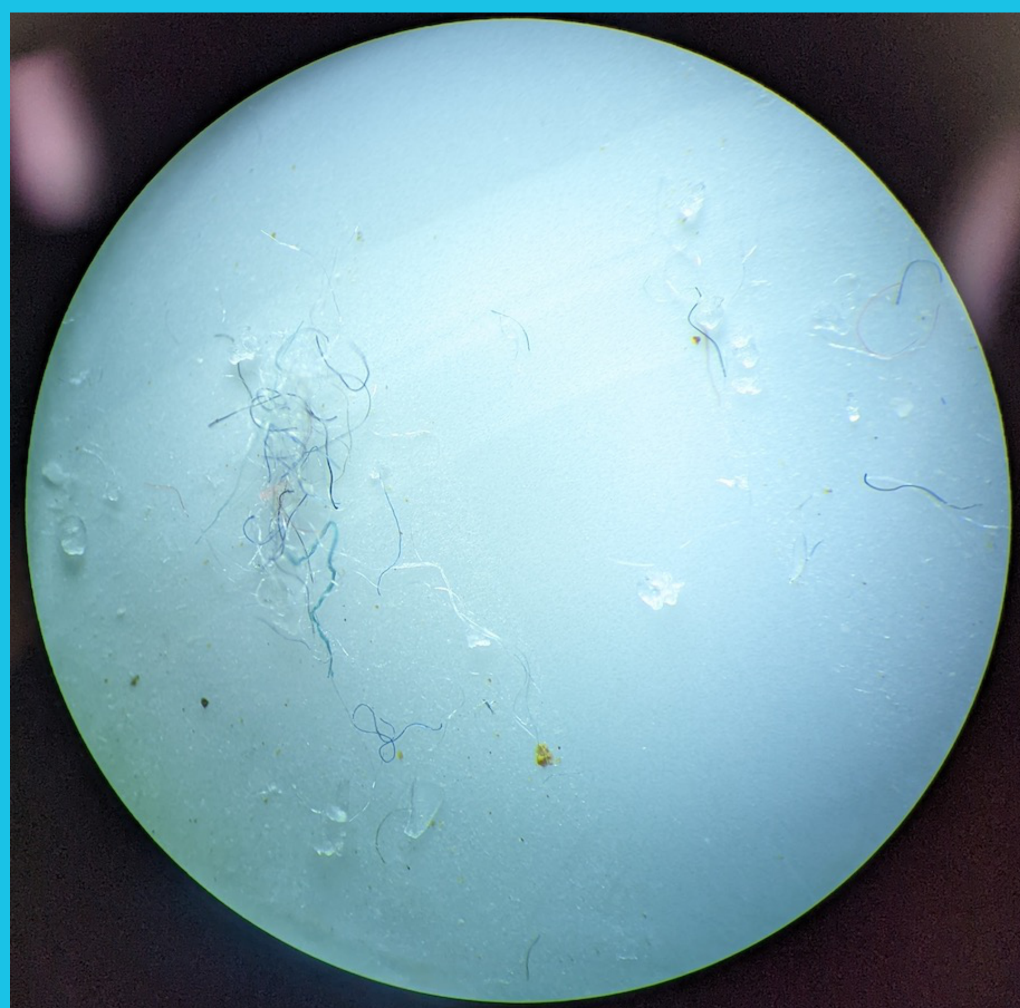
SGS AXYS

Physis

California State University Bakersfield

FEATURE ARTICLE

CCLEAN Microplastics Pilot Monitoring



A CCLEAN microplastic sample viewed under a microscope

INTRODUCTION

Microplastic particles (< 5mm) are considered emerging environmental pollutants, posing threats to aquatic and marine environments, while the impacts to coastal ecosystems remain less understood. There are several pathways for microplastics to enter marine environments, such as by degradation from larger debris and through discharges from rivers and wastewater treatment plants. Microplastic particles, being comprised of potentially toxic compounds and chemical additives, can leach toxins into surrounding environments or into animal tissues if ingested by wildlife (Koelmans et al., 2014; Michishita et al., 2023). Microplastics can also expose toxic chemicals to marine ecosystems by absorbing POPs, potentially posing even greater threats if ingested by higher trophic levels organisms (Tanaka et al., 2013).

David Liitschwager, National Geographic

In response to regulatory agency initiatives to improve understanding of the types and quantities of microplastic particles being discharged into Monterey Bay by municipal wastewater agencies, CCLEAN added microplastics as an emerging contaminant to be measured under the program in 2020. Although there are currently no restrictions for daily loads of microplastics being discharged into Monterey Bay in wastewater, the information provided by this microplastics pilot monitoring program will enable resource managers to assess whether estimated loads from wastewater and rivers are sufficient to warrant further measurements or regulatory actions.

The CCLEAN microplastics pilot study sought to answer three questions:

1. What are the concentrations and loads of microplastics discharged by wastewater and rivers into Monterey Bay?

2. How do seasonal and total loads of microplastics from rivers compare to loads from wastewater?

3. What are the major types of microplastic pollution entering Monterey Bay from wastewater and rivers?

METHODS

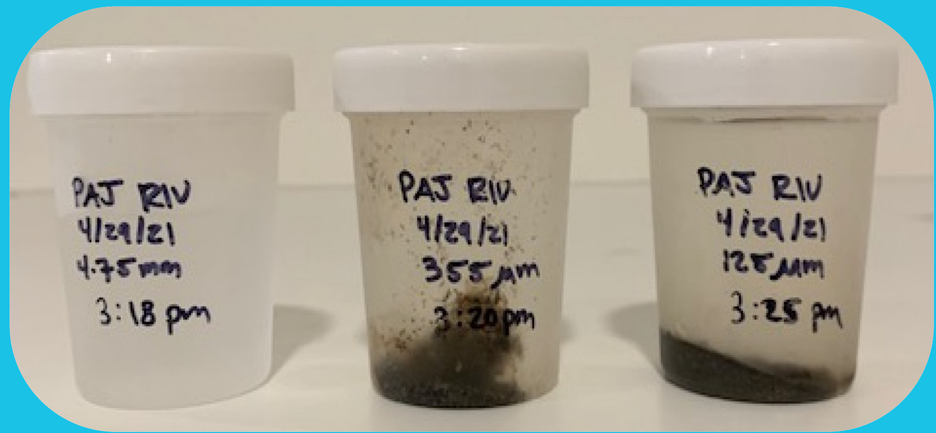
Microplastics were sampled in effluent at five municipal dischargers (e.g., CAWD, M1W, City of Watsonville, City of Scotts Valley, and City of Santa Cruz Wastewater Treatment Facility), as well as in the San Lorenzo, Pajaro, and Salinas Rivers. Sampling occurred twice per year, during the wet and dry seasons, to account for potential fluctuations in daily loads of microplastic particles with changes in public water usage and weather patterns.

Controlled volumes of effluent and river water were passed through stacked brass sieve systems designed to capture three different size classes (i.e., 4.75 mm, 355 µm, 125 µm) of microplastic particles. Volumes were controlled using ISCO Water Samplers, which sampled effluent and river water over approximately 48 hours on weekdays only. Sampling rates and total volumes sampled were site- and season-dependent, with target sampling rates of approximately 1.5 liters every 3 minutes and target sample volumes of approximately 1,000 liters. An equipment mid-point check was performed after approximately 24 hours to confirm that all equipment was operating correctly, and the sieves did not show signs of clogging. Any equipment errors were recorded and corrected before the remaining 24 hours of sampling. If the sieves showed signs of clogging after the 24-hour mid-point check, clogging was recorded and sieve samples were collected immediately to prevent microplastic particle loss.

After approximately 48 hours, particles from each sieve size were collected into a 120 ml p-cup plastic container by rinsing with distilled water that had also been filtered through the smallest sieve size (i.e., 125 µm). To account for possible site contamination, three atmospheric samples were collected at each site per sampling event on the final day of sample collection. The atmospheric sample containers were placed around the facility and uncapped for the average amount of time that all sieve samples were exposed during the sieve sample collection periods at that site.

At the end of each sampling event, all sieve and atmospheric samples were refrigerated and shipped to the (Rae) McNeish lab at CSU Bakersfield to determine microplastic particle concentrations for each site. Residual water from the field was dehydrated from the samples at 47°C, and 30 mL of 30% hydrogen peroxide was used to digest each sample in the sample P-cup container at 47°C over the course of 48 hours. Samples were next filtered onto 1.2 µm polycarbonate filters. To account for contamination from the purple lab coats worn in the McNeish lab, microparticles on the filters were counted via light microscopy twice, with color of each particle recorded the second time.

All filters were stained with Rose Bengal to differentiate organic material (stained purple/pink) from inorganic materials (e.g., plastics). After staining, anthropogenic microparticle counts were performed on 100% of filters, after subtraction of purple fibers due to McNeish Lab purple lab coat contamination at the filter level. Anthropogenic microparticles include both natural-based (e.g., cotton fiber) and manmade (e.g., synthetic fiber) particles. Color (e.g., black, blue, clear) and morphology (i.e., plastic fiber, natural fiber, fiber bundle, fragment, film, foam, and bead) were recorded for each anthropogenic microparticle identified on a filter.



For data QA purposes, each filter was counted and the recorded anthropogenic microparticle counts were also checked twice by McNeish Lab personnel. The 4.75 mm size class was removed from total sample counts, because that size class represents particles larger than microparticles. Additionally, since the atmospheric controls were not fractionated and collected at the sample level, the remaining size classes were summed; therefore, total abundance counts for each site were calculated as the sum of anthropogenic microparticles found on the 355 µm and 125 µm size class filters.

Contamination was accounted for by calculating the average contamination of anthropogenic microparticles for each color-morphology combination across the three atmospheric samples collected for each site. Since field controls were not fractionated, size class-level corrections could not be done, but corrections were performed with the sample-color-morphology combination at the sample level. Contamination averages were rounded to the nearest integer, and the atmospheric color-morphology rounded integer was subtracted from its corresponding effluent or river sample.

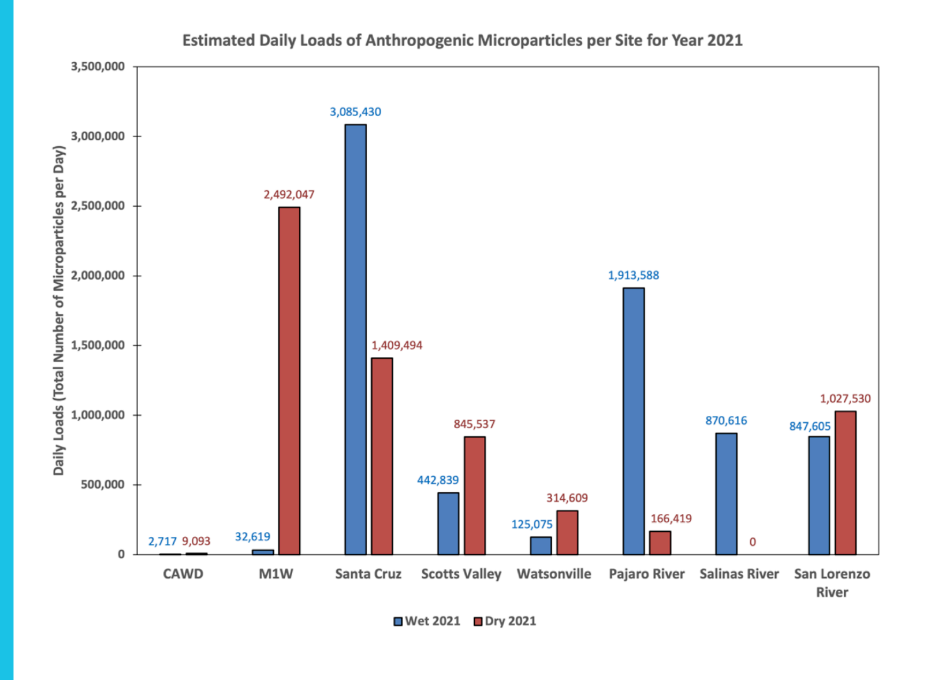
Corrected microparticle counts were lastly used to estimate concentrations of anthropogenic microparticles in each sample, and daily loads of microparticles from each source discharging into Monterey Bay during both the wet and dry season of 2021. Average daily discharges used to estimate daily loads of microparticles were calculated using the average final effluent daily total flow (MLD) and the average daily discharge (L/Day) over all sampling days for effluent and river flows (https://www.usgs.gov/), respectively.

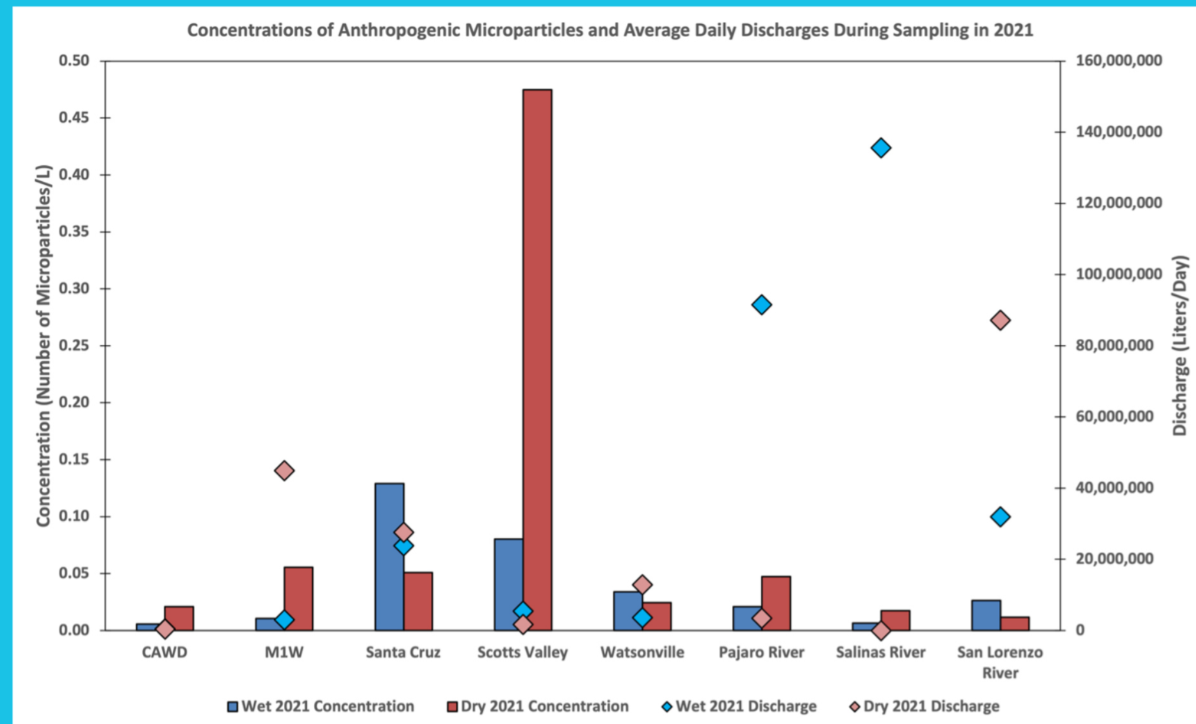
RESULTS

Question 1: What are the concentrations and loads of microplastics discharged by wastewater and rivers into Monterey Bay?

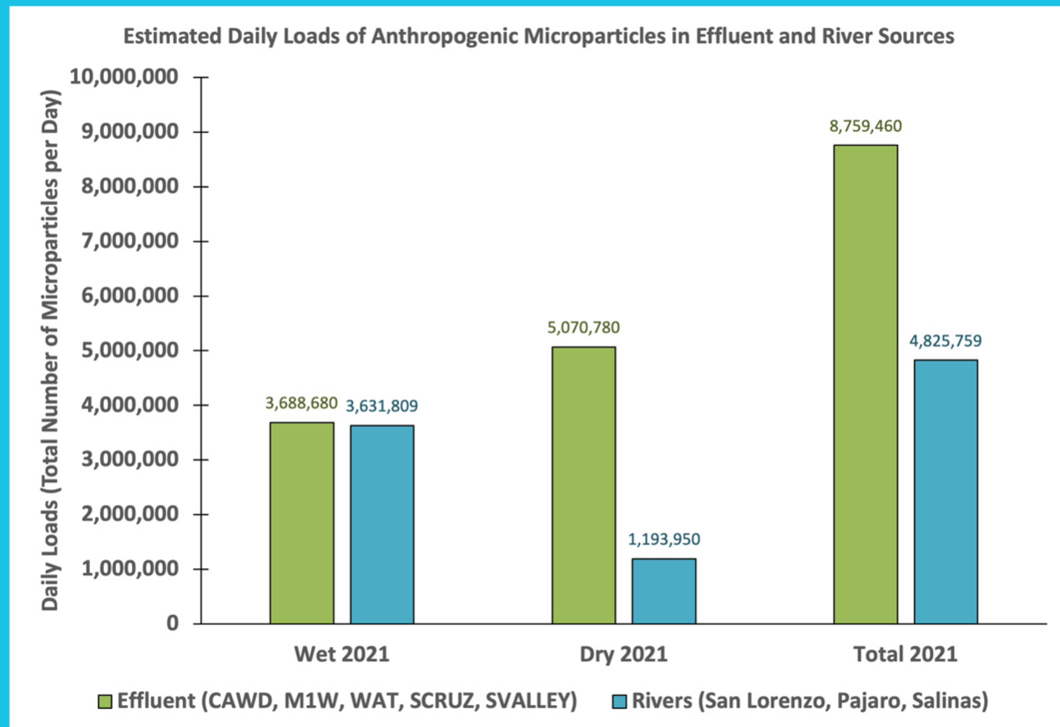
During the wet season of 2021, the highest daily loads of anthropogenic microparticles were found at the City of Santa Cruz Wastewater Treatment Facility, while the lowest daily loads were found at CAWD. During dry season 2021, the highest daily loads of microparticles were found at M1W and the lowest once again at CAWD. City of Scotts Valley had the highest concentration of microparticles during the 2021 dry season, but a low average daily discharge rate, resulting in lower daily loads of microparticles being discharged from the facility.

The Pajaro River had the highest daily loads of anthropogenic microparticles for wet season 2021, while the San Lorenzo River had had the highest daily loads during the dry season. Despite having higher discharges during the wet season compared to most effluent sources, the rivers had generally lower concentrations of microparticles, and therefore lower estimated daily loads compared to most of the effluent sites.





Question 2: How do seasonal and total loads of microplastics from rivers compare to loads from wastewater?



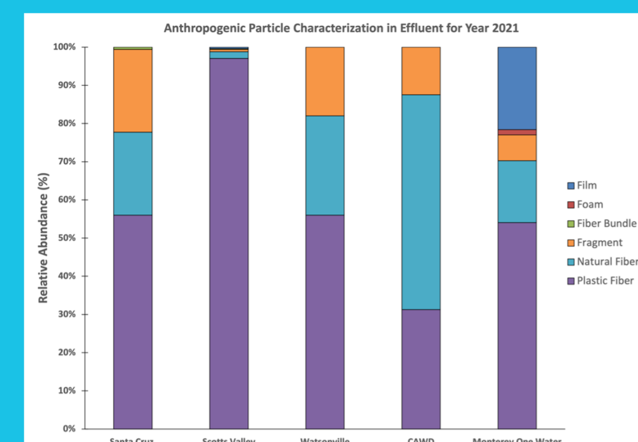
The sum of daily loads of anthropogenic microparticles for all five effluent sites was comparable to the sum of three river sites during wet season 2021 (Figure 3). During the dry season of 2021, the sum of daily loads for the effluent sites exceeded the river sites and was approximately 4.25 times greater. Similarly, the annual sums of daily loads of microparticles for all effluent sites in 2021 was about 1.82 times greater than the sum of daily loads for the river sites, suggesting that WWTP effluent sources may discharge greater loads of anthropogenic microparticles to Monterey Bay on an annual basis compared to river sources.

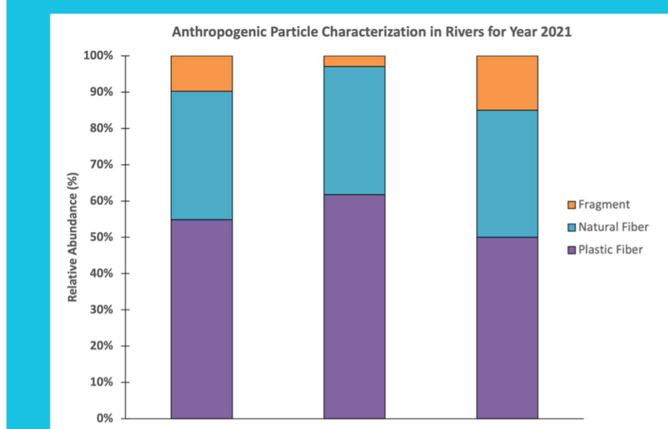
Question 3: What are the major sources and pathways of microplastic pollution to nearshore waters in Monterey Bay?

The dominant anthropogenic microparticle morphology type for all effluent sources, apart from CAWD, was plastic fibers, followed by natural fibers (e.g., cotton fiber) in 2021 (Figure 4). Contrarily, CAWD was largely dominated by natural fibers, followed by plastic fibers. The third most abundant type of plastic material found in effluent sources was fragments. M1W, however, had film particles as its third most abundant microparticle morphology type. Fiber bundles were only identified in City of Santa Cruz effluent and foam particles were only identified in effluent at M1W. Beads were not identified in any of the effluent samples during 2021.

Like effluent sources, plastic fibers were the dominant morphology type identified in all river samples collected during 2021, followed by natural fibers. Fragments were also the third microparticle type identified in river samples. Unlike a couple of the effluent sites, there were no fiber bundle, foam, or film particles identified in any of the river samples. There were also no beads identified in any river samples during 2021.

The result of fibers being the dominant microparticle morphology type identified in effluent and river samples was supported by a recent study in Monterey Bay, where fibers were the most abundant microparticle type (78%) identified across samples of seawater and in the digestive tracts of anchovies and common murres (Michishita et al., 2023). Following fibers, fragments (13%) were the second most abundant microparticle type identified in the study, while foam (6%), film (2%), and beads (1%) were less abundant. It is possible that the higher abundances of microparticle fibers and fragments we identified in effluent and river sources discharging into Monterey Bay are contributing to the high abundances of fibers and fragments identified in seawater and the digestive tracts of marine fish and seabirds within the bay.





City of Santa Cruz Wastewater Treatment Facility Influent

During the dry season of 2021, influent grab samples were collected for Santa Cruz City and Santa Cruz County to estimate differences between anthropogenic microparticle counts found in influent and effluent sources at the City of Santa Cruz Wastewater Treatment Facility. Once per day, on each of the three days of effluent sampling, influent grab samples were collected in 500 mL bottles at both the Santa Cruz City and County influent locations. The influent samples were shipped to the McNeish Lab at CSU Bakersfield, where they were processed with the same methods as the effluent samples, and Rose Bengal staining was used to count microparticles.

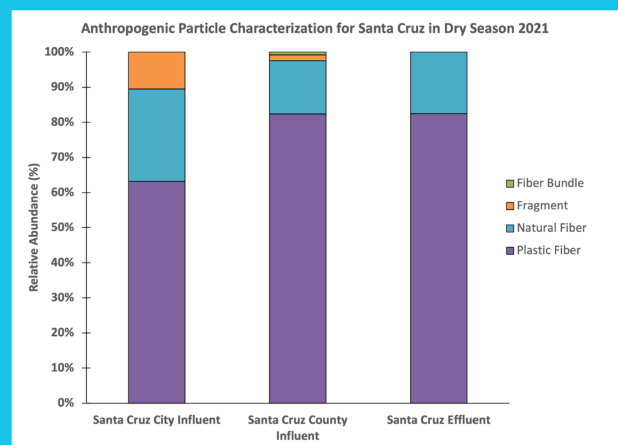
Like the effluent samples, the influent sample data was corrected using the same atmospheric sample contamination data for the City of Santa Cruz Wastewater Treatment Facility and again at Santa Cruz County.

The total number of microparticles was averaged for the three influent samples collected at Santa Cruz City. The total number of microparticles for each morphology type (e.g., plastic fiber) were also averaged across the three samples for each location. Average microparticle counts were used to calculate particle concentrations per liter, and average influent daily flow data (MLD) was used to estimate daily loads of microparticles in Santa Cruz City and County influent sources.

Site	No. Microparticles	
	Per Liter	Per Day
Santa Cruz City Influent	12.67	351,462,701
Santa Cruz County Influent	83.34	2,312,254,608
Santa Cruz Effluent	0.0510	1,409,494

Santa Cruz County influent showed a higher average concentration of anthropogenic microparticles per liter in comparison to the Santa Cruz City influent samples. The concentration of microparticles in Santa Cruz County influent was roughly 6.58 times greater than Santa Cruz City influent. After summing the estimated daily loads of anthropogenic microparticles in both the Santa Cruz City and County influent sources, the percent change between influent and effluent daily loads was approximately 99.95%. This notable decrease in the number of microparticles found in effluent compared to influent water sources at the Santa Cruz Wastewater Treatment Facility suggests that the majority of microparticles found in influent are removed, or settle in the storing tanks, during the facility's wastewater treatment processes before the water is discharged from the facility as effluent. The majority of microparticle morphology types identified in both Santa Cruz City and County influent and effluent were plastic, followed by natural fibers.

Fragments were found in Santa Cruz City influent, while fragments and fiber bundles were found in Santa Cruz County influent. Santa Cruz effluent contained only fibers and no fragments or fiber bundles, suggesting that fragments and fiber bundles may have been removed during wastewater treatment processes during the dry season of 2021.



However, microparticle morphologies identified in the Santa Cruz effluent sample during the wet season of 2021 contained approximately 22% fragment particles, indicating that the removal of fragments between influent and effluent stages was not consistent across seasons.

CONCLUSIONS

The following four conclusions have resulted from the CCLEAN pilot study:

1. In 2021, the sum of daily loads of anthropogenic microparticles from five effluent sources was almost two times greater than the sum of daily loads from three river sources discharging into MBNMS.
2. Fibers, both plastic and natural-based, were the dominant microparticle morphology type in all effluent and river samples collected in 2021. Fragments were the second most abundant microparticle morphology type for all effluent and river sites, apart from M1W, where films were the second most abundant.
3. In dry season of 2021, estimated daily loads of anthropogenic microparticles decreased by > 99% between the combined Santa Cruz City and County influent and Santa Cruz effluent stages. This suggests the majority of anthropogenic microparticles may have been removed, or settled in the storage tanks, during wastewater treatment processes before being discharged as effluent.
4. The settling behavior of microparticles is heavily influenced by its shape or morphology and its density. The buoyancy of microplastic particles is also largely influenced by the polymer types that make up the particle, considering that different polymer types have different densities.

Spectrosopic polymer identification methods, such as Fourier-transform infrared (FT-IR) and Raman spectroscopy, can be used to determine the polymer types that make up the composition of microparticles. These methods can be used to gain a better understanding of which polymer types are most likely to be removed during wastewater treatment processes. Determining polymer types can also be highly useful for identifying microplastic sources within the Monterey Bay region.

CITATIONS

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Tanaka, K., Yamashita, R., Takada, H., 2019. Transfer of hazardous chemical from ingested plastics to higher-trophic-level organisms. In: Takada, H., Karapanagioti, H. K. (Eds.), Hazardous Chemicals Associated with Plastics in the Marine Environment, the Handbook of Environmental Chemistry. Springer International Publishing, Cham. 267-280.

ACKNOWLEDGEMENTS

- Greg Cotten (Kinnetic Environmental, Inc.)
- Rae. E. McNeish, Ph.D. (McNeish Lab, CSU Bakersfield)
- Diana Lin (San Francisco Estuary Institute's Microplastic Workgroup)
- CCLEAN Steering Committee:

  Carmel Area Wastewater District

  Monterey One Water

  City of Watsonville

  City of Santa Cruz

  Scotts Valley Water District


PROGRAM
UPDATES

STATUS AND TRENDS

BACKGROUND

Status and Trends monitoring is a core element of the CCLEAN Program. Since 2001, CCLEAN and its collaborators have monitored persistent pollutants in water, sediments, and biota to meet NPDES permit discharge requirements and inform the protection of beneficial uses of Monterey Bay. Long-term sampling has generated more than 50,000 data points that have been used to document significant trends over time and notable spatial patterns in the region. This has led to the development of 303d listings, documented compliance with permitted effluent limits, and other actions.

Pollutants monitored in the CCLEAN Program comprise contaminants present in nearshore Monterey Bay, wastewater, and sediments that occur at concentrations or loadings that cause exceedances of water quality objectives. These include DDTs, PCBs, chlordanes, and dieldrin compounds.

Additionally, adaptive management of the Program has provided novel results on CECs, including current use pesticides and microplastics.

PROGRAM YEAR ACTIVITIES

All of the monitoring conducted in the CCLEAN Program contributes to status and trends:

- Dry-season grab sampling at eight sediment sites located along the 80-m depth contour in nearshore Monterey Bay
- Wet-season composite sampling at five mussel tissue sampling sites along the coastline of Monterey Bay
- Dry- and wet-season composite sampling at five Wastewater Treatment Plants (WWTP), three river sites, and two ocean buoy sites

PRIORITY QUESTIONS

1. What are the concentrations of persistent pollutants in nearshore waters, sediments, and resident mussels in Monterey Bay, and what are the loads from rivers and wastewater discharges?

2. Do Monterey Bay waters and sediments comply with the California Ocean Plan, and other pertinent guidelines?

3. Are concentrations and loads increasing or decreasing?

4. What are the effects to beneficial uses associated with persistent pollutants?

USES OF PROGRAM DATA

- Describe the status and long-term trends in the quality of nearshore waters, sediments, and associated beneficial uses of Monterey Bay
- Evaluate compliance with California Ocean Plan, California Toxics Rule, and NPDES permit requirements
- Estimate seasonal average concentrations and pollutant loadings discharged to Monterey Bay
- Refine load estimates for future Water Board policy updates
- Inform decisions on control measures for reducing pollutant loadings
- Inform 303(d) listings or de-listings

CURRENT FINDINGS

Status and Trends (S&T) monitoring in the CCLEAN Program prioritizes evaluations of persistent pollutants with discharge limits and water quality objectives. In Program Year 21 (PY21), all three of the ocean samples for PCBs exceeded the Ocean Plan water quality objective. However, there were no Ocean Plan exceedances related to DDTs, dieldrin, or chlordanes. In addition, none of the mussel tissue samples exceeded OEHHA tissue levels for human consumption, nor the EPA health risk levels.

River samples were associated with the majority of threshold exceedances in PY21. Nine concentrations were detected above the California Toxics Rule (CTR) criteria for consumption of water and sediment organisms, with DDTs and dieldrin being associated with the most notable exceedances. Pajaro River exhibited five of the nine exceedances, while three observations on the Salinas River were also significantly above the CTR. Lastly, on the San Lorenzo River, total PCBs exceeded the CTR threshold in the dry-season.

Table of PY21 Water Quality Exceedances

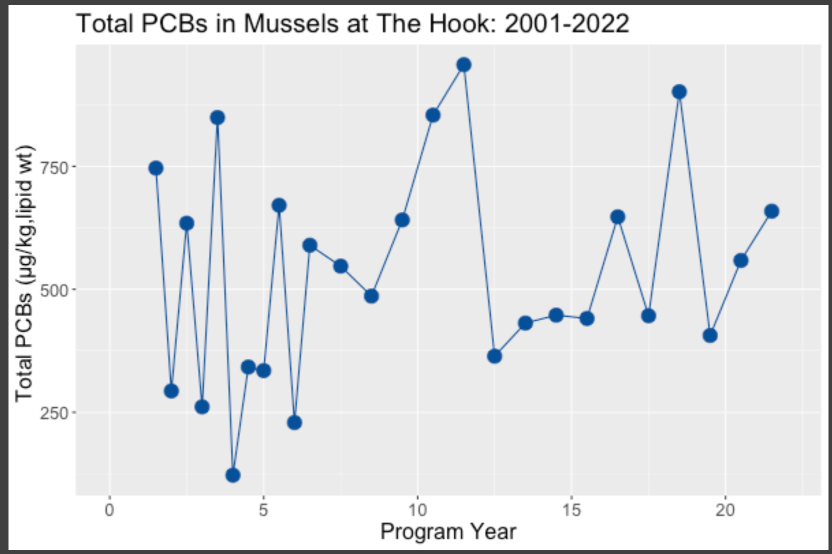
Station	Season	Pollutant	Objective (ng/L)	Seasonal Mean Concentration	Percent Above Objective
North Monterey Bay	Dry	PCBs	0.019	0.024	26%
	Wet			0.030	58%
South Monterey Bay	Wet	PCBs	0.019	0.034	79%
Pajaro River	Wet	Chlordanes	0.57	0.66	16%
		4,4'-DDD	0.83	4.33	>400%
		4,4'-DDE	0.59	14	>2000%
		4,4'-DDT	0.59	7.42	>1000%
		Dieldrin	0.14	1.05	>600%
Salinas River	Wet	4,4'-DDD	0.83	1.47	77%
		4,4'-DDE	0.59	7.50	>1000%
		Dieldrin	0.14	3.1	>2000%
San Lorenzo River	Dry	PCBs	0.17	0.39	32%
Watsonville Effluent	Wet	PCBs	1.62	2.27	40%

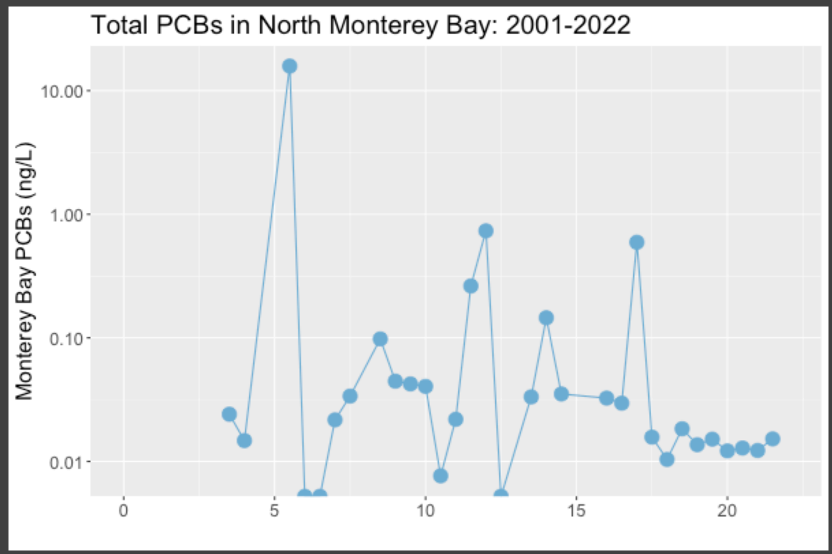
There was one exceedance of an NPDES effluent concentration limit in PY21. The wet season concentration of PCBs in Watsonville effluent was 40% above its NPDES discharge limitation. This observation is consistent with sporadic exceedances that have occurred in wastewater sampling from prior years.

Examining long-term trends in ocean and mussel data has shown that concentrations of the most persistent pollutants have not changed significantly over time. Mussel tissue concentrations of PCBs, DDTs, and dieldrin continue to be elevated, particularly at "The Hook" in Santa Cruz.

Elevated ocean concentrations have often preceded periods of increased mussel tissue bioaccumulation. PCBs in Monterey Bay have regularly attained levels that exceed Ocean Plan water quality objectives. Many of these occurrences were followed by increases in mussel tissue PCB concentrations. However, variability in climate and river discharge over the time-series, coupled with unpredictable inputs from river and wastewater sources have contributed to an overall lack of increasing or decreasing trends.

Due to their prevalence in discharges to the Bay, continued measurements of PCBs in nearshore Monterey Bay is a priority for the CCLEAN Program.





SOURCES AND LOADS

BACKGROUND

CCLEAN has put a large emphasis on determining sources and loads of pollutants to Monterey Bay. Most of the monitored contaminants are POPs, whose uses have been banned for 30–40 years, yet continue to be measured in the environment at concentrations that are sometimes toxic.


Special to the Chronicle / Scott Ange

CCLEAN evaluates pollutants transported to the Bay in wastewater effluent and river discharge. While CCLEAN does not quantify stormwater loads or inputs from Elkhorn Slough, rivers have been shown to be the largest source of POPs to the Bay.

Of the four rivers monitored under the CCLEAN program, the San Lorenzo River is the most urban- influenced, while the Pajaro and Salinas Rivers drain primarily agricultural areas. The fourth river infrequently sampled under the CCLEAN program is the Carmel River, which is relatively unaffected by urban discharges or agricultural run-off. Over the course of the CCLEAN time-series, much larger annual loads of POPs have been discharged from rivers compared to wastewater effluent, as a result of declining wastewater flows, coupled with increased rates of river discharge during the wet season, which transports buried contaminants off the landscape into the nearshore waters of Monterey Bay.

PROGRAM YEAR ACTIVITIES

- Dry- and wet-season composite effluent sampling for POPs and CECs at five WWTP treatment sites
- Dry- and wet-season composite river sampling for POPs and CECs on the San Lorenzo, Pajaro, and Salinas rivers
- Dry- and wet-season composite sampling for POPs and CECs at ocean buoy sites in North and South Monterey Bay

PRIORITY QUESTIONS

1. What are the loads of persistent pollutants from major sources to Monterey Bay?
2. Do the loads of persistent pollutants in rivers exceed the loads in wastewater discharges?
3. What are the major sources and pathways of pollutants to nearshore waters?
4. Are pollutant loads increasing or decreasing?

USES OF PROGRAM DATA

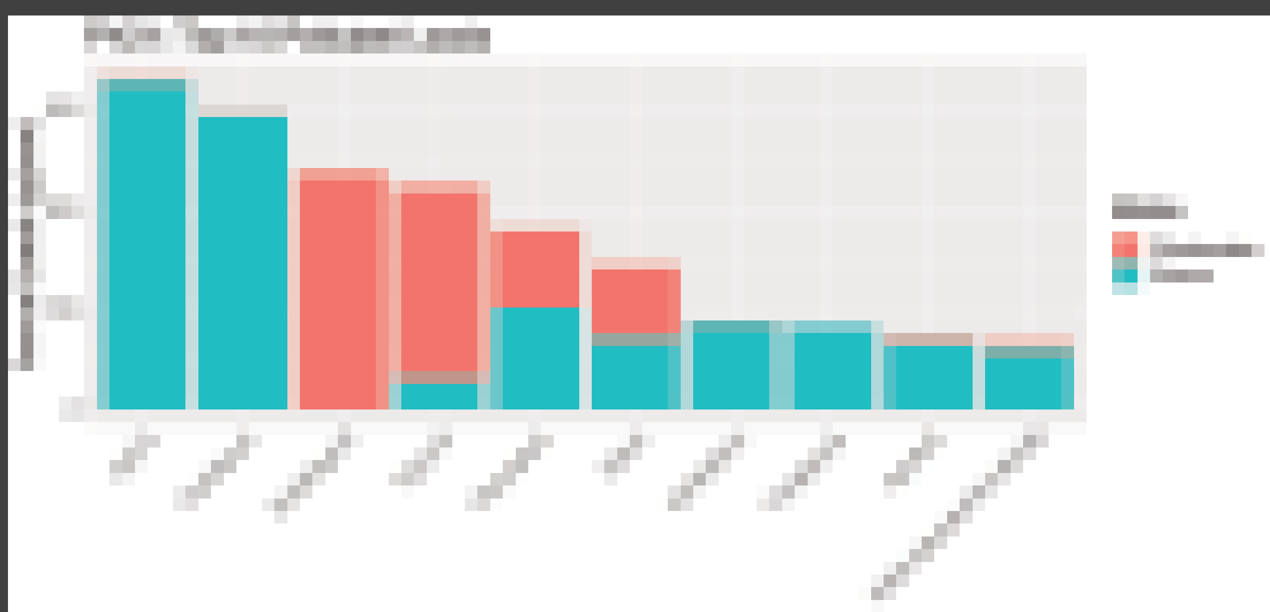
- Evaluation of pollutant loadings from rivers discharging to Monterey Bay
- Evaluate compliance with California Ocean Plan and NPDES monitoring
- Refining load estimates for future policy updates
- Informing decisions on the control measures for reducing pollutant loadings
- Identify rivers to prioritize for management actions

SOURCES AND LOADS

CURRENT FINDINGS

Pollutant loads discharged into Monterey Bay have varied widely among major sources.
In PY21, rivers contributed almost 2x the mass of the top 10 largest loads of pollutants compared to wastewater sources. This observation is consistent with prior years of CCLEAN that have observed significantly higher POP loads derived from rivers than wastewater sources.

The largest load contributions in PY21 were comprised of POPs, including DDTs, oxadiazon, toxaphene, and dacthal. Loads of legacy contaminants were almost exclusively derived from river sources. In addition to the loads of legacy pollutants, several classes of CECs also ranked amongst the highest loads in PY21. These pollutants include fipronils, and the pyrethroids, bifenthrin, permethrin, and cyhalothrin. Additionally, a neonicotinoid compound, imidalacloprid that is also used as an insecticide similar to the pyrethroids, was exclusively detected in wastewater effluent.

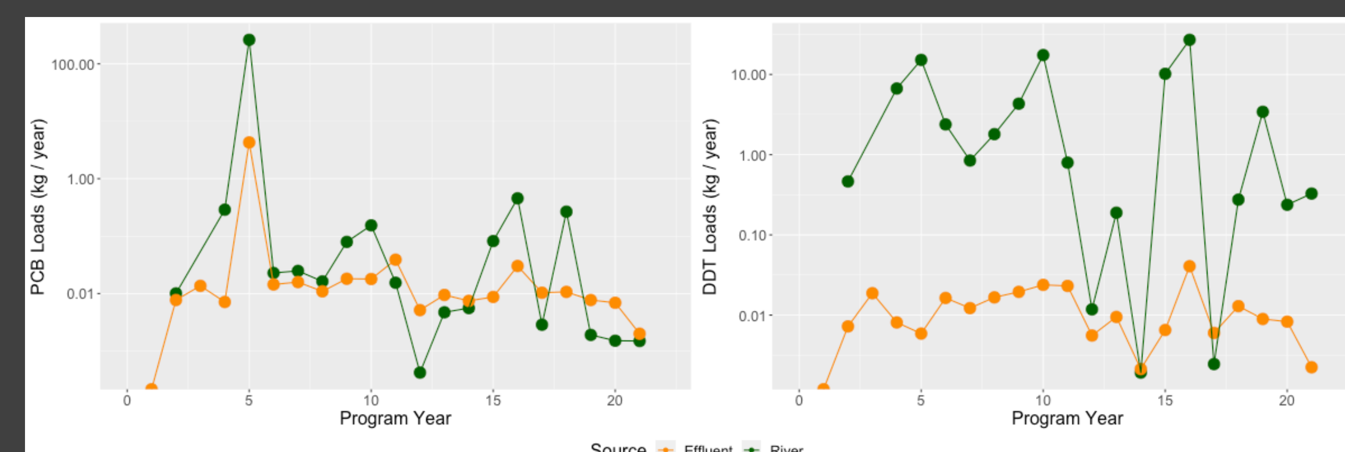


Loads of POPs discharged from rivers have been relatively stable over time. Although some sharp inclines and declines have occurred, these shifts have often been associated closely with climate and rainfall. Wastewater loads have also exhibited a few increases and frequent declines in POP loads over time. The declines in loads have been largely associated with decreases in wastewater flow due to water reclamation efforts. As result, CCLEAN has yet to detect significant decreases in annual loads of persistent pollutants that can be related to control measures.

In PY21, PCB load from rivers and wastewater combined was estimated to be less than 4g, which was the second lowest in the CCLEAN time-series. However, as recently as PY18, the annual PCB load from rivers alone was estimated to be 237g, which ranked fourth highest over the time-series. The relatively similar loads of PCBs from river and wastewater over the years is an indicator of the ubiquitous presence in the region.

In contrast, DDT loads from rivers that drain agriculture-dominated watersheds have been an order of magnitude higher than in wastewater. PY21 estimates of DDT loads was approximately 330g, which was similar to the loads estimates in PY20 and PY18.

CCLEAN has been able to demonstrate the relative importance of sampling rivers to quantify the largest loads of contaminants entering Monterey Bay. Continued monitoring will aim to track progress towards declines in pollutant loads that outpace potential correlations to climate variability.



ORGANIC POLLUTANTS

BACKGROUND

Since its inception, CCLEAN has measured POPs in the ocean, rivers, wastewater, sediments, and resident mussels of Monterey Bay. POPs are legacy contaminants that historically had wide industrial and urban applications. Despite having been banned more than 30 years ago, compounds such as dieldrin, chlordanes, DDTs, and PCBs continue to be widely detected in samples collected from Monterey Bay. Rivers have been the dominant source of POP loads to Monterey Bay.

Significant trends in POPs have been evident in the CCLEAN time-series. Chlordanes in mussels and sediments have been declining at a steady rate over the past 20 years. However, DDTs and PCBs have remained relatively constant, with increasing concentrations noted in particularly high-flow years.

PROGRAM YEAR ACTIVITIES

- Dry- and wet-season composite sampling for POPs at five WWTP treatment sites
- Dry- and wet-season composite sampling for POPs on the San Lorenzo River, Pajaro River, and Salinas River
- Dry- and wet-season composite sampling for POPs in North and South Monterey Bay
- Wet-season sampling for POPs in mussel tissue at five sites
- Dry-season sampling for POPs in sediments at six historic sites and two dredge disposal sites

PRIORITY QUESTIONS

1. What are the loads of POPs from rivers and wastewater, and what are the concentrations in nearshore waters of Monterey Bay?

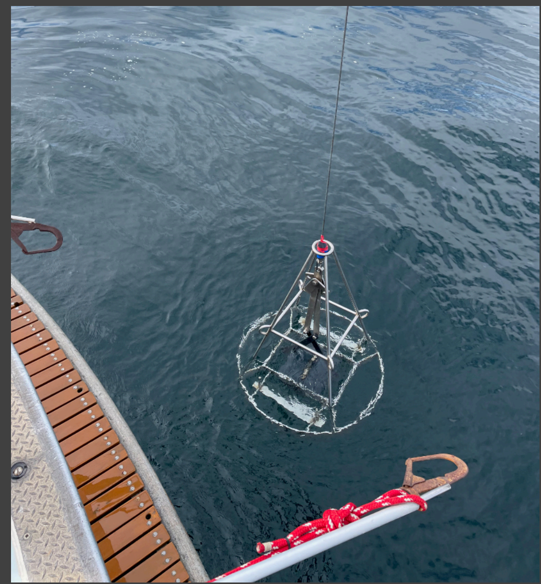
2. Do the loads of POPs from rivers exceed the loads in wastewater discharges?

3. What are the major sources and pathways of POPs to nearshore waters in Monterey Bay?

4. Are concentrations and loads of POPs increasing or decreasing?

USES OF PROGRAM DATA

- Evaluate concentrations and loads of POPs in water, sediments, and mussels
- Estimate POP concentrations and loads discharged from rivers and wastewater sources to support future policy changes
- Identify POPs that exceed Ocean Plan water quality objectives

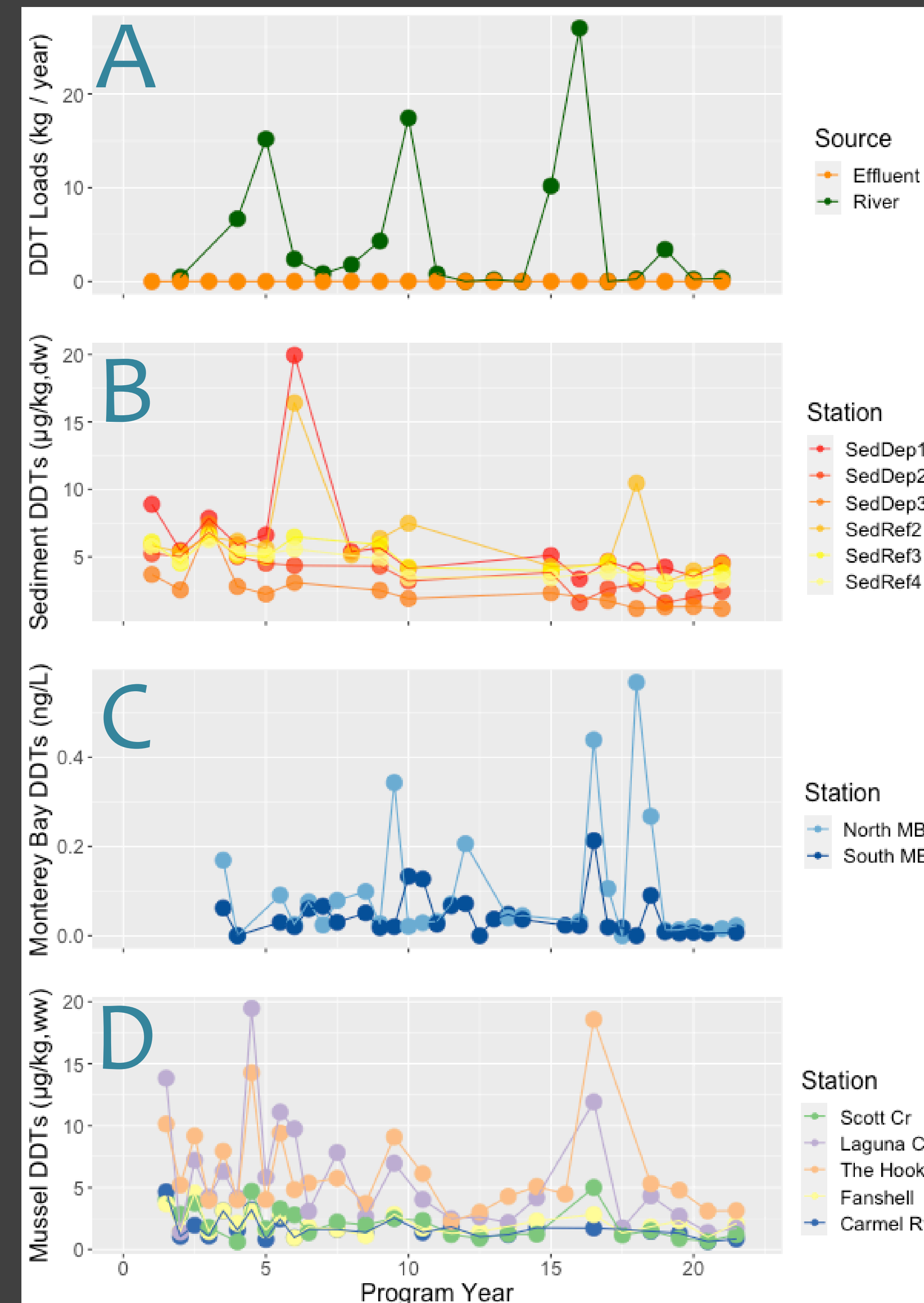


CURRENT FINDINGS

Annual wastewater loads of POPs never exceed those from rivers and are typically orders of magnitude below river loads. The POPs with the largest loads to Monterey Bay in PY21 were DDTs, oxadiazon, toxaphene, and dacthal. DDTs comprised the largest load of the year to Monterey Bay for any single parameter measured. The DDT load from rivers was estimated to be 327g, with just 2.2 g (6.7%) derived from wastewater effluent. In the past 20 years the largest loads of DDTs have consistently occurred during high river flows, including 2004-05, 2009-10, and 2015-16, when DDT load estimates were > 10 kg. The Pajaro and Salinas River watersheds being more agriculturally-influenced have often been responsible for these pulses of annual DDT loads in certain years.

CCLEAN's ocean monitoring has demonstrated that DDTs discharged into Monterey Bay continue to occur at elevated concentrations in nearshore waters and sediments. However, no consistent temporal pattern in DDTs at ocean sites has been evident in the CCLEAN time-series. The lack of trend pattern in both water and sediments may suggests either an inconsistent exposure of CCLEAN's ocean sampling sites to riverine discharges or a diffuse deposition of DDTs in Monterey Bay. Furthermore, although DDTs did not exceed the California Ocean Plan objectives in PY21, DDTs remain above the effect range low thresholds for marine sediment at most sites. Similar to the river loads, there has been a consistent level of DDT contamination in the ocean and sediments, with a few years of notably elevated concentrations. Furthermore, North Monterey Bay has most frequently exhibited the highest ocean concentrations of DDTs, suggesting that it is more influenced by discharge from agricultural areas than South Monterey Bay. This spatial pattern is consistent with trends in mussel tissue DDTS, where the highest concentrations have been found to occur in mussels near Santa Cruz, specifically the Hook and Laguna Creek.

While there is overwhelming evidence in the CCLEAN monitoring data to demonstrate that DDTs are a significant concern for maintaining beneficial uses and that rivers are the primary source of DDTs discharged to Monterey Bay, mitigation measures are still under consideration.



Footnote: Time series of DDT concentrations and loads: A) loads from effluent (orange symbols) and rivers (green symbols); B) Monterey Bay sediment concentrations (dark symbols=outer bay sites; light symbols=inner bay sites); C) Monterey Bay ocean concentrations (dark blue=South Monterey Bay, NMB, and light blue=North Monterey Bay; and D) Monterey Bay mussel tissue concentrations.

EMERGING CONTAMINANTS

BACKGROUND

CECs are classes of chemicals that, in general, are not actively regulated, but are known to cause harm to humans and aquatic life. Progress in recent years has seen toxicity criteria developed for a few individual contaminants.

CCLEAN monitoring for CECs was initiated in 2016 and has to-date identified several contaminant classes of potential concern:

- PFAS — widespread applications in industrial and consumer products;
- fipronil, neonicotinoids and pyrethroids — insecticides with widespread urban uses; and
- carbamates, organophosphorus pesticides — crops and mosquito control for agricultural practices.

In PY21, the CCLEAN program also began investigating microplastic contamination in Monterey Bay (Feature Article on Page 16).

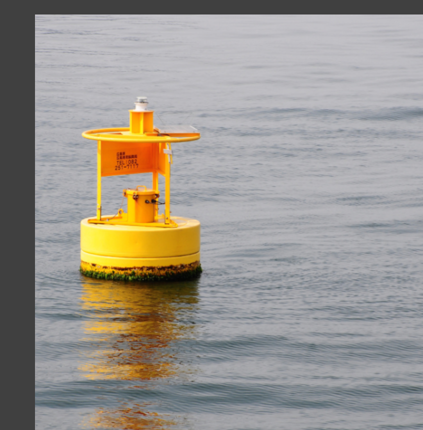
PROGRAM YEAR ACTIVITIES

- Dry- and wet-season composite sampling for CECs at five WWTP sites
- Dry- and wet-season composite sampling for CECs on the San Lorenzo River, Pajaro River, and Salinas River
- Dry- and wet-season composite sampling for CECs at ocean buoy sites in North and South Monterey Bay
- Microplastics pilot study (see Feature Article on Page 18)

PRIORITY QUESTIONS

1. What are the concentrations and loads of CECs from major sources to Monterey Bay?
2. Do the loads of CECs from rivers exceed the loads in wastewater discharges?
3. What are the major sources and pathways of CECs to nearshore waters?
4. Are concentrations of CECs increasing or decreasing?

USES OF PROGRAM DATA



- Identify CECs to prioritize for management actions
- Evaluate contribution of wastewater discharges to CECs in nearshore waters
- Estimate pollutant concentrations and loads of CECs to support future policy development
- Inform decisions on the control measures for reducing CECs in effluent

EMERGING CONTAMINANTS

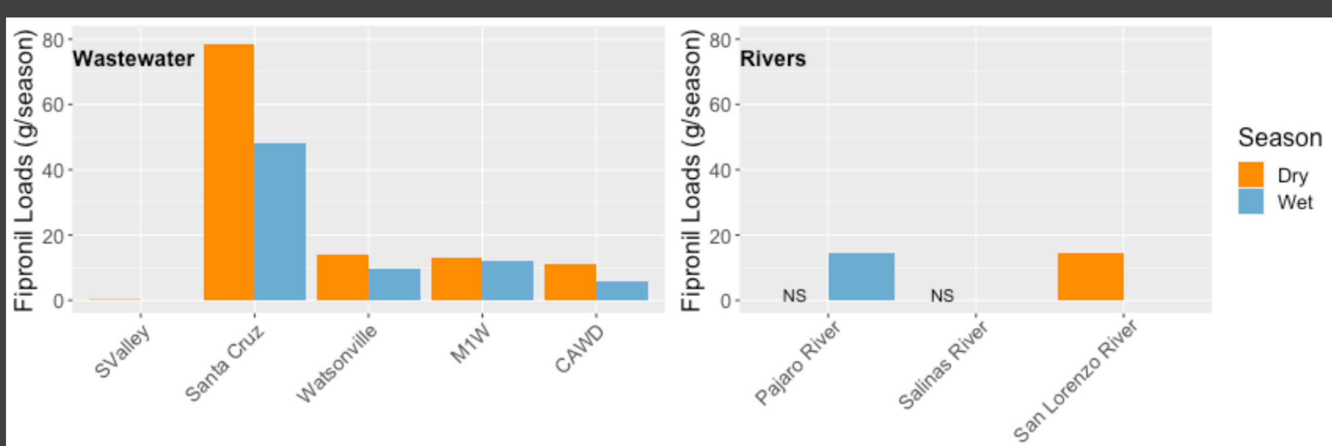
CURRENT FINDINGS

The CCLEAN Program has been monitoring contaminants of emerging concern (CECs) that consist of current-use pesticides, herbicides, and insecticides that have both urban and agricultural uses in the region. The classes of CECs of highest concern exhibit relatively high concentrations and loads, which include several types of fipronils, pyrethroids, and neonicotinoid compounds, all of which have been shown to be toxic to fish and aquatic invertebrates.

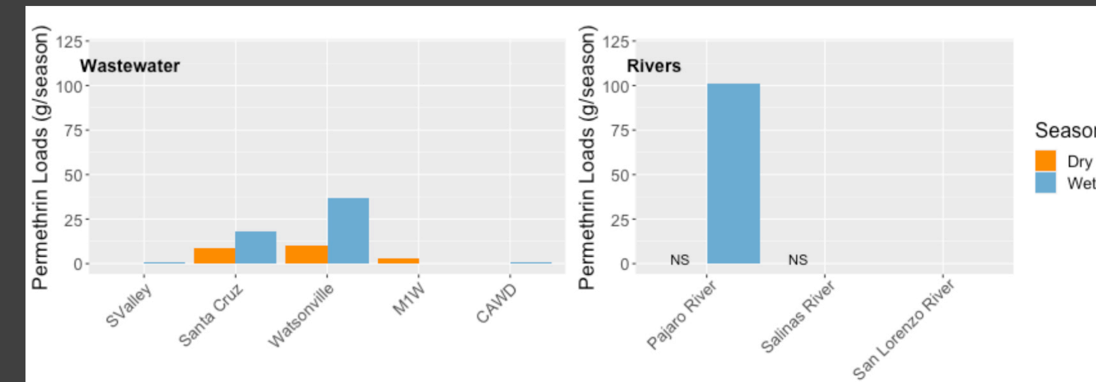
Fipronils have often been higher during the dry season. In PY21, seasonal fipronil loads were highest for Santa Cruz effluent, with almost twice the load occurring in the dry season compared to the wet season. Watsonville, M1W, and CAWD each contributed similar loads. Dry vs. wet season loads were relatively similar for M1W, while CAWD and Watsonville effluent exhibited a dry season predominance.

Fipronil was inconsistently detected in rivers, and thus the load from rivers was lower than for wastewater. Fipronil was below detection on the Salinas River and San Lorenzo River, while loads from the San Lorenzo River in the dry season and the Pajaro River in the wet season were relatively equal.

Pyrethroids (e.g. Permethrin, Bifenthrin), on the other hand, have often been highest in the agriculturally influenced Salinas and Pajaro. In PY21, Permethrin loads in wastewater were 50% lower than from river sources.

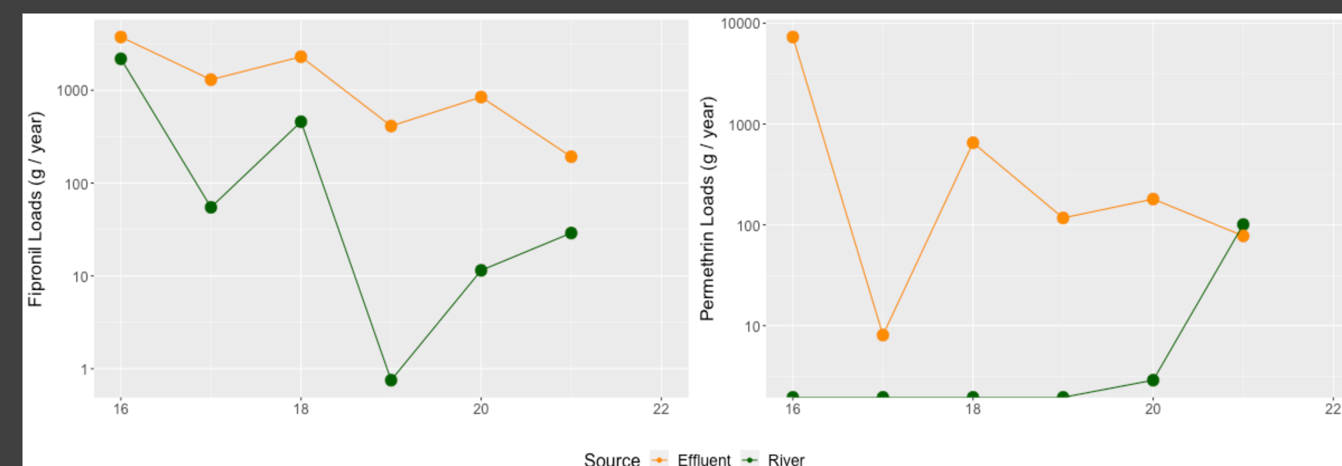


Footnote: Pajaro and Salinas were not sampled (NS) in the dry season of PY21



Footnote: Pajaro and Salinas were not sampled (NS) in the dry season of PY21

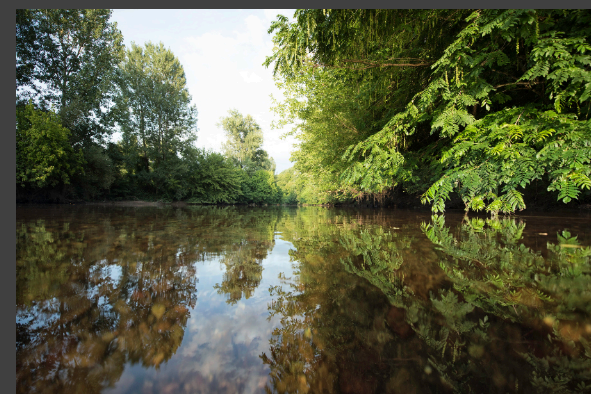
Higher Permethrin loads occurred in the wet season, especially in Watsonville and Santa Cruz wastewater effluent, which were highly similar in the dry season. Wet-season permethrin load from the Pajaro River were greater than all five WWTP combined. This higher load draining the largely agriculturally-influenced Pajaro River appears consistent with the use of permethrin in agriculture practices, and subsequent transport in river discharges.



CCLEAN's CEC monitoring to-date has spanned six years of largely drought conditions, which prevents definite statements about increasing or decreasing trends. Here, Fipronil and Permethrin are presented as examples of the variability in CEC loads during this period. Fipronil loads in both effluent and river sources were greatest in PY16 when higher than average rainfall occurred in the region. Since that year, river loads have remained relatively unchanged, and effluent loads appear to have declined. Permethrin loads declined between PY16 and PY17, but have since been relatively stable in effluent.

NUTRIENTS

BACKGROUND



Increasing abundance of nutrients are known to sustain blooms of phytoplankton in Monterey Bay. Excessive growth of noxious phytoplankton, known as harmful algal blooms (HABs), can affect beneficial uses by negatively impacting marine animals that inhabit Monterey Bay, as well as recreational water contact and shellfish consumption.

Nutrients enter Monterey Bay from land based sources including rivers, wastewater discharge, and the Elkhorn Slough. However, >99% of the annual contribution of nutrients in Monterey Bay is known to be derived from upwelling sources. Algal blooms often occur in the dry season at the relaxation of upwelling and when land-based run-off is at a minimum. As a result of the potential link between nearshore accumulations of nutrients and HABs, CCLEAN measures seasonal concentrations of nutrients in rivers and utilized monthly concentrations measured by CCLEAN participants in effluent discharging into Monterey Bay.

Current regulatory objectives aim to minimize discharge of all nutrients under the narrative objective of the Ocean Plan to prevent “objectionable growth” of aquatic plants and phytoplankton. Currently, only ammonium has a numerical wastewater limit, which varies by discharger.

PROGRAM YEAR ACTIVITIES

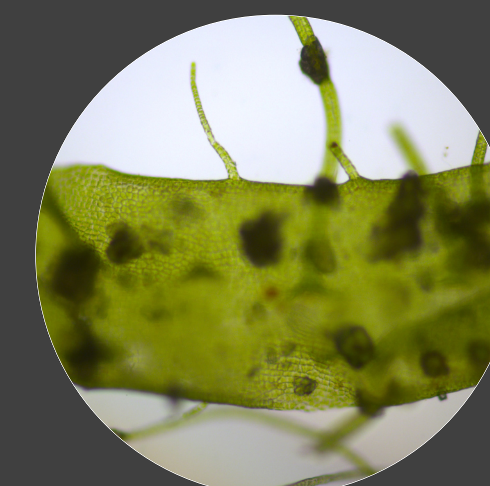
- Monthly nutrient monitoring in effluent at five WWTP sites
- Dry- and wet-season grab sampling for nutrients on the San Lorenzo River, Pajaro River, and Salinas River

PRIORITY QUESTIONS

1. What are the concentrations and loads of nutrients from major sources to Monterey Bay?
2. Do the loads of nutrients in nearshore waters exceed the loads in wastewater discharges?
3. What are the major sources and pathways of nutrients to nearshore waters?
4. Are concentrations of nutrients increasing or decreasing?

USES OF PROGRAM DATA

- Identify nutrients to prioritize for management actions
- Evaluate whether nutrients cause objectionable aquatic growth or degrade indigenous biota.
- Estimate nutrient concentrations to support future policy development
- Inform decisions on the control measures for reducing nutrient loadings to Monterey Bay

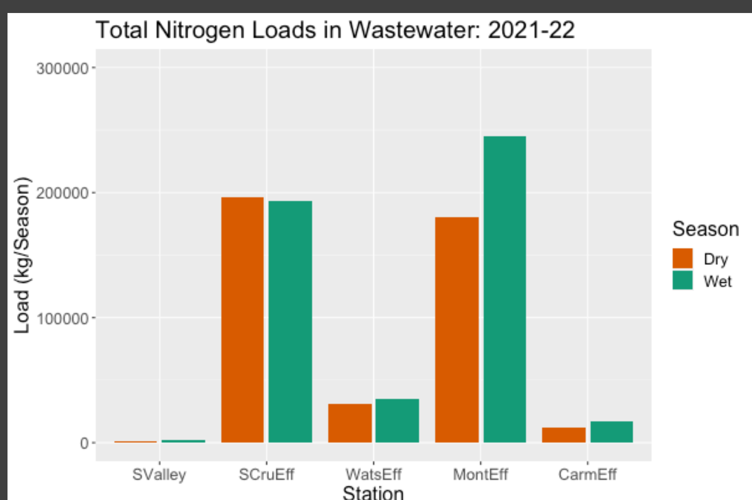


NUTRIENTS

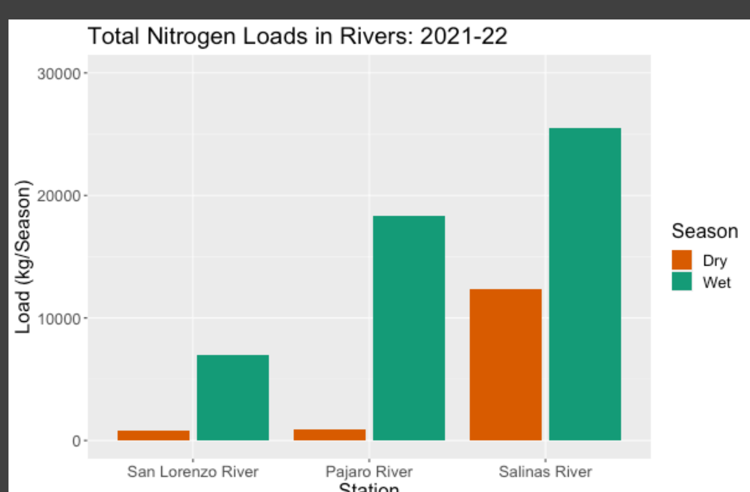
CURRENT FINDINGS

Total nitrogen (ammonia + nitrate) and phosphate loads are the primary indicators for nutrient enrichment to nearshore waters of Monterey Bay. Nutrient concentrations and loads measured in effluent are sometimes greater than discharged in rivers, indicating that wastewater can be a potentially important source of nutrients to Monterey Bay.

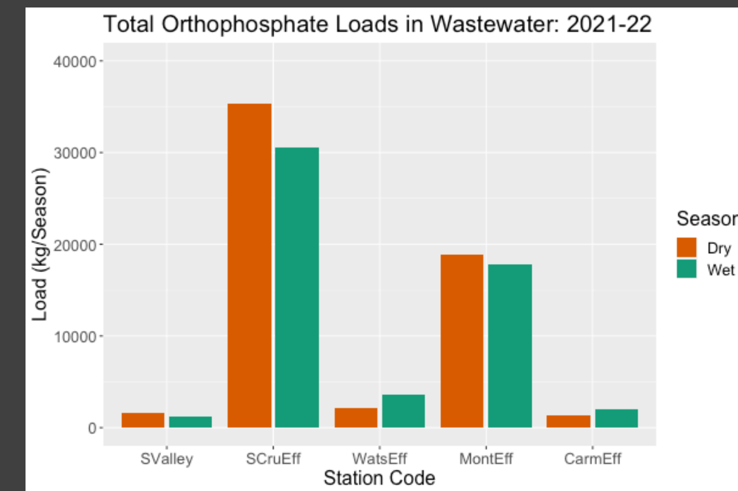
During PY21, the amount of total nitrogen estimated to be discharged to Monterey Bay was dominated by City of Santa Cruz and M1W wastewater effluent, which averaged 400,000 kg annually. The loads of total nitrogen from wastewater sources were generally similar between seasons, except for M1W, which was about 25% higher in the wet season.



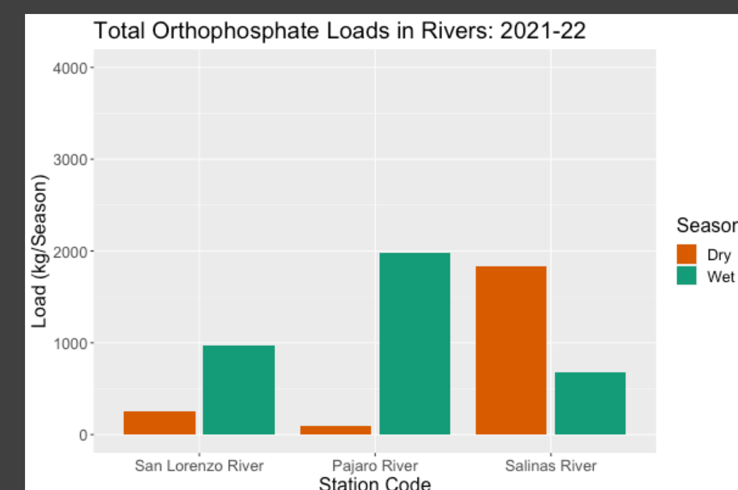
City of Watsonville, M1W, and CAWD are the only CCLEAN wastewater dischargers that currently have NPDES effluent limits for ammonia. None of these entities exceeded the 6-month seasonal median concentration or loads criteria in PY21.

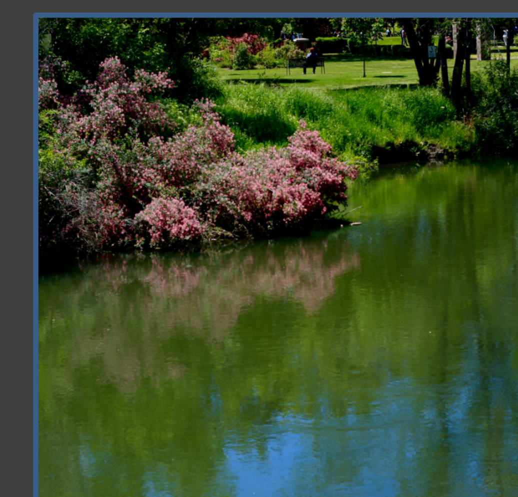


Rivers in PY21 contributed an order of magnitude lower amounts of total nitrogen (<50,000 kg) than wastewater sources. The Salinas and Pajaro rivers were notable for discharging higher loads relative to the San Lorenzo River, reflecting the higher agricultural influence of those watersheds. Furthermore, there was a strong seasonal signal to river load with the wet season contributing the vast majority of the total nitrogen load from each of the rivers.



Total phosphate loads during PY21 were similarly dominated by wastewater discharges from Santa Cruz and M1W. However, phosphate concentrations were more variable with season than total nitrogen. In rivers, a higher load of phosphate was observed for the San Lorenzo and Pajaro rivers in the wet season but this pattern differed for Salinas River, which indicated a significantly higher load in the dry season. This may suggest that the Salinas River receives significant inputs of phosphates in the dry season that are not as prevalent in the other rivers that discharge to the Bay.





CCLEAN estimates for land-based sources of nitrogen are comparatively low in contrast to oceanic sources. The annual contribution of nitrogen from upwelling and upwelling-related physical processes is estimated at 5 x10^8 kg N/y. As a result, it is highly unlikely that the contribution of nitrogen from effluent or river sources plays a major role in initiating or sustaining blooms of phytoplankton in Monterey Bay. While oceanic sources of nutrients dominant in Monterey Bay, localized effects due to river and wastewater discharges cannot be ruled out.

SEDIMENTS

BACKGROUND

Sediment supply to the ocean is important to the health and functioning of nearshore Monterey Bay and the National Marine Sanctuary. Sediment is primarily delivered to the Bay during episodic river discharge events that transport material from the surrounding watersheds into creeks, canals, and tributaries. Annually, sediment is also dredged from the Moss Landing entrance channel, harbor, and adjacent areas, and redistributed offshore at dredge disposal sites.

CCLEAN has been monitoring marine sediment contamination in Monterey Bay since the Program began in 2001, largely focused on pollutants of concern, and more recently, CECs. Historically, this monitoring also included annual assessment of benthic communities, which has since decreased in frequency to every five years.

Over the course of the time series, persistent pollutants in marine sediments have been shown to attain concentrations at levels of concern, particularly at the dredge disposal sites. CCLEAN continues to track trends in several legacy pollutants that have shown significant declines over the past 20 years.

PROGRAM YEAR ACTIVITIES

In the current program year, CCLEAN sediment monitoring consisted of dry season grab sampling for the following samples:

- For POPs at three long-term sediment sites and two dredge disposal sites
- For CECs at four long-term sediment sites and two dredge disposal sites
- For total organic carbon and grain size at six long-term sediment sites and two dredge disposal sites

PRIORITY QUESTIONS

1. What are the concentrations of persistent pollutants in marine sediments of Monterey Bay?

2. Are concentrations in marine sediments at levels that could lead to effects on fish, benthic species, or other aquatic life?

3. What are the major sources and pathways of persistent pollutants to marine sediments in Monterey Bay?

4. Are concentrations of persistent pollutants in marine sediment increasing or decreasing?

USES OF PROGRAM DATA

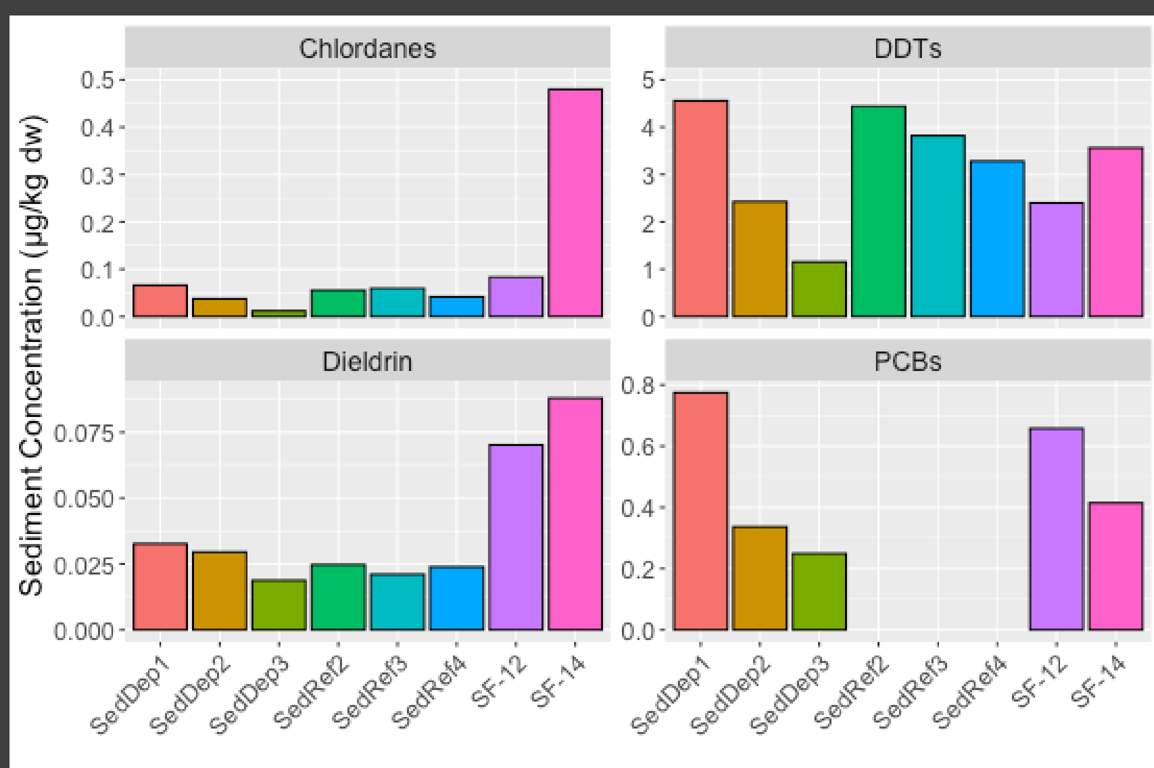
- Identify pollutants in sediment to prioritize for management actions
- Estimate pollutant concentrations in sediments to support future policy development
- Inform decisions on the control measures for reducing pollutant concentrations
- Evaluate whether sediment contaminants vary according to wastewater or river discharges
- Evaluate whether effluent discharge accumulates to toxic levels in marine sediments
- Evaluate whether concentrations of substances listed in the Ocean Plan have increased in marine sediments to levels that would degrade indigenous biota
- Evaluate whether wastewater or river discharges result in degraded benthic communities

SEDIMENTS

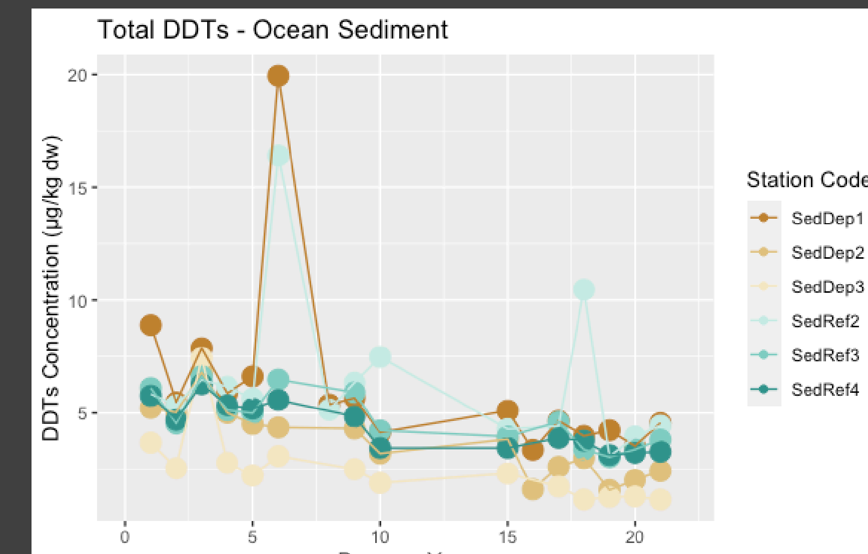
CURRENT FINDINGS

Annual dry-season monitoring of Monterey Bay ocean sediment contamination continues to detect persistent legacy contaminants. In PY21, DDTs and dieldrin were found to be relatively high at 5 of 6 nearshore sites and both dredge disposal sites (SF-12, SF-14). DDTs were observed > 4 µg/kg (dry wt), which is 3X the NOAA Effects Range Level (ERL = 1.58 µg/kg) where incidence of sediment toxicity are increased. Dieldrin was also observed at more than 3X the NOAA ERL (0.02 µg.kg), with concentrations > 0.06 µg/kg.

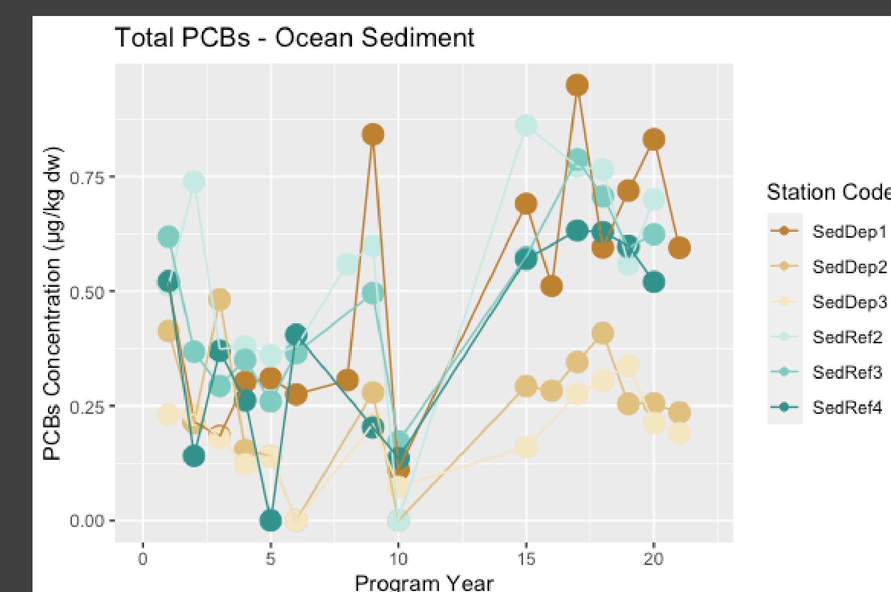
Chlordanes concentrations in PY21 were lower than at the dredge disposal sites, and at least an order of magnitude below the effects range where toxicity would be more likely. PCBs have historically been observed at levels above the NOAA ERL. In PY21, one site, Sed-Dep 1 was found to exhibit concentration greater than in dredge sediments. However, these concentrations were notably of lesser concern and much below the NOAA ERL.



Evaluations of trends in sediment concentrations have indicated very slow declines in several contaminants, including DDTs and Dieldrin. For example, the average slope in sediment DDTs over time suggests a decline of approximately 0.165 µg/kg per year. DDTs at the initiation of the CCLEAN program was frequently above 5 µg/kg, while concentrations since 2015 have only exceeded this level once; in PY18 at SedRef2.



PCB concentrations in sediment have not exhibited any clear decline for over 20 years. In-fact, since CCLEAN transitioned to more robust analytical methods in 2015, PCB concentrations have often been detected at concentrations in excess of the levels reported from the early years of the program. PCB load in the Bay continue to be ubiquitous and not as influenced by climatic variation as the load of DDTs.



ACKNOWLEDGEMENTS

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